Guide to references on III–V semiconductor chemical etching

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Abstract

The literature on chemical etching of III–V semiconductors is reviewed with the intent to organize citations in categories useful to device and materials investigators. Descriptive citations are grouped by the intended etch application and subgrouped by specific semiconductors for both wet and dry etching. A separate section groups citations by the various chemical compositions used as etchants so that a broad view of results and issues can be accessed. The final section lists references by author, with complete titles and notes of their relevance to etching.

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1. Introduction

There is a large extent of literature on etchants, but it is frequently hard to locate specific information. The purpose of this reference guide is to direct the III–V semiconductor device researcher to chemical etchants suitable for particular applications and provide descriptions and useful results. There are many excellent reviews of etchants that provide background for understanding the chemistry, and which give limited lists of applicable etchants with references. There are also many investigations characterizing specific etchants in detail. Other etchants are simply described as a side issue to their application in device fabrication or materials characterization. The references compiled here give a very broad sampling of what is available up to April 2000.

This guide is given as four annotated sections to make the etching information as accessible as possible. Section 2 lists wet etchants by their applications, Section 3 lists dry etchants by their application, Section 4 lists the wet chemical etchants by chemical composition, and the last part is a list of the references, providing both titles and notation of the contents to establish the context of the etchant data.

The wet etchant application categories in Section 2 are grouped into common themes. Notes on different etchants are given, however, no judgement is made about the significance of the data. Some information is valuable and some is trivial, yet may give insight into device fabrication. Citations to references in the last part are indicated by first author’s name and year with postscripts a, b, c, etc. when multiple references occur for a particular year.

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The dry etchant application categories in Section 3 are grouped into common themes. As with Section 2, citations to references in the last part are indicated by first author’s name and year with postscripts a, b, c, etc. when multiple references occur for a particular year.

The wet chemical etchant list in Section 4 is ordered alphabetically by chemical, however, reference notes are grouped under only one arbitrarily chosen component of multi-component etchants. Other commutations of the components are included to direct the reader to the appropriate listing. H₂O is usually not considered as a designated chemical component in the list, thus in most cases dilute and concentrated etchants are grouped together.

The etchant reference list of the last part is ordered alphabetically by first author. Complete titles and notes are given. The notes include data on materials, etch rates and specific etch conditions when possible.

Hopefully this guide will help lead to the appropriate literature for detailed information.

2. Wet etch applications

2.1. Wet chemical etching reviews

Review of wet chemical etching of III–Vs, covering electrochemical mechanisms of etching and practical application of etchants; material selective etchants, defect revealing etchants, profile etching; Ref. (Notten, P.H.L., 1993)

III–V semiconductor etchant review: gives pre-1962 data on chemical etchants for InSb, GaSb, AlSb, InAs, GaAs, InP, GaP; Ref. (Faust, J.W., 1962)

Review: general discussion of etch pit dislocation and hillock formation; Ref. (Faust, J.W., 1959)

Review of electrochemical behavior of semiconductor electrodes; Ref. (Gerischer, H., 1959)

Treatise on photochemical behavior of semiconductors; discusses thermodynamics and kinetics of photodecomposition and function of electrolyte junction solar cells; Ref. (Gerischer, H., 1979)

Review: silicon defect etch pit delineation; Ref. (Heimann, R.B., 1982)

Review of III–V etching; describes mechanisms for (1) anodic (electrochemical) etching; (2) electroless etching (redox potential driven and illumination driven); (3) chemical etching; Ref. (Kelly, J.J., 1988)

Review of Si and Ge etching; GaAs etching, GaAs electrochemical etching, GaAs thermochemical etching; GaP etching; Ref. (Kern, W., 1978a)

Review: chemical etching of insulators, semiconductors, and conductors; describes etching principles and techniques; provides tables of etchants for GaAs, GaP, AlN, BN, BP, AlSb, GaN, GaSb, InAs, InP, InSb; Ref. (Kern, W., 1978b)

Photochemical etching review: p–n dopant selectivity; surface relief etching; InGaAsP/InP and GaAs; Ref. (Kohl, P.A., 1989)
Treatise on photoelectrochemistry of semiconductor surfaces; Ref. (Pleskov, Yu.V., 1986)

Review of GaAs etchant types, defect types, and defect revealing etchants; Ref. (Stirland, D.J., 1976)

Review of etching behavior; gives definitions:

*Preferential* — anisotropic etchants show markedly different etch rates on different low index crystallographic planes

*Non-preferential* — etchants show etch rate independent of orientation

*Selective* — etchants show markedly different etch rates for different semiconductor compositions

*Non-selective* — etchants show etch rates independent of composition; Ref. (Tijburg, R., 1976a)

Review of semiconductor etching; discusses chemical process, effect of illumination, effect of adding metal ions, and crystallographic effects. Gives tables of etchants for Si, Ge, SiC, GaAs, GaP, GaSb, InAs, InP, InSb, ZnS, ZnSe, ZnTe, CdS, CdSe, CdTe, PbS; Ref. (Tuck, B., 1975)

Review: InP etching overview; wet chemical and dry etching; Ref. (Adachi, S., 1990a)

Review: GaAs etching overview; wet and dry etching; Ref. (Ashby, C.I.H., 1990a)

Review: InP wet chemical etching; with (1) defect or damage revealing etchant table, (2) polishing etchant table, and (3) pattern etchant table; Ref. (Adachi, S., 1990b)

Review: wet and dry chemical etching of GaAs; classifies wet etchants as non-electrolyte (those with rates which are diffusion limited or chemical reaction limited) and electrolyte (those based on anodic oxidation followed by dissolution of products); gives tables of wet and dry etchants; Ref. (Ashby, C.I.H., 1990f)

Review of GaAs etching and surface preparation; discusses etching mechanisms, diffusion and reaction rate limiting etching, anodic etching, and surface preparation; Ref. (Mukherjee, S.D., 1985)

Review: photochemical processing of semiconductors; Ref. (Rauth, D.R., 1992)

Review: chemical etching principles: dissolution of ionic crystals; dissolution of semiconductors; etch pit formation; electrochemical etching; photoetching; gas phase etching; Ref. (Sangwal, K., 1992)

Review: STM study of surface reconstruction and effect on etching behavior; Ref. (Boland, J.J., 1998)

Review: electrochemistry of III–V semiconductors; Ref. (Gomes, W.P., 1994)

Review: wet etching of GaAs

H$_2$SO$_4$:H$_2$O$_2$:H$_2$O; review of GaAs etch characteristics

Br$_2$/methanol; review of GaAs etch characteristics

Electrochemical etching of GaAs; review of anodic and cathodic etch characteristics; Ref. (Williams, R., 1990b)
2.2. Wet chemical lattice feature delineation

Etch pit defect delineation etchants

**InP**

HBr:CH₃COOH (1:10); InP defect delineation; etch rate = 1.7 μm/min; Ref. (Akita, K., 1979)

HBr:HF (10:1); InP defect delineation; etch rate = 0.9 μm/min; Ref. (Akita, K., 1979)

HBr:HF (1:5) and (1:10); InP dislocation etch pit delineation study with A–B etch comparison; Ref. (Kotani, T., 1980)

HBr:HF (1:5); InP dislocation etch pit delineation for 5 min at 20°C; Ref. (Susa, N., 1980a,c, 1981)

HBr:H₃PO₄ (1:2) {Huber etch}; InP defect delineation; etch rate = 0.25 μm/min; gives data on etch rates and etch pit delineation versus etchant composition; Ref. (Akita, K., 1979)

HBr:H₃PO₄ (1:2) {Huber etch}; InP delineation of pits, ridges, and striations, 1–2 min at 20°C; Ref. (Brown, G.T., 1980)

HBr:H₃PO₄ (1:2) {Huber etch}; InP dislocation etch pit delineation; Ref. (Huber, A., 1975)

HBr:H₃PO₄ (1:2) {Huber etch}; InP dislocation etch pit delineation for 150 s; Ref. (Westphalen, R., 1989)

HBr:H₃PO₄ (1:2) {Huber etch}; InP first step etch pit delineation; 1–2 min at 20°C gives symmetrical etch pits; followed by H₂SO₄:H₂O₂:H₂O (1:1:1); InP second step free etch of 30 μm for elongated etch pit delineation for (1 0 0) orientation determination; 5 min at 85°C; Ref. (Caridi, E.A., 1984)

HBr:H₃PO₄ (1:2) {Huber etch}; Application: InP and InGaAsP epilayer etch pit defect delineation at room temperature; Ref. (Nakamura, M., 1993)

H₃PO₄:HBr (2:1) {Huber etch}; Application: InP dislocation etch pit delineation; Ref. (Tamari, N., 1982a)

H₃PO₄:HBr (2:1) (Huber etch); Application: InP defect delineation etch; 2 min at room temperature. CrO₃:AgNO₃:H₂O:HF (1 g:8 mg:2 ml:1 ml) (A–B etch); Application: InP defect delineation etch; 60 min at 60°C; Ref. (Hirano, R., 1993)

HBr:H₄PO₄ (1:2) (Huber etch); Application: InP and InGaAsP defect delineation in 4 μm thick epilayers; Ref. (Nakamura, M., 1993)

H₂PO₄:HBr (2:1) {Huber etch}; Application: InP dislocation etch pit delineation; Ref. (Kimura, T., 1991)

HBr:HNO₃ (3:1); InP dislocation delineation on (1 1 1) and (1 0 0); Ref. (Chu, S.N.G., 1982)
HBr:HNO₃ (3:1); Application: InP (1 1 1) dislocation etch pit delineation; for 7 s; Ref. (Fornari, R., 1989)

HBr:HNO₃ (3:1); InP dislocation delineation, superior reproducibility to H₃PO₄:HBr (2:1) {Huber etch}; Ref. (Lourenco, J.A., 1984)

HCl:HNO₃:HF (5:3:4); InP grain boundary delineation; no effect on first-order twins; Ref. (Hershenson, L., 1980)

HNO₃:HCl:Br (20:10:0.25); InP and GaP dislocation delineation; 5 s for (1 1 1); 60 s for (1 0 0); Ref. (Clarke, R.C., 1973)

CrO₃:AgNO₃:H₂O:HF (1 g:8 mg:2 ml:1 ml) {A–B etch}; InP delineation of pits, ridges, and striations, 30–90 min at 60°C; Ref. (Brown, G.T., 1980)

A–B etch; InP dislocation etch pit delineation; and comparison with HCl:HNO₃:H₂O (1:3:6) and HCl:HNO₃:Br₂ (10:20:0.25); Ref. (Huber, A., 1975)

A–B etch; Layer interface and defect delineation in GaAs, InP, InGaAs, InGaP, GaP; for As-compounds several seconds at 20°C; for P-compounds many minutes at 50–75°C; Ref. (Olsen, G.H., 1974)

A–B etch; Application: InP dislocation delineation; 60°C for 20–30 min; Ref. (Takeda, Y., 1980)

H₂O:AgNO₃:CrO₃:HF (2 ml:8 mg:1 g:1 ml); A–B etch; Application: InP dislocation etch pit delineation; Ref. (Woodward, J., 1982)

AgNO₃:HF:HNO₃:H₂O (40 mg:16 ml:24 ml:32 ml) {R–C etch}; Application: InP (1 1 1)B dislocation delineation; etch time a few hours; Ref. (Lee, T.P., 1980)

AgNO₃:HF:HNO₃:H₂O (40 mg:16 ml:24 ml:32 ml) {R–C etch}; InP dislocation etch pit delineation; Ref. (Takeda, Y., 1978)

CrO₃:HF:H₂O (5:1:x) {Sirtl etch}; InP defect delineation under white or laser light; etch rates for 6 < x < 11; Ref. (Weyher, J.L., 1985)

H₃PO₄:H₂O₂ (1:1); InP and InGaAs lattice defect delineation with selective photoetching; Ref. (Gottschalch, V., 1982)

HCl:HNO₃:H₂O (1:6:6); Application: InP dislocation etch pit delineation; Ref. (Mullin, J.B., 1970)

Anodization: InP; defect delineation; Ref. (Elliott, C.R., 1981)

1 M NaOH is electrolyte; n-InP defect delineation electrochemical etch under illumination

H₃PO₄:HBr (2:1) {Huber etch}; defect delineation comparison; Ref. (Yamamoto, A., 1981)

HBr:H₂O₂:HCl:H₂O (20:2:20:20): InP (1 1 1) and (1 0 0) dislocation etch pit delineation; etch pit shape and formation depend on H₂O₂ and water concentration; shelf time of this etchant is about 12 h; Ref. (Huo, D.T.C., 1989a)
Defect delineation etchants; Application to InP and InGaAsP: H$_3$PO$_4$:HBr (2:1) {Huber etch} at RT for $\sim$2 min HNO$_3$:H$_2$O:HCl (6:6:1), at 60°C for 90 s. HCl:HNO$_3$:Br$_2$ (40:80:1) {RRE etch} at 25°C for 10 s. H$_2$O:AgNO$_3$:CrO$_3$:HF (10 ml:40 mg:5 g:8 ml) {A–B etch} at 75°C for 30 min HBr:HF (1:15), at RT for 1–5 min; Ref. (Mahajan, S., 1981)

HNO$_3$:H$_2$O$_2$ (1:1); InP {1 1 0} defect delineation etch at 100°C; etch rate $\sim$ 2.5 μm/min K$_3$Fe(CN)$_6$:H$_2$O (15 g:100 ml) = part 1, and KOH:H$_2$O (15 g:100 ml) = part 2; part 1:part 2 (3:1); InP etch pit defect delineation under illumination for 10 min, etch rate $\sim$ 0.14 μm/min for both (1 1 0) and (1 1 0); Ref. (Srnanek, R., 1993)

HF:CH$_3$COOH:H$_2$O$_2$; and H$_3$PO$_4$:HF (1:1); electrolytes for photoelectrochemical defect etch pit delineation in InP; compared with chemical defects etchant results from: HNO$_3$:HBr (1:3) H$_3$PO$_4$:HBr (1:2) (Huber etch); Ref. (Faur, M., 1993)

HBr–K$_2$Cr$_2$O$_7$–H$_2$O (BCA etch); InP etch dependence on solution composition; diffusion controlled polishing etch to kinetically controlled defect etch; Ref. (Weyher, J.L., 1994)

**GaAs**

H$_2$O:AgNO$_3$:CrO$_3$:HF (2 ml:8 mg:1 g:1 ml) {A–B etch}; GaAs dislocation etch pit delineation. A–B etch; Ref. (Abrahams, M.S., 1965)

AgNO$_3$:HF:HNO$_3$:H$_2$O (40 mg:16 ml:24 ml:32 ml) {RC etch}; GaAs (1 1 1) dislocation etch pit delineation. Added AgNO$_3$ reveals etch pits on both (1 1 1)A and (1 1 1)B; Ref. (Richards, J.L., 1960)

HCl:H$_2$O$_2$:H$_2$O (1:1:1); GaAs first step surface roughening etch. 10 min; followed by H$_2$SO$_4$:H$_2$O$_2$:H$_2$O (1:8:8); GaAs second step free etch of 50 μm for elongated etch pit delineation for (1 0 0) orientation determination; 3 min at 55°C; Ref. (Caridi, E.A., 1984)

H$_3$PO$_4$:H$_2$O$_2$ (10:1); GaAs (1 0 0) etch pit delineation and cleaved cross-section layer delineation, 3 min under illumination; Ref. (Gottschalch, V., 1979)

KOH:NaOH (50 mol%:50 mol%): GaAs defect delineation etch; used at 170°C eutectic melting temperature; keeps surfaces smooth compared to molten KOH; shows defects in nominally zero-dislocation GaAs; Ref. (Lesoff, H., 1984)

KOH, molten (350°C); GaAs (1 0 0) dislocation etch pit delineation; Ref. (Takenaka, T., 1978); (Elliot, A.G., 1987)

KOH molten (450°C); Application: GaAs defect etch pit delineation; Ref. (Look, C.C., 1989); (Sewell, J.S., 1989)

KOH molten (400°C); GaAs (1 0 0) 10 min for defect etch pit delineation; Ref. (Stirland, D.J., 1986)

KOH, molten (400°C): GaAs {1 0 0}; dislocation etch pit delineation; 30 min Ref. (Angilello, R.J., 1975)
KOH molten (350°C); GaAs defect etch pit delineation; relationship of pit density to structural defects; Ref. (Tartaglia, J.M., 1991)

KOH molten; Application: GaAs (1 0 0) dislocation etch pit delineation. Sirtl etch, modified; GaAs (1 1 1) dislocation etch pit delineation; Ref. (Elliot, A.G., 1987)

KOH molten (400°C) for 3–4 s; GaAs epilayer etch pit dislocation delineation; Ref. (Uen, W.Y., 1993)

KOH molten; GaAs epilayer etch pit defect delineation; 3 mm etch depth. AgNO₃:CrO₃:HF:H₂O (8 mg:1 g:1 ml:2 ml) {A–B etch}; GaAs epilayer etch pit defect delineation; ~10 μm etch depth; Ref. (Takagishi, S., 1993)

H₂SO₄:H₂O₂:H₂O (4:1:1); GaAs substrate cleaning for OMVPE growth; 2 min at 50°C. KOH molten (350°C); defect delineation; for 5–10 min to reveal etch pits; Ref. (Takagishi, S., 1992)

Sirtl etch, modified; GaAs (1 1 1) dislocation etch pit delineation; Ref. (Elliot, A.G., 1987)

CrO₃:HCl:H₂O; GaAs defect delineation study; shows etch characteristics dependence on composition; gives high defect sensitivity for low HCl/CrO₃ ratios under illumination; Ref. (van de Ven, J., 1986a)

CrO₃:HF:H₂O; GaAs (1 0 0) etch and photoetch defect delineation; Ref. (Weyher, J., 1983a,b)

CrO₃:HF:H₂O (1:2:3); GaAs defect delineation; ultrasonic aided; etch rate at 40°C 0.5 μm/min; etch depth 0.5–2 μm to produce etch pits; Ref. (Chen, N., 1993)

HF:CrO₃:H₂O; diluted Sirtl-like (DSL) photoetching; GaAs; identification of etch features with transmission electron microscopy; Ref. (Frigeri, C., 1993)

HF:CrO₃ (1:5) diluted with H₂O (1:1) {DSL; diluted Sirtl-like etch with light}; GaAs photoetch, 30 s for etch pit delineation of dislocations; Ref. (Frigeri, C., 1989)

CrO₃:HF:H₂O; diluted Sirtl-like (DSL) photoetching; Application: GaAs defect delineation; Ref. (Frigeri, C., 1991)

HF:HNO₃:H₂O (1:3:4); GaAs first step etch followed by second step A–B etch to reveal growth striations in LEC material; Ref. (Miyazawa, S., 1982)

HNO₃:HF:H₂O (3:1:4); GaAs delineation of growth striae; 2 min at 20°C; Ref. (Plaskett, T.S., 1965)

HF:H₂O₂:H₂O (1:1:10); GaAs photoetch dislocation etch pit delineation; Ref. (Nishizawa, J., 1979)

A–B etch; Layer interface and defect delineation in GaAs, InP, InGaAs, InGaP, GaP; for As-compounds several seconds at 20°C; for P-compounds many minutes at 50–75°C; Ref. (Olsen, G.H., 1974)

A–B etch; GaAs (1 0 0) 5 min at room temperature for defect etch pit delineation; Ref. (Stirland, D.J., 1986)
A–B etch; GaAs dislocation etch pit delineation study; Ref. (Stirland, D.J., 1977)

A–B etch; GaAs dislocation etch pit delineation. KOH molten at 300°C; GaAs dislocation etch pit delineation; Ref. (Stirland, D.J., 1978)

A–B etch; GaAs etch pit defect delineation; 3 min at room temperature; etch rate ~ 3 μm/min
NaOH–KOH eutectic, molten; GaAs etch pit defect delineation; 30 min at 350°C, etch rate ~ 0.08 μm/min; when used in sequence with A–B etch more information is revealed than with either etch individually; Ref. (Nordquist, P.E.R., 1993)

H2SO4:H2O2:HF (3:2:2); heats spontaneously to 90°C. H2SO4:H2O2:HF (1:4:1); H2SO4:H2O2:HF (1:1:2); best shape pits for crystal orientation; for GaAs room temperature etch rate ~ 6 μm/min; Ref. (Kuhn-Kuhnenfeld, F., 1976)

H2SO4:H2O2:H2O (10:1:1); GaAs striation pattern delineation in semi-insulating LEC material; 20–30 min at 10°C under illumination; Ref. (Fujisaki, Y., 1993)

AgNO3:HF:HNO3:H2O (40 mg:16 ml:24 ml:32 ml) {RC etch}; Application: GaAs dislocation propagation behavior study; Ref. (Yonenaga, I., 1993)

NH4OH electrochemical etch; GaAs; dislocation etch pit delineation; comparison with A–B etch and molten KOH etch; Ref. (Wagner, W.R., 1981)

NH4OH:H2O electrochemical etch with pH = 10.6–13.4; GaAs delineation of striations, dislocations and twins; Ref. (Green, L.L., 1977)

CrO3:HF:H2O (DSL, diluted Sirtl-like with light photoetch); defect delineation in GaAs; comparison to EBIC images; Ref. (Frigeri, C., 1990)

H2SO4:H2O2:H2O (20:1:1); GaAs striation delineation etch. H2SO4:H2O2:H2O (15:1:1); GaAs striation delineation etch. H2SO4:H2O2:H2O (8:1:1); GaAs striation delineation etch. AB etch; GaAs striation delineation etch. AB:H2O (1:5); GaAs striation delineation etch. Diluted Sirtl etch; GaAs striation delineation etch; Ref. (Pandelisev, K.A., 1990)

Bi(NO3)3:H2O2:HCl (0.38 g (Bi(NO3)25H2O) in 15 ml H2O2 mixed with conc. HCl in the ratio 3:1); subsurface defect delineation on polished GaAs; Ref. (Sankaranarayanan, K., 1997)

CrO3:HF:H2O (DS, diluted Sirtl-like etch and DSL diluted Sirtl-like with light photoetch); defect delineation in GaAs; comparison to KOH (molten) defect delineation; Ref. (Weyher, J.L., 1986)

DSL (dilute Syrtl like) etch to reveal As precipitates for TEM study; Ref. (Weyher, J.L., 1998)

InGaAs(P)

H2O:AgNO3:CrO3:HF (10 ml:40 mg:5 g:8 ml) {A–B etch}; InGaAsP LPE layer defect delineation; 25 min at 65°C; Ref. (Shirafuji, J., 1981)

A–B etch; Application: InGaAs dislocation etch pit delineation; Ref. (Ahmad, K., 1979)
A–B etch; Application: dislocation delineation for InGaAs 3 min at 20°C; Ref. (Takeda, Y., 1978, 1980)

A–B etch:HF (1:3); Application: InGaAs dislocation etch pit delineation for 10 s at 60°C; HF slows the etch rate; Ref. (Susa, N., 1980a,c)

A–B etch, modified: H₂O₄:AgNO₃:CrO₃:HF (10 ml:140 mg:5 g:8 ml); InGaAsP dislocation etch pit delineation; 30 min at 75°C; Ref. (Theil, F.A., 1979)

H₃PO₄:H₂O₂ (10:1); Ga₀.₉₈In₀.₀₂As (1 0 0) etch pit delineation and cleaved cross-section layer delineation, 3 min under illumination; Ref. (Gottschalch, V., 1979)

H₃PO₄:H₂O₂ (1:1); InP and InGaAs lattice defect delineation with selective photoetching; Ref. (Gottschalch, V., 1982)

KOH:K₃Fe(CN)₆:H₂O (8 g:0.5 g:100 ml); 10 min etching InGaAsP under illumination to reveal defects; etch rate ∼ 1.5 μm/h; not useful on Zn-doped p-layers; Ref. (Lourenco, J.A., 1984)

NH₄OH:H₂O₂:H₂O; InGaAs dislocation etch pit delineation; Ref. (Susa, N., 1981)

H₃PO₄:HBr (2:1) {Huber etch}; InGaAsP dislocation etch pit delineation; 2 min at 25°C; Ref. (Theil, F.A., 1979)

HCl:HNO₃:H₂O (6:1:6); InGaAsP dislocation etch pit delineation; 90 s at 25°C; Ref. (Theil, F.A., 1979)

HNO₃:HCl:Br (20:10:0.25) {RRE etch}; InGaAsP dislocation etch pit delineation; 10 s at 25°C; Ref. (Theil, F.A., 1979)

InSb

H₂O₂:[HF + H₂O + 0.4% butylthiobutane] (1:1); InSb {1 1 1}Sb dislocation delineation; Ref. (Gatos, H.C., 1961)

InSb {1 1 1}; dislocation etch pit delineation; Ref. (Gatos, H.C., 1960a)

InSb {1 1 0} and {1 0 0}; dislocation etch pit delineation; Ref. (Gatos, H.C., 1960b)

InSb:HNO₃ (1:1); InSb polish etch, 2–5 s, following mechanical polishing to delineate dislocation etch pits; Ref. (Venables, J.D., 1958)

GaSb

HF:HNO₃:CH₃COOH (2:18:40); GaSb first step prior to defect delineation etch. Br₂/methanol (2%); GaSb (1 1 1)A etch pit defect delineation etch. HCl:H₂O₂; GaSb etch pit defect delineation etch for all other orientations; Ref. (Doerschel, J., 1992)

HNO₃:HF:CH₃COOH (6:2:1); GaSb polycrystalline material cleaning prior to Czochralski growth. KOH:H₂O (45% solution); GaSb first step prior to defect etching; 2 min under continuous stirring at
room temperature. \( \text{CH}_3\text{COOH} : \text{HNO}_3 : \text{HF} \ (20:9:1) \); GaSb \( \{111\} \) first step etch pit defect delineation for 1 min, followed by \( \text{Br}_2 / \text{methanol} \ (5\%) \) for 11 min; Ref. (Stepanek, B., 1992)

Defect delineation in GaSb: CP-4 40\% diluted in \( \text{H}_2\text{O} \); etch pit delineation only on \( \{111\} \). \( \text{Br}_2 / \text{methanol} \ (3\%); \) etch pit delineation only on \( \{111\} \). \( \text{HCl} : \text{HNO}_3 : \text{H}_2\text{O} \ (6:1:6); \) unreproducible etch pit delineation. \( \text{HCl} : \text{H}_2\text{O}_2 \ (2:1); \) unreproducible etch pit delineation. \( \text{H}_2\text{SO}_4 : \text{H}_2\text{O}_2 \ (5:1); \) etch pit delineation on \( \{111\} \), \( \{111\}B \), \( \{110\} \), \( \{110\} \), striations on \( \{111\} \) and \( \{110\} \); precipitates on \( \{111\} \), \( \{110\} \). \( \text{CrO}_3 \ (5 \text{ M aq. sol.}): \text{HF} \ (5:1); \) etch pit delineation on \( \{111\} \), \( \{111\}B \), \( \{110\} \), \( \{110\} \), striations on \( \{111\} \) and \( \{110\} \); precipitates on \( \{111\} \) and \( \{110\} \). \( \text{KMnO}_4 \ (\text{sat.}): \text{HF} : \text{CH}_3\text{COOH} \ (1:1:1); \) growth striations on \( \{110\} \) in n-type GaSb. \( \text{Ce(SO}_4)_2 \ (0.1 \text{ M}); \) \( \text{HNO}_3 : \text{CH}_3\text{COOH} \ (1:2:2); \) growth striations on \( \{110\} \) in Te-doped GaSb; Ref. (Costa, E.M., 1997)

\( \text{HF} : \text{CH}_3\text{COOH} : \text{KMnO}_4 \ (0.4 \text{ M}) \ (1:1:1); \) Application: striation defect delineation in GaSb after 5.5 min etch. \( \text{HNO}_3 : \text{HCl} : \text{H}_2\text{O} \ (1:1:1); \) Application: etch pit defect delineation in GaSb; Ref. (Nishinaga, T., 1997)

**GaP**

\( \text{HNO}_3 : \text{HCl} : \text{Br} \ (20:10:0.25); \) InP and GaP dislocation delineation; 5 s for \( \{111\} \); 60 s for \( \{100\} \); Ref. (Clarke, R.C., 1973)

\( \text{H}_3\text{PO}_4 : \text{H}_2\text{O}_2 \ (1:1); \) GaP \( \{100\} \) etch pit delineation and cleaved cross-section layer delineation, 15 min under illumination; Ref. (Gottschalch, V., 1979a)

A–B etch; with \( A = 40 \text{ ml} \text{H}_2\text{O}:40 \text{ g} \text{CrO}_3 \), \( B = 40 \text{ ml} \text{H}_2\text{O}:0.3 \text{ g} \text{AgNO}_3 \); \( A:B \ (3:1); \) GaP 15 min at boiling; etch pits show 1-to-1 correlation with \( \text{H}_3\text{PO}_4 : \text{H}_2\text{O}_2 \) photoetch; Ref. (Gottschalch, V., 1979a)

A–B etch; Layer interface and defect delineation in GaAs, InP, InGaAs, InGaP, GaP; for As-compounds several seconds at 20°C; for P-compounds many minutes at 50–75°C; Ref. (Olsen, G.H., 1974)

\( \text{Br}_2 / \text{ethanol} \ (20\%); \) GaP dislocation etch pit delineation; 30–60 s. \( \text{FeCl}_3 : \text{HCl} : \text{H}_2\text{O} \ (27 \text{ g}:250 \text{ ml}:350 \text{ ml}), \) boiling; GaP dislocation etch pit delineation; 12–18 min \( \text{KOH} : \text{K}_3\text{Fe(CN)}_6 : \text{H}_2\text{O} \ (6 \text{ g}:4 \text{ g}:50 \text{ ml}) \) boiling; GaP dislocation etch pit delineation; 1–2 min; Ref. (Val’kovskaya, M.I., 1967)

\( \text{H}_2\text{SO}_4 : \text{H}_2\text{O}_2 : \text{HF} \ (3:2:2); \) heats spontaneously to 90°C. \( \text{H}_2\text{SO}_4 : \text{H}_2\text{O}_2 : \text{HF} \ (1:4:1); \) \( \text{H}_2\text{SO}_4 : \text{H}_2\text{O}_2 : \text{HF} \ (1:1:2); \) best shape pits for crystal orientation; for GaP etch pit delineation use at 60–90°C for 3–15 min; Ref. (Kuhn-Kuhnenfeld, F., 1976)

A–B etch; GaAs dislocation etch pit delineation study; Ref. (Stirland, D.J., 1977)

\( \text{AgNO}_3 \ (10 \text{ mg}) : \text{HF} \ (4 \text{ ml}) : \text{HNO}_3 \ (6 \text{ ml}) : \text{H}_2\text{O} \ (8 \text{ ml}) \) (RC etchant); etch pit delineation in GaP; Ref. (Okada, H., 1999)

\( \text{H}_2\text{O} : \text{AgNO}_3 : \text{CrO}_3 : \text{HF} \ (10 \text{ ml}:40 \text{ mg}:5 \text{ g}:8 \text{ ml}) \ \{A–B etch\}; \) GaP defect delineation; 50 min at 75°C. \( \text{H}_2\text{O} : \text{AgNO}_3 : \text{HNO}_3 : \text{HF} \ (8 \text{ ml}:10 \text{ mg}:6 \text{ ml}:4 \text{ ml}) \ \{ \text{RC etch} \}; \) GaP defect delineation; 3 min at 60°C; Ref. (Iizuka, T., 1971)
GaP defect delineation using: $\text{H}_2\text{O}:\text{AgNO}_3:\text{CrO}_3:\text{HF}$ (10 ml:40 mg:5 g:8 ml); 15–60 min at 75°C {A–B etch}. $\text{H}_2\text{O}:\text{AgNO}_3:\text{HNO}_3:\text{HF}$ (8 ml:10 mg:6 ml:4 ml); 1–3 min at 60°C {RC etch}. $\text{H}_2\text{O}:\text{KOH}:\text{K}_3\text{Fe(CN)}_6$ (50 ml:6 g:4 g); 1–2 min at 100°C; etch rate = 20–25 μm/h; $\text{H}_2\text{O}:\text{HCl}:\text{HNO}_3$: (10 ml:10 ml:5 ml); at 50°C; etch rate = 2–5 μm/min. The higher temperatures and changes in compositions are necessary to retard precipitates which accumulate on the etched surface; Ref. (Saul, R.H., 1968)

**GaAsP**

$\text{H}_3\text{PO}_4:\text{H}_2\text{O}_2$ (1:1); GaAs$_{0.2}$P$_{0.8}$ (1 0 0) etch pit delineation and cleaved cross-section layer delineation, 10 min under illumination; Ref. (Gottschalch, V., 1979a)

$\text{H}_3\text{PO}_4:\text{H}_2\text{O}_2$ (10:1); GaAs$_{0.6}$P$_{0.4}$ (1 0 0) etch pit delineation and cleaved cross-section layer delineation, 15 min under illumination; Ref. (Gottschalch, V., 1979a)

A–B etch; Application: GaAsP dislocation etch pit delineation; Ref. (Stringfellow, G.B., 1969)

**AlGaAs**

$\text{H}_3\text{PO}_4:\text{H}_2\text{O}_2$ (10:1); AlGaAs (1 0 0) etch pit delineation and cleaved cross-section layer delineation, 3 min under illumination; Ref. (Gottschalch, V., 1979a)

**AlGaSb**

$\text{HF}:\text{CH}_3\text{COOH}:\text{KMnO}_4$ (0.05 M) (1:1:1); AlGaSb striation and defect delineation etch; Ref. (Bischopink, G., 1993a); (Bischopink, G., 1993b)

**GaN**

KOH molten; GaN dislocation etch pit delineation; 10 min at 360°C; Ref. (Kozawa, T., 1996)

KOH molten (360°C); etch pit delineation in GaN layers; SEM and TEM observations; Ref. (Shojima, K., 2000)

$\text{H}_3\text{PO}_4:\text{H}_2\text{SO}_4$ (1:4); GaN defect delineation etch; 230°C for 10 min; Ref. (Ono, Y., 1998)

$\text{H}_3\text{PO}_4$ (85%); GaN epilayer etch at 190°C for etch figure growth assessment; Ref. (Shintani, A., 1976)

**Si**

Review: silicon defect etch pit delineation; Ref. (Heimann, R.B., 1982)

Study: Si (1 0 0) dislocation etch pit delineation etches: HF:CrO$_3$ (5 M) (1:1) {Sirtl etch}; Si non-linear etch rate ~ 3.5 μm/min HF:K$_2$Cr$_2$O$_7$ (0.15 M) {Secco etch}; Si etch rate = 1.5 μm/min with ultrasonic agitation. HF:CrO$_3$ (0.15 M) {Alternate Secco etch}; Si etch rate ~ 1 μm/min with ultrasonic agitation. HF:HNO$_3$:CH$_3$COOH (1:3:1) {Dash etch}; Si non-linear etch rate ~ 0.1 μm/
min, n-substrate with illumination. HF:HNO₃ (155:1) {Schimmel etch}; Si non-linear etch rate ∼ 1.8 μm/min, n-substrate with illumination; Ref. (Schimmel, D.G., 1976)

HNO₃:CH₃COOH:HF (3:2:2); Si wafer chemical polish prior to etch pit study. HF:K₂Cr₂O₇ (0.15 M) (2:1) {Secco etch}; Study: Si dislocation etch pit delineation; etch rate = 1.5 μm/min; Ref. (Secco d’Aragona, F., 1972)

HF:0.15 M K₂Cr₂O₇ (2:1) {Secco etch}; Application: Si wafer defect delineation; Ref. (Kesan, V.P., 1991)

Orientation determination from etching anisotropy

InP

H₃PO₄:HBr (2:1) {Huber etch}; InP first step etch pit delineation; 1–2 min at 20°C gives symmetrical etch pits; followed by H₂SO₄:H₂O₂:H₂O (1:1:1); InP second step free etch of 30 μm for elongated etch pit delineation for (1 0 0) orientation determination; 5 min at 85°C; Ref. (Caridi, E.A., 1984)

HCl:H₂O₂ (1:1); InP (1 0 0) orientation determination; Ref. (Keavney, C.J., 1984)

HBr:CH₃COOH; InP (1 0 0) orientation determination etch; Ref. (Nagai, H., 1980)

0.4N FeCl₃ in HCl; InP (1 0 0) orientation determination; Ref. (Olsen, G.H., 1979)

HCl; InP (1 0 0) orientation determination identification of [1 1 0] and [1 1 0] directions; Ref. (Stulz, L.W., 1983)

HCl:H₂O (4:1); Application: InP (1 0 0) orientation determination; ⟨1 1 0⟩ versus ⟨1 1 0⟩; Ref. (Suematsu, Y., 1982); (Iga, K., 1980c); (Kambayashi, T., 1980)

0.4N FeCl₃ in HCl; InP (1 0 0) orientation determination from etch pit elongation; Ref. (Tuck, B., 1973)

HCl conc.; InP; Application: low angle groove etch to reduce optical reflection in solar cells; Ref. (Jenkins, P., 1991)

GaAs

HCl:H₂O₂:H₂O (1:1:1); GaAs first step surface roughening etch. 10 min; followed by H₂SO₄:-H₂O₂:H₂O (1:8:8); GaAs second step free etch of 50 μm for elongated etch pit delineation for (1 0 0) orientation determination; 3 min at 55°C; Ref. (Caridi, E.A., 1984)

HNO₃:tartaric acid (3:1); GaAs; (1 1 1)A etches faster than (1 1 1)B; Ref. (Faust, J.W., 1960)

HCl:HNO₃:H₂O 1:1:1; GaAs; (1 1 1)A etches faster than (1 1 1)B; Ref. (Faust, J.W., 1960)
HCl:HNO₃:H₂O (2:1:2); GaAs discrimination of (1 1 1)A from (1 1 1)B surfaces; Ref. (White, J.G., 1959)

H₂O₂:NaOH (3:1); GaAs; (1 1 1)A etches faster than (1 1 1)B; Ref. (Faust, J.W., 1960)

H₂SO₄:H₂O₂:HF (1:1:2); best shape pits for crystal orientation; for GaAs room temperature etch rate ~ 6 μm/min; Ref. (Kuhn-Kuhnenfeld, F., 1976)

**GaP**

H₂SO₄:H₂O₂:HF (1:1:2); best shape pits for crystal orientation; for GaP etch pit delineation use at 60–90°C for 3–15 min; Ref. (Kuhn-Kuhnenfeld, F., 1976)

**InSb**

HF:H₂O₂:H₂O (1:1:4); InSb, InAs, GaAs; (1 1 1)A etches faster than (1 1 1)B; Ref. (Faust, J.W., 1960)

HF:HNO₃:H₂O (1:1:4); InSb; (1 1 1)A etches faster than (1 1 1)B; Ref. (Faust, J.W., 1960)

HNO₃:HF:CH₃COOH:Br₂ (75:15:15:0.06); InSb {1 1 1}A and {1 1 1}B etch figures for determining orientation polarity; Ref. (Warekois, E.P., 1959)

**InAs**

HCl conc.; InAs; (1 1 1)A etches faster than (1 1 1)B; Ref. (Faust, J.W., 1960)

HNO₃:HF:CH₃COOH:Br₂ (75:15:15:0.06); InAs; (1 1 1)A etches faster than (1 1 1)B; Ref. (Faust, J.W., 1960)

**GaSb**

HCl:H₂O₂:H₂O (1:1:2); GaSb; (1 1 1)A etches faster than (1 1 1)B; Ref. (Faust, J.W., 1960)

HNO₃:tartaric acid (1:3); GaSb; (1 1 1)A etches faster than (1 1 1)B; Ref. (Faust, J.W., 1960)

HF:HNO₃:H₂O (1:1:1); GaSb; (1 1 1)A etches faster than (1 1 1)B; Ref. (Faust, J.W., 1960)

HCl conc.: CuCl (1.0N); GaSb surface etching to determine crystal orientation; Ref. (Godines, J.A., 1994)

*Layer delineation etchants*

**InP**

K₃Fe(CN)₆:KOH; Application: InP LPE layer interface delineation; Ref. (Astles, M.G., 1973)
KOH:K₃Fe(CN)₆:H₂O (6 g:4 g:50 ml); Application: InP cleaved cross-section layer delineation; ~5 min at 20°C; selectively etches InGaAsP on InP; Ref. (Clarke, R.C., 1970); (Clarke, R.C., 1973); (Susa, N., 1981); (Hales, M.C., 1970)

KOH:K₃Fe(CN)₆:H₂O; InP cleaved cross-section layer delineation; Ref. (Kim, J.S., 1992)

A–B etch; Layer interface and defect delineation in GaAs, InP, InGaAs, InGaP, GaP; for As-compounds several seconds at 20°C; for P-compounds many min at 50–75°C; Ref. (Olsen, G.H., 1974)

AgNO₃:CrO₃:HF:H₂O (40 mg:5 g:8 ml:10 ml) {A–B etch}; Application: InP layer delineation; Ref. (Rosztoczy, F.E., 1970)

InGaAs/InP

KOH:K₃Fe(CN)₆:H₂O; Application: InGaAs/InP and p–n junction cleaved cross-section layer delineation; Ref. (Ando, H., 1981)

HF:HNO₃:H₂O (50:1:50) + 5 mg K(FeCN)₆; Application: InGaAs/InP cleaved cross-section layer delineation; Ref. (Coleman, J.J., 1978)

KOH:K₃Fe(CN)₆:H₂O (6 g:4 g:50 ml); Application: InGaAs/InP cleaved cross-section layer delineation; etches InGaAs selectively; etch rate ~ 2 μm/min. This works best for multilayer delineation where the top layer is InP; etch rate is too fast to use on InGaAs layer directly; Ref. (Hyder, S.B., 1979)

H₂SO₄:H₂O₂:H₂O (1:1:10); InGaAs/InP interface delineation; Ref. (Susa, N., 1980a,c)

K₃Fe(CN)₆:KOH:H₂O (1 g:1 g:16 g); InP/InGaAs layer delineation under illumination; Ref. (Nordell, N., 1992)

InGaAsP/InP

KOH:K₃Fe(CN)₆:H₂O; Application: InGaAsP/InP cleaved cross-section layer delineation; Ref. (Hsieh, J.J., 1976)

HF:HNO₃; Application: InGaAsP/InP LPE layer cross-section delineation; Ref. (Akiba, S., 1980)

KOH:K₃Fe(CN)₆:H₂O; Application: InGaAsP/InP cleaved cross-section layer delineation; Ref. (Itaya, Y., 1979); (Ng, W.W., 1981); (Sakai, K., 1981)

KOH:K₃Fe(CN)₆:H₂O (6 g:4 g:50 ml); Application: InGaAsP/InP cleaved cross-section layer delineation; ~5 s at 20°C; Ref. (Rezek, E.A., 1980)

HF:H₂O₂:H₂O (1:1:10); InGaAsP/InP interface delineation; Ref. (Susa, N., 1981)

A–B etch; Application: InGaAsP/InP layer interface delineation a few seconds at 100°C; Ref. (Wright, P.D., 1977)
Ar ion etch; InGaAsP/InP cross-section interface layer delineation; Ref. (Zargar’yants, M.N., 1983)

FeCN:KOH:H2O; cleaved cross-section layer delineation stain for SEM study; Ref. (Bertone, D., 1999)

AlGaAs/GaAs

KOH:K3Fe(CN)6:H2O (12 g:9 g:70 ml); Application: GaAlAs/GaAs cleaved cross-section layer delineation; Ref. (Colas, E., 1990)

K3Fe(CN)6:KOH:H2O (8:12:100 by weight); AlGaAs/GaAs layer delineation; Ref. (Zhu, Y., 1991)

H2O:AgNO3:CrO3:HF (10 ml:40 mg:5 g:8 ml) {A–B etch}; GaAs/AlGaAs layer cross-section interface delineation; {1 1 1} facets along {0 1 1}; {2 2 1} facets along {0 1 1}; Ref. (Demeester, P., 1988)

NaClO (5% solution); AlGaAs/GaAs stained, chemi-mechanical beveled cross-section quantum well layer delineation; Ref. (Holonyak, N., 1979)

NH4OH(30% aq.):H2O2(30% aq.) (3:100); AlGaAS on GaAs layer delineation; a few seconds; Ref. (Nagmune, Y., 1993)

HCl:H2O2:H2O (1:4:40); Application: AlGaAs/GaAs stain for SEM cross-sections; Ref. (Maranowski, S.A., 1993)

HCl:H2O2:H2O (1:4:40); Application: AlGaAs/GaAs cross section stain, 5 s; Ref. (Sugg, A.R., 1993)

HNO3:HF (1:3); GaAs layer delineation. HNO3:HF:H2O (1:3:4); GaAs layer delineation. HNO3:HF:H2O (3:1:5); GaAs layer delineation. KOH:K3Fe(CN)6[(120 g KOH + 500 ml H2O):(80 g K3Fe(CN)6 + 500 ml H2O)]; GaAs layer delineation; Ref. (Colliver, D.J., 1976)

GaP

Photochemical dislocation etch pit delineation and cleaved cross-section layer delineation:

H3PO4:H2O2 (1:1); GaP (1 0 0), 15 min under illumination
H3PO4:H2O2 (1:1); GaAs0.2P0.8 (1 0 0) 10 min under illumination
H3PO4:H2O2 (10:1); GaAs0.6P0.4 (1 0 0) 15 min under illumination
H3PO4:H2O2 (10:1); GaAs (1 0 0) 3 min under illumination
H3PO4:H2O2 (10:1); Ga0.98In0.02As (1 0 0) 3 min under illumination
H3PO4:H2O2 (10:1); AlGaAs (1 0 0) 3 min under illumination

A–B etch; with A = 40 ml H2O:40 g CrO3; B = 40 ml H2O:0.3 g AgNO3; A:B (3:1); GaP 15 min at boiling; etch pits show 1-to-1 correlation with H3PO4:H2O2 photoetch; Ref. (Gottschalch, V., 1979a)

A–B etch; Layer interface and defect delineation in GaAs, InP, InGaAs, InGaP, GaP; for As-compounds several seconds at 20°C; for P-compounds many minutes at 50–75°C; Ref. (Olsen, G.H., 1974)
The p–n junction delineation etchants

HCl:H₂O (1:20); GaAs n-type selective photoetch from GaAs p-type, selectivity > 15,000. GaAs n-type selective etch from GaAs semi-insulating, selectivity ~30; Ref. (Khare, R., 1991) Photo-chemical etching review: p–n dopant selectivity; surface relief etching; InGaAsP/InP and GaAs; Ref. (Kohl, P.A., 1989)

KOH:K₃Fe(CN)₆:H₂O (8 g:0.5 g:100 ml); InGaAsP p–n junction delineation. A–B etch tried, but too fast attack; Ref. (Lourenco, J.A., 1983)

KOH:Fe(CN)₆:H₂O (6 g:4 g:50 ml); Application: p–n junction photochemical delineation for Zn diffusion assessment in InGaAsP/InP structures; Ref. (Hou, D.T.C., 1990)

HNO₃:H₂O (1:20); GaAs photoetching p–n junction delineation; dopant selective: n-etching under illumination; p-type does not etch; no GaAs dark etching; Ref. (Ruberto, M.N., 1991)

HF:H₂O (1:10); GaAs and InP photoetch p–n junction delineation; dopant selective; n-etches under illumination; p-type does not etch; Ref. (Ruberto, M.N., 1991)

HNO₃:HCl:H₂O (1:1:100); InP photoetch p–n junction delineation; Ref. (Ruberto, M.N., 1991)

A–B etch; Application: GaAs epilayer p–n junction delineation; Ref. (Sin, Y.K., 1991)

HCl:HNO₃:H₂O (1:1:20); InGaAsP and InP p–n junction delineation photoetch; dopant selective: n-etches under illumination; p-type does not etch; very sharp boundaries; Ref. (Williamson, J., 1993)

HF:H₂O₂:H₂O (1:1:10); Application: InGaAs diffused p–n junction cross-section delineation; 15–20 s under illumination; Ref. (Yamamoto, Y., 1980)

Ferric sulfate(non-ahydrate):EDTA(disodium salt of ethylenediaminetetraacetic acid):H₂O (5 g:3 g:100 ml); GaAs photoelectrochemical p–n junction delineation; Ref. (Greene, P.D., 1977)

HF:HNO₃:H₂O (1:3:2); InAs p–n junction delineation; 1–3 min; Ref. (Sharma, B.I., 1966) (see also Section 3.c. Dopant Selective Etchants)

2.3. Wet chemical mesa etching

2.3.1. Non-selective etchants

Limited to references where the etchant was specifically identified as non-selective

InGaAsP/InP

Br₂/methanol; Application: InGaAsP/InP non-selective mesa etch; Ref. (Capasso, F., 1980); (Hurwitz, C.E., 1978); (Wright, P.D., 1980a,b,c)

Br₂/methanol; Application: InGaAsP/InP non-selective mesa etch for laser fabrication; Ref. (Arai, S., 1981); (Mito, I., 1982)
Br₂/methanol; Application: InGaAsP/InP non-selective etch for photodiodes; Ref. (Takahashi, K., 1981)

Br₂/methanol (0.2%); InP/InGaAsP; with SiOₓ masked patterns etch etch rate is enhanced by Br diffusion from masked areas; at low Br concentrations etch rate is diffusion limited and is independent of concentration, temperature and crystallographic orientation; Ref. (Brenner, T., 1994)

HCl:HNO₃ (1:3); InGaAsP/InP non-selective mesa etch; data is given on etch wall profiles; Ref. (Coldren, L.A., 1983)

HCl:HNO₃ (1:2); equal etch rate on InP and InGaAsP = 0.16 μm/s; Ref. (Furuya, K., 1981)

HCl:HNO₃:H₂O (2:3:6); InP etch rate = 1 μm/min; non-selective; Ref. (Colliver, D.J., 1976)

HCl:HNO₃:H₂O (2:2:1); InP etch rate = 2 μm/min; non-selective; Ref. (Colliver, D.J., 1976)

HBr:H₃PO₄:K₂Cr₂O₇ (2:2:1); InP and InGaAsP equal etch rate = 1.5 μm/min; does not attack photoresist; Ref. (Adachi, S., 1982a)

HBr:CH₃COOH:K₂Cr₂O₇ (1:1:1); InP and InGaAs mesa etch, equal rates for both; Ref. (Frei, M.R., 1991)

HBr:CH₃COOH:K₂Cr₂O₇ (2:2:1); nearly equal etch rate ~ 2.5 μm/min for InGaAsP and InP.
HBr:CH₃COOH:K₂Cr₂O₇ (1:1:1); Application: InGaAsP/InP laser; does not erode photoresist; provides very smooth and nearly vertical walls; Ref. (Adachi, S., 1982d)

HBr:H₂O₂:H₂O (1:1:10); InGaAsP/InP non-selective etch; Ref. (Wallin, J., 1992)

Saturated Br₂ water:H₃PO₄:H₂O (2:1:15); InP etch rate = 56 Å/s at 22°C; InGaAs etch rate = 43 Å/s.
Saturated Br₂ water:HCl:H₂O (10:1:20); gives etch rate dependence on acid concentration; Ref. (Saitoh, T., 1982)

HCl:CH₃COOH:H₂O₂ (2:1:2) {KKI etch}; Application: InGaAsP/InP (1 0 0) non-selective etch; shows etch profiles; Ref. (Iga, K., 1979a,b,c, 1980a,b,c)

HCl:CH₃COOH:H₂O₂ (1:1:1) {KKI etch}; Application: InGaAsP/InP non-selective mesa etch at 25°C; Ref. (Sakai, S., 1979a)

HCl:CH₃COOH:H₂O (6:4:1); Application: InGaAs/InP mesa etch at 8°C; Ref. (Küsters, A.M., 1993)

HCl:H₂O (1:1); InGaP mesa etch; Ref. (Pearton, S.J., 1993c)

Saturated bromine water:HBr:H₂O; second step following RIE etch for patterns in InP; Ref. (Bertone, D., 1999)

HCl:CH₃COOH:H₂O₂ (1:2:2); non-selective etch of InGaAs/InP; rate = 90–130 Å/s at 15°C. SBW/ HBr:HNO₃:H₂O (1:1:8); (SBW is prepared by putting 3 ml Br into 100 ml deionized water. SBW
and HBr are mixed in proportions of 1–50 vol.%. Color of HBr changes to light yellow; non-selective etch of InGaAs/InP; rate = 15–20 Å/s at 4°C; etch of 500–1000 Å wide electron waveguide features with photoresist mask; Ref. (Maximov, I., 1999)

**AlGaAs/GaAs**

HNO₃:H₂O (1:10–100); GaAs and AlGaAs non-selective etch under illumination; Ref. (Fink, Th., 1993a,b)

H₃PO₄:H₂O₂:CH₃OH (2:1:1); Application: AlGaAs/GaAs mesa etch; near identical etch rates for GaAs and AlₓGa₁₋ₓAs for x < 0.33; Ref. (Peng, L.-M., 1992)

H₃PO₄:H₂O₂:H₂O (1:1:1); GaAs and AlGaAs mesa etch; Ref. (Pearton, S.J., 1993c)

H₃PO₄:H₂O₂:H₂O (1:1:10); Application: non-selective etch of AlGaAs/GaAs and InAlGaAs/InAlAs; Ref. (Cho, H.K., 1999)

Citric acid:H₂O₂:H₂O (4:1:1); non-selective GaAs, AlGaAs etch rate ~ 4000 Å/min; Ref. (Mao, B.-Y., 1994)

H₃PO₄:H₂O₂:methanol (28:16:84); non-selective GaAs and AlGaAs; Ref. (Fricke, K., 1994)

H₃PO₄:H₂O₂:methanol (2:1:1); AlGaAs/GaAs near identical etch rates; Ref. (Peng, L.-M., 1992)

Citric acid (1 wt.% anhydrous to 1 wt.% water):H₂O₂:H₂O (5:1:75); GaAs/Al₀.₃Ga₀.₇As non-selective etch; GaAs rate = 15.3 nm/min; AlGaAs rate = 17.6 nm/min; Ref. (Cho, S.-J., 1999)

H₃PO₄:H₂O₂:H₂O (4:1:180); non-selective etch for GaAs/AlGaAs; Ref. (Moon, E.-A., 1998)

Citric acid:H₂O₂ (100:1); study of oxidation/dissolution etch mechanism and selectivity of GaAs and AlGaAs; Ref. (Schneider, M., 1987)

Citric acid:H₂O₂ (1:1); GaAs/AlGaAs/InGaAs blanket etch; AlGaAs etch rate is ~1/3 that of GaAs and InGaAs; Ref. (Tan, I.-H., 1992)

**InGaP/GaAs**

HBr:Br₂:H₂O (5:0.1:100); Application: non-selective mesa etch for InGaP/GaAs; etch rate 0.6 μm/min for both materials; Ref. (Ginoudi, A., 1992)

HCl:H₂SO₄:H₂O₂:H₂O (m:1:10:2000, with 0.6 < m < 1.5); rate dependence and selectivity for In₀.₅Ga₀.₅P, InGaAsP and GaAs; Ref. (Ito, H., 1995)

**AlGaInP/GaAs**

HCl:HIO₃:H₂O (1:1:x, where 5 < x < 100); non-selective etchant for GaAs/AlGaInP; etch rates from 300 to 2500 Å/min depending on x; good etch morphology and stability with time.
HCl:KIO₃ (1:1) with KIO₃ at 0.1 mol/l; non-selective etchant for GaAs/AlGaInP; etch rates from ~1000 Å/min; good etch morphology and stability with time; undercutting of AlGaInP
HCl:K₂Cr₂O₇; non-selective etchant for GaAs/AlGaInP; similar to HCl:KIO₃; Ref. (Zaknoune, M., 1998)

**InAs/GaSb/AlGaSb**

H₃PO₄ non-selective etch for InAs/GaSb/AlGaSb; Ref. (Yoh, K., 1991)

H₂SO₄:H₂O₂:H₂O (1:8:80); Application: InAs/AlSb mesa etch; Ref. (Brown, E.R., 1994)

2.3.2. **Material selective etchants**

**InP from InGaAs**

H₃PO₄:HCl (3:1); InP selective etch from InGaAs; Ref. (Dambkes, H., 1984); (Dupuis, R.D., 1991)

H₃PO₄:HCl (4:6); Application: InP selective etch from InGaAs; Ref. (Houston, P.A., 1987)

HCl:H₃PO₄ (1:10); Application: InP selective etch from InGaAs using SiN mask for HBT fabrication; Ref. (Ouacha, A., 1993)

HCl:H₃PO₄:H₂O (3:1:1); InP etch at 0°C, material selective from InGaAs; shows sidewall deformation for nanometer geometries

HCl:CH₃COOH (1:4); InP material selective etch from InGaAs; gives near vertical sidewalls for nanometer geometries; Ref. (Inamura, E., 1989)

HCl:H₂O (4:1); Application: InP selective removal from InGaAs etch stop layer to allow backside SIMS measurements of metal contact diffusion profiles in InGaAs/InP structures; Ref. (Chen, W.L., 1992)

HCl:H₂O (5:1); InP substrate removal from InGaAs/InAlAs structure for transfer to glass substrate; Ref. (Arscott, S., 2000)

HCl:H₂O (3:1); InP selective etch from ~30 Å InGaAs mask layer; InP etch rate at 4°C ~300 Å/s

H₂SO₄:H₂O₂:H₂O (1:1:10); InGaAs selective etch from ~30 Å InP mask layer; using direct-write lithography on the thin semiconductor mask with focused Ga ion beam

Ar ion-assisted Cl₂ selective etching of InP and InGaAs; Ref. (Temkin, H., 1988)

HCl:propylene glycol (1:2); Application: InP selective etch from InGaAs mask layer; Ref. (Ishibashi, T., 1981)

KF (0.75N):HF (0.75N); Application: InGaAs/InP photochemical etch; n-substrate wafer is biased to deplete the surface; incident light generates holes which assist oxidation to promote etching; 175 µm in 4 h; etch depth stops at p-InGaAs; diameter continues to widen; Ref. (Forrest, S.R., 1982)

Reactive ion etch; ClIC₃ with H₂, He, O₂, Ne or Ar; GaAs and InP; GaAs and InP etch selectivity depend on gas combinations; Ref. (Law, V.J., 1992)
HCl:CH₃COOH (1:4); selective etch of InP from InGaAs; 220 Å/s; Ref. (Miyamoto, Y., 1998)

HCl:CH₃COOH (1:1); Application: selective removal of InP from InGaAs/AlInGaAs structure; Ref. (Bélier, B., 2000)

HCl:H₂O (5:1); InP rate ~15 μm/min
HCl:H₂O (1:1); InP rate <100 Å/min
HCl:H₂O (5:3); selective etchant to remove a sacrificial InP layer from between an InGaAs mask and an InGaAs etch stop layer to form micromachined cantilevers; Ref. (Mounaix, P., 1998)

InP from InGaAsP

HCl; InP selective etch from InGaAsP; Ref. (Adachi, S., 1982c)

HCl does not attack GaAs but reacts with InAs and InP; Ref. (Phatak, S.B., 1979)

HCl conc.; InP (1 0 0) etch rate = 5.4 μm/min; InP selective etch from InGaAsP; Ref. (Ferrante, G.A., 1983)

HCl conc.; InP selective etch from InGaAsP; Ref. (Kelly, J.J., 1988); (Koch, T.L., 1987); (Liau, Z.L., 1982); (Chen, P.C., 1981); (Kawanishi, H., 1979)

HCl dilute; InP selective etch from InGaAsP; Ref. (Nelson, R.J., 1980); (Ng, W., 1981)

HCl:H₂O (4:1); Application: InP selective etch from InGaAsP; Ref. (Murotani, T., 1980); (Oe, K., 1980); (Utaka, K., 1980a,b); (Wright, P.D., 1982); (Arai, S., 1981); (Abe, Y., 1981); at 4°C; Ref. (Wallin, J., 1992)

HCl:H₂O (4:1); Application: InP selective etch from InGaAsP at 15°C for laser fabrication; Ref. (Chen, K.L., 1985)

HCl:H₂O (1.5:1); InP selective etch from InGaAsP; Ref. (Chen, T.R., 1982)

HCl:H₂O (1:1); InP selective etch from InGaAsP; Ref. (Adachi, S., 1982c)

HCl:H₂O₂ (1:1); InP selective etch from InGaAsP; Ref. (Adachi, S., 1982c)

HCl:CH₃COOH (1:1); InP selective etch from InGaAsP; Ref. (Adachi, S., 1982c)

HBr; InP selective etch from InGaAsP; Ref. (Adachi, S., 1982c)

HBr:CH₃COOH (1:1); InP selective etch from InGaAsP; Ref. (Adachi, S., 1982c)

H₃PO₄:HBr (1:1); InP selective etch from InGaAsP; Ref. (Adachi, S., 1982c)
H₃PO₄:HCl (1:1); InP selective etch from InGaAsP; Ref. (Adachi, S., 1982c); (Fritzche, D., 1981); (Kaminov, I.P., 1979); (Lourenco, J.A., 1984); (Stone, J., 1981)

HCl:H₃PO₄ (1:1); InP selective etch from InGaAsP; etch rate = 4.0 µm/min for bulk InP; etch rate = 6.5 µm/min for LPE InP layers; Ref. (Conway, K.L., 1982)

<table>
<thead>
<tr>
<th>HCl:H₃PO₄</th>
<th>InP etch rate (selective from InGaAsP) (µm/min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1:1) 60°C</td>
<td>27</td>
</tr>
<tr>
<td>(1:4) 60°C</td>
<td>4.8</td>
</tr>
<tr>
<td>(1:6) 60°C</td>
<td>3.0</td>
</tr>
<tr>
<td>(1:1) 20°C</td>
<td>2</td>
</tr>
</tbody>
</table>

Ref. (Fiedler, F., 1982)

HCl:H₃PO₄ (2:3); InP bulk etch rate = 2.5 µm/min; no measurable InGaAsP or InGaAs etching after 30 min; Ref. (Conway, K.L., 1982)

HCl:H₃PO₄ (1:1); InP selective etch from InGaAsP; gives etch rate dependence for (1 1 1)A and (1 1 1)B on etch composition; Ref. (Phatak, S.B., 1979)

HCl:H₃PO₄ (3:1); Application: InP selective etch from InGaAsP; Ref. (Temkin, H., 1984)

HCl:HClO₄ (1:1); InP selective etch from InGaAsP; etch rate = 6 µm/min; Ref. (Fiedler, F., 1982)

H₃PO₄:HCl (13:5); InP selective etch from InGaAsP; Ref. (Olsen, G.H., 1979)

HCl:H₃PO₄ (1:8); selective removal of InP from InGaAsP in laser array process; Ref. (Rothman, M.A., 1992)

H₃PO₄ does not attack GaAs; Ref. (Phatak, S.B., 1979)

Glycerine:HCl:HClO₄ (1:2:2); InP selective etch from InGaAsP; etch rate = 2 µm/min at 20°C; similar rates on n- and Si-InP; with smooth mesa surfaces; Ref. (Fiedler, F., 1982)

HF:HBr (1:10); Application: InP selective etch from InGaAsP; Ref. (Ueda, O., 1980a,b)

HBr:HNO₃:H₂O; Application: InP mesa stripe using an InGaAsP interface layer to control the sidewall shape for reproducible height and width; Ref. (Huang, R.-T., 1990)

CH₃COOH:HCl (1:1); selective InP removal from InGaAsP; etch rate ~ 1 µm/min for fresh solution; rate decreases after 30 min; Ref. (Kallstenius, T., 1999a)

**InP from InAlAs**

HCl:H₃PO₄:CH₃COOH (1:1:2); InP selective etch from InAlAs; selectivity > 85; InP etch rate = 3000 Å/min; Ref. (He, Y., 1992)
InGaAs from InP

InGaAs selective etches from InP:
- Tartaric acid:H2O2 (1:1); InGaAs etch rate = 3000 Å/min; InP etch rate = 6 Å/min; Ref. (Clawson, 1978)
- Tartaric acid:H2O2:H2O (1:1:10); InGaAs etch rate = 1000 Å/min
- Tartaric acid:H2O2:H2O (1:1:20); InGaAs etch rate = 600 Å/min
- H2SO4:H2O2:H2O (1:1:10); InGaAs etch rate = 9000 Å/min
- H2SO4:H2O2:H2O (1:1:20); InGaAs etch rate = 4500 Å/min
- H2SO4:H2O2:H2O (1:1:60); InGaAs etch rate = 700 Å/min
- HF:H2O2:H2O (1:1:10); InGaAs etch rate = 6300 Å/min
- HF:H2O2:H2O (1:1:20); InGaAs etch rate = 3000 Å/min; Ref. (Elder, D.I., 1984)
- H2SO4:H2O2:H2O (1:8:1); Application: InGaAs selective etch from InP; Ref. (Antell, G.R., 1984)
- H2SO4:H2O2:H2O (1:10:220); Application: InGaAs/InAlAs mesa etch; selective from InP stop layer; Ref. (Bahl, S.R., 1991, 1992)
- H2SO4:H2O2:H2O (3:1:1); InGaAs selective etch from InP; Ref. (Susa, N., 1981); (Takeda, Y., 1980); (Dupuis, R.D., 1991)
- H2SO4:H2O2:H2O (4:1:1); InGaAs selective etch from InP; Ref. (Ishibashi, T., 1981)
- H2SO4:H2O2:H2O (3:5:50) InGaAs selective etch from InP; Ref. (Houston, P.A., 1987)
- H2SO4:H2O2:H2O (1:10:220); selective etch of InGaAs layer with InP etch-stop layer for HFET; Ref. (Greenberg, D.R., 1992)
- H2SO4:H2O2:H2O (1:1:20); Application: InGaAs selective etch from InP; Ref. (Ouacha, A., 1993)
- H2SO4:H2O2:H2O (1:1:40); selective InAlAs/InGaAs HFET mesa etch from InP; Ref. (Daumann, W., 1997)
- KOH:K3Fe(CN)6:H2O (6 g:4 g:50 ml); Application: InGaAs/InP cleaved cross-section layer delineation; etches InGaAs selectively; etch rate ~ 2 μm/min; Ref. (Hyder, S.B., 1979)
- H3PO4:H2O2 (5:1); Application: InGaAs selective etch from InP; pattern for OMVPE overgrowth; Ref. (Kim, J.S., 1992)
- H3PO4:H2O2:H2O (1:1:38); Application: InGaAs and InAlAs etch rate = 1000 Å/min at 21.5°C; does not attack InP; Ref. (Ohno, H., 1982)
- H3PO4:H2O2:H2O (1:1:40); Application: InGaAs selective etch from InP for HEMT gate recess at 20°C; Ref. (Küsters, A.M., 1993)
H₃PO₄:H₂O₂:H₂O (1:1:20); Application: InGaAs selective etch from InP for MISFET gate recess; Ref. (Schubert, E.F., 1988)

H₃PO₄:H₂O₂:H₂O (1:1:8); Selective etch of InGaAs mask patterns on InP; at 25°C in light, 120 nm InGaAs etches through in ~25 s
  H₃PO₄:H₂O₂:H₂O (1:1:32); Selective etch of InGaAs mask patterns on InP; at 25°C in light, 120 nm InGaAs etches through in ~60 s; Ref. (Elías, P., 1999)

HNO₃ reacts little with arsenides but has no effect on InP; Ref. (Phatak, S.B., 1979)

HBr:H₃PO₄:H₂O (1:1:8); InGaAs etch at 0°C to define a lithography pattern for the purpose of using the thin InGaAs as an etch mask for underlying InP; eliminates mask undercutting; Ref. (Inamura, E., 1989)

Citric acid:H₂O₂; table of etch rates for InGaAs/InAlAs/InP; Ref. (DeSalvo, G.C., 1992)

C₄H₆O₆:H₂O₂:H₂O (5:5:1); selective etch of InGaAs layer from InP; 8 min for 3000 Å; Ref. (Kallstenius, T., 1999a)

Citric acid:H₂O₂:H₂O (20:1:50); InGaAs selective etch from InP; 7 Å/s; Ref. (Miyamoto, 1998)

Citric acid (50 wt.%):H₂O₂ (3:1); selective etch to define InGaAs mask pattern for HCl etching of InP; Ref. (Wang, J., 1998)

Tartaric acid:H₂O₂:H₂O (1:1:10); selective etch of InGaAs from 75 Å InP etch stop layer; InGaAs rate (room temperature) = 750 Å/min; a bluish surface appears with the final removal of InGaAs then disappears as etching terminates at the InP stop layer; Ref. (Mullin, D.P., 1994)

K₃Fe(CN)₆ (0.05 M); selective removal of In₀.₅₃Ga₀.₄₇As and In₀.₇₂Ga₀.₂₈As₀.₆₁P₀.₃₉ from InP; selectivity ~200; electrochemical study of etch mechanism; Ref. (Theuwis, A., 1999b)

InGaAsP from InP

Ce⁴⁺:H₂SO₄ solution; InGaAsP selective etch from InP; Ref. (Kelly, J.J., 1988)

H₂SO₄:H₂O₂:H₂O (1:1:1); InGaAsP selective etch from InP; Ref. (Adachi, S., 1982c)

H₂SO₄:H₂O₂:H₂O (3:1:1); InGaAsP selective etch from InP; Ref. (Adachi, S., 1982c); (Abe, Y., 1981); (Chen, P.C., 1981); (Fritzche, D., 1981); (Utaka, K., 1980a,b)

H₂SO₄:H₂O₂:H₂O (5:1:1); Application: InGaAsP selective etch from InP for laser fabrication; Ref. (Nishi, H., 1979)

H₂SO₄:H₂O₂:H₂O (5:1:1); InGaAsP selective etch from InP; Ref. (Olsen, G.H., 1979)

H₂SO₄:H₂O₂:H₂O (8:1:1); Application: InGaAsP selective etch from InP; Ref. (Wallin, J., 1992)


<table>
<thead>
<tr>
<th>H₂SO₄:H₂O₂:H₂O</th>
<th>InGaAsP etch rate (µm/min)</th>
<th>InP etch rate (µm/min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(3:1:1) 20°C</td>
<td>0.7</td>
<td>0.014</td>
</tr>
<tr>
<td>(3:1:1) 30°C</td>
<td>1.6</td>
<td>0.035</td>
</tr>
<tr>
<td>(3:1:1) 20°C</td>
<td>0.6</td>
<td>0.012</td>
</tr>
<tr>
<td>(3:1:1) 30°C</td>
<td>–</td>
<td>0.030</td>
</tr>
</tbody>
</table>

Ref. (Fiedler, F., 1982)

H₂SO₄:H₂O₂:H₂O (1:1:10); InP (1 1 1) etch rate = 30 Å/min; InP (1 0 0) etch rate is negligible
H₂SO₄:H₂O₂:H₂O (1:1:10); In₀.₇₃Ga₀.₂₇As₀.₆₃P₀.₃₇ (1 0 0) etch rate = 1000 Å/min
H₂SO₄:H₂O₂:H₂O (1:1:10); In₀.₈₃Ga₀.₁₇As₀.₃₉P₀.₆₁ (1 0 0) etch rate = 420 Å/min
H₂SO₄:H₂O₂:H₂O (1:1:10); In₀.₉₀Ga₀.₁₀As₀.₀₄P₀.₉₆ (1 0 0) etch rate = 75 Å/min; Ref. (Ferrante, G.A., 1983)

H₂SO₄:H₂O₂:H₂O (2:3:2); InGaAsP selective etch from InP; Ref. (Stone, J., 1981)

K₂Cr₂O₇:H₂O₂:HCl (3:1:2); InGaAsP selective etch from InP; Ref. (Adachi, S., 1982c)

KOH:K₃Fe(CN)₆:H₂O; or H₂SO₄:H₂O₂:H₂O; Application: InGaAsP selective etch from InP for laser fabrication; Ref. (Chen, T.R., 1982)

KOH:K₃Fe(CN)₆:H₂O (6 g:4 g:50 ml); selectively etches InGaAsP on InP; Ref. (Coldren, L.A., 1983); (Clarke, R.C., 1970); (Li, G., 1981)

KOH:K₃Fe(CN)₆:H₂O (24 g:16 g:140 ml); InGaAsP selective etch from InP; etch rate = 4.1 µm/min; InP etch rate < 0.05 µm/min (fresh solution mixed daily); Ref. (Conway, K.L., 1982)

KOH:K₃Fe(CN)₆:H₂O (10 g:0.2 g:50 ml); Application: InGaAsP strip mesa etch for DH lasers; selective etch from InP; Ref. (Liau, Z.L., 1982)

KOH:K₃Fe(CN)₆:H₂O (8 g:12 g:100 ml) solution used for InGaAsP selective etch from InP; Ref. (Lourenco, J.A., 1984)

HNO₃; InGaAsP selective etch from InP; Ref. (Olsen, G.H., 1979)

HNO₃:HCl (n:1); InGaAsP selective etch from InP for n > 5; does not attack photoresist; Ref. (Yeats, R.E., 1977)

HBr:HNO₃:H₂O (1:1:30); Application: InGaAsP selective etch from InP; Ref. (Koch, T.L., 1987)

**InAlAs from InP**

H₂SO₄:H₂O₂:H₂O (1:10:220); Application: InGaAs/InAlAs mesa etch; selective from InP stop layer; Ref. (Bahl, S.R., 1991, 1992)
H₃PO₄:H₂O₂:H₂O (1:1:38); Application: InGaAs and InAlAs etch rate = 1000 Å/min at 21.5°C; does not attack InP; Ref. (Ohno, H., 1982)

Citric acid:H₂O₂; Ref. (Tong, M., 1992a)

**AlAs from InP**

HF:H₂O₂:H₂O (1:1:10)
Citric acid:H₂O:H₂O₂ (1:1:8); AlAs selective etch from InP as a sacrifice layer to lift-off InP epilayer from the substrate; Ref. (Bailey, S.G., 1993)

**InGaAs from InAlAs**

Succinic acid:H₂O₂ (6:1) pH = 5.5 by adding NH₄OH; InGaAs selective etch from InAlAs; Ref. (Bahl, S.R., 1992)

Use of organic acids and AlAs etch stop layers for InGaAlAs/InP structures:

**Organic acid solutions:**
- OA = oxalic acid:H₂O (15 g:2 l), pH = 6.3 (by adding ammonia)
- OCA = oxalic acid:H₂O:citric acid (25 g:2 l:100 g), pH = 6.3
- MA = malonic acid:H₂O (75 g:1 l), pH = 6.1
- SA = succinic acid:H₂O (200 g:1 l), pH = 4.2

**Etchant solutions** (for InGaAs selective etch from InAlAs and InAlAs selective etch from AlAs):

<table>
<thead>
<tr>
<th>Etchant solution</th>
<th>Etch rate (nm/min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>OA:H₂O₂ (20:1)</td>
<td></td>
</tr>
<tr>
<td>In₀.₅³Ga₀.₄₇As</td>
<td>40</td>
</tr>
<tr>
<td>In₀.₅₂Al₀.₄₈As</td>
<td>20</td>
</tr>
<tr>
<td>AlAs</td>
<td>0.57</td>
</tr>
<tr>
<td>OCA:H₂O₂ (25:1)</td>
<td></td>
</tr>
<tr>
<td>In₀.₅³Ga₀.₄₇As</td>
<td>75</td>
</tr>
<tr>
<td>In₀.₅₂Al₀.₄₈As</td>
<td>5</td>
</tr>
<tr>
<td>AlAs</td>
<td>0.20</td>
</tr>
<tr>
<td>MA:H₂O₂ (25:1)</td>
<td></td>
</tr>
<tr>
<td>In₀.₅³Ga₀.₄₇As</td>
<td>100</td>
</tr>
<tr>
<td>In₀.₅₂Al₀.₄₈As</td>
<td>6</td>
</tr>
<tr>
<td>AlAs</td>
<td>1.23</td>
</tr>
<tr>
<td>SA:H₂O₂ (15:1)</td>
<td></td>
</tr>
<tr>
<td>In₀.₅³Ga₀.₄₇As</td>
<td>120</td>
</tr>
<tr>
<td>In₀.₅₂Al₀.₄₈As</td>
<td>60</td>
</tr>
<tr>
<td>AlAs</td>
<td>0.12</td>
</tr>
<tr>
<td>GaAs</td>
<td>180</td>
</tr>
</tbody>
</table>

Ref. (Broekaert, T.P.E., 1992a,b)
Organic acid: ammonia: peroxide solutions; InGaAs selective etch from InAlAs; InAlAs selective etch from AlAs stop layers; data is given for the following organic acids:
- Adipic
- Methylsuccinic
- Dimethylsuccinic
- Fumaric
- Maleic
- Citric
- Propane tricarboxlic
- Butane tetracarboxlic
- Acetic; Ref. (Broekaert, T.P.E., 1992b)

Citric acid:H₂O₂ (10:1); Study: InAlAs selective etch from InP, selectivity > 187; InGaAs selective etch from InP, selectivity > 480. InGaAs selective from InAlAs, selectivity only 2.5. Shows etch profiles. InP etch rate at 20°C = 0.05 Å/s; InAlAs etch rate at 20°C = 10 Å/s; InGaAs etch rate at 20°C = 24 Å/s; Ref. (Tong, M., 1992a)

Citric acid:H₂O₂ (1:1); InGaAs selective etch from InAlAs = 25. InGaAs etch rate at 20°C = 25 Å/s; InAlAs etch rate at 20°C = 1 Å/s; Ref. (Tong, M., 1992a)

Citric acid:H₂O₂ range (0.5:1)–(50:1); GaAs, InP, AlGaAs, InGaAs, InAlAs etch rates (selectivities are tabulated in the reference)

<table>
<thead>
<tr>
<th>Volume ratio of citric acid/H₂O₂</th>
<th>Etch rates of layers on InP substrate (Å/min)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>In₀.₅₃Ga₀.₄₇As</td>
</tr>
<tr>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>0.2</td>
<td>–</td>
</tr>
<tr>
<td>0.5</td>
<td>1235</td>
</tr>
<tr>
<td>1.0</td>
<td>1116</td>
</tr>
<tr>
<td>2.0</td>
<td>1438</td>
</tr>
<tr>
<td>5.0</td>
<td>1433</td>
</tr>
<tr>
<td>7.0</td>
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</tr>
<tr>
<td>10.0</td>
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<tr>
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</tr>
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<td>665</td>
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</tr>
<tr>
<td>100</td>
<td>–</td>
</tr>
<tr>
<td>∞</td>
<td>0</td>
</tr>
</tbody>
</table>

Ref. (DeSalvo, G.C., 1992)

Review of InGaAs selective etches: citric acid:H₂O₂ (1:1); InGaAs selective etch from InAlAs
- NH₄OH:H₂O₂ (1:30)
- H₂SO₄:H₂O₂:H₂O (1:1:10)
- H₃PO₄:H₂O₂:H₂O (1:1:8)
- HCl:H₂O (3:1)
- Reactive ion etching; CH₄:H₂; CH₃:Br; HBr; Ref. (Adesida, I., 1993a)
Citric acid: H₂O₂ (1:1); InGaAs selective etch from InAlAs; selectivity 25. InGaAs etch rate 22 Å/s; InAlAs etch rate 0.89 Å/s; Ref. (Tong, M., 1992c)

Reactive ion etch; HBr; InGaAs selective etch from InAlAs; selectivity of 160; Ref. (Agarwala, S., 1993a,b,c,d)

Succinic acid (C₄H₆O₄): H₂O₂: NH₃ (20:4:1); selective InGaAs from InAlAs; InGaAs etch rate $\dot{\epsilon} = 5$ Å/s; InAlAs etch rate $\dot{\epsilon} = 0.07$ Å/s; Ref. (Daumann, W., 1997)

Succinic acid: H₂O₂ (30:1); selective etch of InGaAs from InAlAs; selectivity is 1030 for layers lattice-matched to InP

Succinic acid: H₂O₂ (15:2); selective etch of InGaAs from InAlAs; selectivity is 70 for strained layers on GaAs; Ref. (Fourre, H., 1996)

Adipic acid: NH₄OH: H₂O₂ (1 g adipic acid in 5 ml H₂O; NH₄OH to adjust pH over the range 5.3–7.0: H₂O₂ added in the range of volume ratios of 0.013–0.12); InGaAs removal from InAlAs; selectivity up to 250; Ref. (Higuchi, K., 1997)

**InAlAs from InGaAs**

HCl: H₂O (3:1); Study: In₀.₅₂Al₀.₄₈As selective etch from In₀.₅₃Ga₀.₄₇As; etch rate = 108 Å/s; (InGaAs etch rate < 200 Å/h); more dilute solutions will not etch InAlAs; (InGa)₀.₈Al₀.₂As exhibits no etch rate; (InGa)₀.₆₆Al₀.₃₄As etch rate = 18.3 Å/s; Ref. (Sauer, N.J., 1992)

HCl: H₂O (3:1); selective removal of In₀.₅₂Al₀.₄₈As from In₀.₅₃Ga₀.₄₇As for MEMS; Ref. (Seassal, C., 1996)

**GaAs from AlGaAs**

HNO₃: H₂O (1:200); GaAs selective etch from AlGaAs under illumination; Ref. (Fink, Th., 1993a)

HNO₃: H₂O (1:20); GaAs and AlGaAs photoetch with AlAs stop layer; hole confinement to the GaAs buried layer results in its lateral etching; Ref. (Ruberto, M.N., 1989)

H₂O₂ with NH₄OH added to adjust pH from 7.2 to 8.6; GaAs selective etch from Al₀.₁₆Ga₀.₈₄As with selectivity $> 30$ at pH = 8.4; Ref. (Kenefick, K., 1982)

NH₄OH: H₂O₂ (1:60); GaAs selective removal from AlGaAs by jet thinning; GaAs etch rate at 0°C = 60 μm/h with selectivity of 60; Ref. (Lepore, J.J., 1980)

NH₄OH: H₂O₂ (1:225) {pH = 7.04}; Application: GaAs selective removal from Al₀.₂₅Ga₀.₇₅As; GaAs etch rate = 6 μm/h with selectivity of 10; Ref. (Logan, R.A., 1973a)

NH₄OH: H₂O₂ (1:225) {pH = 7}; Application: GaAs selective etch from AlGaAs; Ref. (Merz, J.L., 1979)

NH₄OH: H₂O₂ (1:170); Application: GaAs selective etch from Al₀.₄₂Ga₀.₅₈As; Ref. (Fricke, K., 1994)
NH\textsubscript{4}OH:H\textsubscript{2}O\textsubscript{2} (pH \sim 7.6); Application: GaAs selective substrate removal from AlGaAs; Ref. (Sugg, A.R., 1993)

K\textsubscript{3}Fe(CN)\textsubscript{6}:K\textsubscript{4}Fe(CN)\textsubscript{6} (with NaOH or HCl to buffer pH); GaAs selective etch from AlGaAs for pH > 9; AlGaAs selective etch from GaAs for pH between 5 and 9; Ref. (Logan, R.A., 1973a)

C\textsubscript{6}H\textsubscript{4}O\textsubscript{2}:C\textsubscript{4}H\textsubscript{6}O\textsubscript{2} (quinone–hydroquinone) with NaOH or HCl to buffer the pH. GaAs selective etch from AlGaAs for pH = 10; AlGaAs selective etch from GaAs for pH = 1; Ref. (Tijburg, R.P., 1976a)

KI:I\textsubscript{2} (0.3 mol/l KI + 0.04 mol/l I\textsubscript{2}, with pH = 9.4); GaAs selective etch from AlGaAs; etch rate = 1 \mu m/min; Ref. (Tijburg, R.P., 1976a)

Chlorox:H\textsubscript{2}O (1:4) {where Chlorox household bleach is 5.25% NaOCl solution}; Application: GaAs selective etch from AlGaAs; Ref. (Yang, Y.J., 1987)

Citric acid:H\textsubscript{2}O\textsubscript{2} (10:1); GaAs selective etch from Al\textsubscript{0.3}Ga\textsubscript{0.7}As, selectivity = 90; GaAs etch rate = 0.21 \mu m/min at 18°C; Al\textsubscript{0.3}Ga\textsubscript{0.7}As etch rate = 0.022 \mu m/min at 18°C; Ref. (Juang, C., 1990)

\begin{tabular}{|c|c|}
\hline
\textit{x} & Etch rate ratio \\
\hline
0.17 & 1.5 \\
0.30 & 155 \\
0.45 & 260 \\
1.00 & 1450 \\
\hline
\end{tabular}

Ref. (Tong, N., 1992b)

Citric acid:H\textsubscript{2}O\textsubscript{2}; table of etch rates for GaAs/AlGaAs/InGaAs; Ref. (DeSalvo, G.C., 1992)

0.5 M citric acid + 0.5 M potassium citrate (buffer solution)

Buffer:H\textsubscript{2}O\textsubscript{2} (5:1); GaAs selective etch from AlGaAs or AlAs. Used for reproducible fabrication of integrated circuit GaAs FETs with etch stop layer of 25 Å Al\textsubscript{0.35}Ga\textsubscript{0.65}As or 8 Å AlAs. The buffered solution is insensitive to dilution or contamination. GaAs etch rate = 45 Å/s; Ref. (Brunemeier, B.E., 1993)

Citric acid:H\textsubscript{2}O\textsubscript{2} (3:1); GaAs selective etch from AlAs stop etch layer; Ref. (Grundbacher, R., 1993)

Citric acid:H\textsubscript{2}O\textsubscript{2} (m:1, with 1 < m < 9); GaAs substrate removal using AlAs or AlGaAs etch stop layers; problems with etch stop layer oxidation

NH\textsubscript{4}OH:H\textsubscript{2}O\textsubscript{2}; GaAs substrate removal using AlAs or AlGaAs etch stop layers; Ref. (Carter-Coman, C., 1997)

Citric acid:H\textsubscript{2}O\textsubscript{2} (2:1); Application: selective removal of GaAs from Al\textsubscript{0.26}Ga\textsubscript{0.74}As; selectivity of 70:1; Ref. (Dimroth, F., 1997)
Citric acid:H$_2$O$_2$; study of concentration and pH for selective etch of GaAs from Al$_{0.22}$Ga$_{0.78}$As; selectivity of 200 at 20°C and 500 at 0°C; GaAs rate = 1000 Å/min; Ref. (Hue, X., 1998)

Citric acid:H$_2$O$_2$ (4:1); selective removal of GaAs from AlAs (and of low Al content AlGaAs from high Al content AlGaAs); shows dependence of etch rates (selectivity) on volume ratio; Ref. (Kim, J.-H., 1998)

Citric acid:NH$_4$OH:H$_2$O$_2$ (citric acid pH adjusted to 6.5 with NH$_4$OH; citric acid:H$_2$O$_2$ ratio = 100); selective etch of GaAs from Al$_{0.15}$Ga$_{0.85}$As and Al$_{0.3}$Ga$_{0.7}$As; shows etch rate dependence on concentration and pH; Ref. (Kitano, T., 1997)

Citric acid:H$_2$O$_2$ (4:1); etches GaAs selectively from Al$_x$Ga$_{1-x}$As; selectivity $\approx 110$; Ref. (Lee, H.J., 1995)

Citric acid:H$_2$O$_2$ (5:1); selective removal of GaAs substrate from a AlAs (or AlGaAs) etch stop layer; Ref. (Novák, J., 1996)

Citric acid:H$_2$O$_2$; selective removal of GaAs substrate from Al$_{0.7}$Ga$_{0.3}$As etch stop layer

NH$_4$OH:H$_2$O$_2$; selective removal of GaAs substrate from Al$_{0.7}$Ga$_{0.3}$As etch stop layer; Ref. (Zhang, C., 1999)

H$_3$PO$_4$:H$_2$O$_2$:H$_2$O (4:1:90); Application: n-GaAs selective etch from Al$_{0.4}$Ga$_{0.6}$As at 25°C; Ref. (Watanabe, H., 1993a,b)

NH$_4$OH:H$_2$O$_2$:H$_2$O (1:3:16); Application: selective removal of GaAs from AlGaAs; Ref. (Ankri, D., 1982)

NH$_4$OH:H$_2$O$_2$:H$_2$O (30:1:72 by weight); selective removal of GaAs substrate from Al$_{0.7}$Ga$_{0.3}$As etch stop layer; Ref. (Moran, P.D., 1999)

NH$_4$OH:H$_2$O$_2$:H$_2$O (1:1:20); Application: selective pattern etch through GaAs mask layer onto AlGaAs spacer layer; Ref. (Peake, G.M., 1997)

NH$_4$OH:H$_2$O$_2$ (1:30); Application: selective removal of GaAs from AlGaAs etch stop layer for micromachining; undercutting etch rate is 2 μm/min; non-uniform etching after 5 min

NH$_4$OH:H$_2$O$_2$ (1:50); Application: selective removal of GaAs from AlGaAs etch stop layer for micromachining; undercutting etch rate is 1 μm/min; non-uniform etching after 5 min

(Succinic acid:NH$_4$OH):H$_2$O$_2$ (15:1); Application: selective removal of GaAs from AlGaAs etch stop layer for micromachining; very slow lateral etch rate

Citric acid:H$_2$O$_2$ (5:1); Application: selective removal of GaAs from AlGaAs etch stop layer for micromachining; undercutting etch rate is 0.09 μm/min; excellent uniformity and reproducibility; Ref. (Ribas, R.P., 1998)

NH$_4$:H$_2$O$_2$:H$_2$O (1:10:10); selective patterning of a GaAs mask on AlGaAs; Ref. (Schumacher, C., 1999)
**AlGaAs from GaAs**

HCl; Application: Al$_{0.5}$Ga$_{0.5}$As selective etch from GaAs; Ref. (Dumke, W.P., 1972)

HCl, hot; selective removal of Al$_x$Ga$_{1-x}$As from GaAs if $x > 0.42$

HF, hot; selective removal of Al$_x$Ga$_{1-x}$As from GaAs if $x > 0.38$; Ref. (Malag, A., 1993)

K$_2$Fe(CN)$_6$:K$_4$Fe(CN)$_6$ (with NaOH or HCl to buffer pH); GaAs selective etch from AlGaAs for pH $> 9$; AlGaAs selective etch from GaAs for pH between 5 and 9; Ref. (Logan, R.A., 1973a)

Ce(SO$_4$)$_2$:Ce(NO$_3$)$_3$; AlGaAs selective etch from GaAs; Ref. (Tijburg, R.P., 1976a)

FeCl$_3$:FeCl$_2$; AlGaAs selective etch from GaAs; Ref. (Tijburg, R.P., 1976a)

C$_6$H$_4$O$_2$:C$_4$H$_6$O$_2$ (quinone–hydroquinone) with NaOH or HCl to buffer the pH. GaAs selective etch from AlGaAs for pH = 10; AlGaAs selective etch from GaAs for pH = 1; Ref. (Tijburg, R.P., 1976a)

H$_2$SO$_4$:H$_2$O$_2$:H$_2$O (1:8:80); Application: Al$_{0.1}$Ga$_{0.9}$As contact layer removal for waveguide fabrication; Ref. (Caracci, S.J., 1993)

NH$_4$OH:H$_2$O$_2$:H$_2$O (2:0.7:100); Application: Al$_{0.42}$Ga$_{0.58}$As selective etch from GaAs; Ref. (Fricke, K., 1994)

NH$_4$OH:H$_2$O$_2$ (1:30); selective etch of Al$_{0.6}$Ga$_{0.4}$As sacrificial layer for micromachining GaAs; Ref. (Uennisishi, Y., 1994)

NH$_4$OH:H$_2$O$_2$:H$_2$O (3:1:130); mesa etch for AlGaAs/InGaAs; 3000 Å/min

Citric acid:H$_2$O$_2$:H$_3$PO$_4$:H$_2$O (55:5:1:220); mesa etch for AllnAs/InGaAs; 480 Å/min; Ref. (Berg, E.W., 1998)

Citric acid:H$_2$O$_2$:H$_2$O; Study of GaAs versus Al$_{0.28}$Ga$_{0.72}$As etch rate dependence on citric acid:H$_2$O$_2$ ratio and on H$_2$O concentration. Citric acid:H$_2$O$_2$ (4:1); selective etch of GaAs from Al$_{0.28}$Ga$_{0.72}$As; Ref. (Mao, B.-Y., 1994)

K$_2$Cr$_2$O$_7$:H$_3$PO$_4$:H$_2$O; Application: AlGaAs selective etch from GaAs; Ref. (Ren, F., 1994)

KI:I$_2$ (0.3 mol/l KI + 0.1 mol/l I$_2$, with pH = 9); Al$_x$Ga$_{1-x}$As ($x < 0.15$) selective etch from GaAs; with pH = 11 is GaP selective etch from InGaP or AlGaAs; Ref. (Tijburg, R.P., 1976a,b)

KI:I$_2$:H$_2$O (27.8 g:16.25 g:25 ml) with pH adjusted by adding an equal amount of H$_2$SO$_4$ (diluted with H$_2$O to pH = 0.9); selective etch of Al$_{0.3}$Ga$_{0.7}$As from GaAs; selectivity of 137 at 20°C and 330 at 3°C; Ref. (Lau, W.S., 1997)

I$_2$:KI:H$_2$O (65 g:113 g:100 g); selective removal of Al$_x$Ga$_{1-x}$As from GaAs if $x > 0.1$; Ref. (Malag, A., 1993)

KI:I$_2$:H$_3$PO$_4$ (pH $< 2$); Application: selective AlGaAs etch to transfer and undercut the GaAs mask pattern onto underlying GaAs for shadowed MOVPE regrowth
HF:H₂O (1:10); Application: AlGaAs spacer layer lift-off (10 h) to reveal microlens pattern; Ref. (Peake, G.M., 1997)

(Succinic acid: NH₄OH, pH adjusted over the range 4.9–5.3):H₂O₂ (15:1), (25:1) and (50:1). AlₓGa₁₋ₓAs etch rate versus pH and x; Ref. (Merrit, S.A., 1993)

HF; AlGaAs selective etch from GaAs; Ref. (Merz, J.L., 1979)

HF; Ga₀.₃Al₀.₇As selective etch from GaAs; Application: removal of GaAs solar cell layers from the substrate; Ref. (Konagai, M., 1978)

HF:H₂O (1:10); selective removal of A₀.₇Ga₀.₃As etch stop layer from wafer bonded GaAs template layer; Ref. (Moran, P.D., 1999)

HF conc.; selective undercut pattern in AlGaAs masked by GaAs; Ref. (Schumacher, C., 1999)

HF (10%); GaAs epitaxial layer lift-off by selectively etching a thin Al₀.₈₅Ga₀.₁₅As release layer to separate from the substrate (up to 2 in. diameter); Ref. (van Geelen, A., 1997)

HF (48%); selective removal of AlₓGa₁₋ₓAs from GaAs: AlₓGa₁₋ₓAs etch rates versus x at 80°C; Ref. (Wu, X.S., 1985)

HF; selective removal of Al₀.₇Ga₀.₃As etch stop layer from GaAs layer
HCl:H₂O (1:1); selective removal of Al₀.₇Ga₀.₃As etch stop layer from GaAs layer
Alternate H₂O₂ 1 min soak followed by HCl:H₂O (1:1) 1 min soak (3 cycles) of GaAs surface to reduce roughness after AlGaAs layer removal; Ref. (Zhang, C., 1999)

AlAs from AlGaAs and GaAs

HF (10%); AlAs selective etch lift-off of a AlGaAs/GaAs layer; selectivity of >10⁷ between AlAs and Al₀.₄Ga₀.₆As; onset of etching occurs for compositions greater than 40–50% aluminum; Ref. (Yablonovitch, E., 1987)

HF (10%); Application: AlAs selective etch from GaAs; used for lift-off of InGaAs/GaAs layer for TEM analysis; Ref. (Zou, J., 1993)

HF, dilute; selective removal of AlAs from GaAs; selectivity > 10⁷; Ref. (Novák, J., 1996)

HF:H₂O (10 wt.%); selective etch of AlAs layer from GaAs for lift-off separation
HF:H₂O (10 wt.%) with a surfactant and antifoaming agent (Morita Chemicals, Ltd.); selective etch of AlAs layer from GaAs for lift-off separation; increase of rate with temperature; Ref. (Sasaki, Y., 1999)

H₂O:buffered HF (40:1) where buffered HF is NH₄F (36%):HF (6.4%) (7:1); selective removal of AlAs from GaAs and of high Al content AlGaAs from low Al content AlGaAs; shows dependence of etch rates (selectivity) on volume ratio; Ref. (Kim, J.-H., 1998)
HCl dilute; AlAs etch stop layer removal from GaAs; Ref. (Grundbacher, R., 1993)

**GaAs from InGaAs**

H$_2$O$_2$ buffered with NH$_4$OH (pH = 7); Application; GaAs selective etch from InGaAs; at 21°C the GaAs etch rate = 740 Å/min; the In$_{0.18}$Ga$_{0.82}$As etch rate = 67 Å/min; Ref. (Gréus, Ch., 1991)

H$_2$O$_2$ (30%) buffered with NH$_4$OH to pH = 7.0; GaAs etch rate = 740 Å/min; In$_{0.18}$Ga$_{0.82}$As etch rate = 67 Å/min; Ref. (Schmidt, A., 1992)

H$_2$O$_2$:NH$_4$OH (250:1), pH = 7.3; GaAs selective etch from InGaAs, selectivity > 50; attacks photoresists; use SiO$_2$ photolithographic mask defined by buffered HF etch

K$_3$Fe(CN)$_6$:K$_4$Fe(CN)$_6$.3H$_2$O (14.8 g:19.0 g:200 ml H$_2$O; buffered with 3 ml HCl:H$_2$O {1:1000} to pH = 6.7); GaAs and Al$_{0.3}$Ga$_{0.7}$As selective etch from In$_{0.1}$Ga$_{0.9}$As; selectivity > 8

H$_3$PO$_4$:H$_2$O (1:4); GaAs oxide removal prior to etching and InGaAs oxide removal following the above etch; Ref. (Hill, D.G., 1990)

**InGaAs from GaAs and AlGaAs**

Citric acid:H$_2$O$_2$ range (0.5:1)–(50:1); GaAs, InP, AlGaAs, InGaAs, InAlAs etch rates (selectivities are tabulated in the reference)

<table>
<thead>
<tr>
<th>Volume ratio of citric acid/H$_2$O$_2$</th>
<th>Etch rates of layers on GaAs substrate (Å/min)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>GaAs</td>
</tr>
<tr>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>0.5</td>
<td>60</td>
</tr>
<tr>
<td>1.0</td>
<td>69</td>
</tr>
<tr>
<td>1.5</td>
<td>–</td>
</tr>
<tr>
<td>2.0</td>
<td>85</td>
</tr>
<tr>
<td>3.0</td>
<td>2169</td>
</tr>
<tr>
<td>4.0</td>
<td>2235</td>
</tr>
<tr>
<td>5.0</td>
<td>3140</td>
</tr>
<tr>
<td>6.0</td>
<td>–</td>
</tr>
<tr>
<td>7.0</td>
<td>2882</td>
</tr>
<tr>
<td>8.0</td>
<td>–</td>
</tr>
<tr>
<td>9.0</td>
<td>–</td>
</tr>
<tr>
<td>10.0</td>
<td>2513</td>
</tr>
<tr>
<td>15.0</td>
<td>1551</td>
</tr>
<tr>
<td>20.0</td>
<td>762</td>
</tr>
<tr>
<td>50</td>
<td>397</td>
</tr>
<tr>
<td>∞</td>
<td>0</td>
</tr>
</tbody>
</table>

Ref. (DeSalvo, G.C., 1992)

Citric acid:H$_2$O (1 g of anhydrous citric acid:1 ml water); Application: InGaAs selective removal from GaAs; GaAs 40 Å/min; In$_{0.2}$Ga$_{0.8}$As 751 Å/min; Ref. (Reed, J.D., 1995)
H₂SO₄:H₂O₂:H₂O (1:8:80); selective removal of InGaAs from InGaP in MQW laser fabrication; Ref. (Jones, A.M., 1998)

**InGaP from GaAs**

H₃PO₄:HCl:H₂O (1:1:1); In₀.₅Ga₀.₅P selective etch from GaAs; InGaP etch rate = 900 Å/min at 25°C; data show rate dependence on etch composition; Ref. (Lothian, J.R., 1992a)

H₃PO₄:HCl (1:1); InGaP selective etch from GaAs; Ref. (Razeghi, M., 1991)

H₃PO₄:HCl:H₂O; Application; InGaP selective etch from GaAs; selectivity dependence on composition; Ref. (Ren, F., 1994)

HCl:H₃PO₄ (1:3); Application: InGaP selective etch from GaAs; HBT fabrication; Ref. (Song, J.-I., 1994)

HCl:H₃PO₄ (3:1) and (1:1); selective etch of InGaP from GaAs; Ref. (Arslan, D., 1999)

HCl:H₃PO₄ (1:3); Application: selective etch of InGaP from GaAs; Ref. (Hanson, A.W., 1993)

HCl:H₂O (m:1, with 0.6 < m < 1.5); rate dependence for In₀.₅Ga₀.₅P, InGaAsP and GaAs; Ref. (Ito, H., 1995)

HCl:H₂O (3:2); Application: selective etch of InGaP from GaAs; Ref. (Kobayashi, T., 1989)

H₃PO₄:HCl:H₂O (1:1:1); InGaP selectively etched from GaAs; rate is reaction limited at the surface; rate increases with HCl content; Ref. (Lothian, J.R., 1992b)

HCl:H₂O (1:1); Application: selective etch of InGaP from GaAs; Ref. (Lu, S.S., 1992)

HCl; selective etch of InGaP from GaAs; Ref. (Brown, G.J., 1994)

**AlInP from GaAs**

HCl:H₂O (1:5); Al₀.₅In₀.₅P etch rate = 600 Å/min at 25°C; Al₀.₅In₀.₅P selective etch from GaAs; Ref. (Lothian, J.R., 1992c)

HCl:H₂O (1:10); Application: In₀.₅Al₀.₅P selective etch from GaAs; Ref. (Kuo, J.M., 1994)

HCl:H₂O (1:1); Application: selective removal of InAlP layer form GaAs; 20 s; Ref. (Holmes, A.L., 1995)

**GaAs from InGaP**

H₂SO₄:H₂O₂:H₂O (5:1:1); Application: GaAs selective etch from InGaP; Ref. (Olsen, G.H., 1978)
H₂SO₄:H₂O₂:H₂O (1:1:10); Application: InGaAs/AlGaAs MQW laser using 30 Å InGaP etch stop
layer; Ref. (Hobson, W.S., 1992)

H₂SO₄:H₂O₂:H₂O (1:8:80); Application: selective removal of GaAs from InAlP stop layer; 1 min;
Ref. (Holmes, A.L., 1995)

H₂SO₄:H₂O₂:H₂O (1:8:200); Application: selective etch of GaAs from InGaP; Ref. (Hanson, A.W.,
1993)

NH₄OH:H₂O₂:H₂O (10:4:500); Application: GaAs selective etch from InGaP for FET fabrication;
Ref. (Razeghi, M., 1991)

NH₄OH:H₂O₂:H₂O; Application: selective removal of GaAs from InGaP; Ref. (Ginoudi, A.,
1992)

NH₄OH:H₂O₂ (pH = 8.4); Application: selective etch of GaAs from InGaP; Ref. (Lu, S.S., 1992)

Citric acid:H₂O₂ (10:1); selective, anisotropic etch for shaping cantilevers in 2 μm GaAs layers with
InGaP etch stop layer; Ref. (Arslan, D., 1999)

H₃PO₄:H₂O₂:H₂O (1:1:10); selective etch of GaAs from InGaP; Ref. (Brown, G.J., 1994)

H₃PO₄:H₂O₂:H₂O (3:1:50); Application: selective etch of GaAs from InGaP; Ref. (Kobayashi, T.,
1989)

GaP from InGaP

KI:I₂ (0.3 mol/l KI + 0.1 mol/l I₂, with pH = 9); with pH = 11 is GaP selective etch from InGaP or
AlGaAs; Ref. (Tijburg, R.P., 1976a)

(AlₓGa₁₋ₓ)₀.₅In₀.₅P selective dependence on x (compositional selectivity: x in (AlₓGa₁₋ₓ)₀.₅In₀.₅P
undoped

<table>
<thead>
<tr>
<th>Etch rates (Å/s)</th>
<th>x = 0</th>
<th>x = 0.4</th>
<th>x = 0.7</th>
<th>x = 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>H₂SO₄ (60°C)</td>
<td>2.5</td>
<td>29</td>
<td>97</td>
<td>217</td>
</tr>
<tr>
<td>H₂SO₄ (70°C)</td>
<td>6.3</td>
<td>53</td>
<td>171</td>
<td>373</td>
</tr>
<tr>
<td>HCl:H₂O (1:1) (25°C)</td>
<td>2.9</td>
<td>102</td>
<td>383</td>
<td>478</td>
</tr>
</tbody>
</table>

Ref. (Stewart, T.R., 1992)

AlSb or GaSb from InAs

HF; Application: AlSb selective etch from InAs for layer lift-off. InAs layer masked with black wax
is removed from GaAs substrate by etch of an intermediate sacrificial AlSb layer. GaSb is attacked
by HF but can be lifted off by using a thin InAs etch stop layer; Ref. (Ozbay, E., 1993)
HF:H₂O (1:20) or (1:40); Selective etch of sacrificial AlSb layer to lift-off an InAs layer from a GaAs substrate; Ref. (Fastenau, J., 1995)

HF:H₂O₂:H₂O (2:1:20); Selective etch of GaSb from InAs stop layer; Ref. (Fastenau, J., 1995)

Photoresist developer Microdeposit MF319 as etchant; GaSb and AlGaSb selective etch from InAs NH₄OH dilute; GaSb and AlGaSb selective etch from InAs; Ref. (Yoh, K., 1991)

InAlN from GaN or InN

AZ400K developer solution (~10% KOH active ingredient); Selective etchant of InₓAl₁₋ₓN with x as high as 75%; etch rates given over temperature range of 20–80°C; does not etch pure InN or GaN; Ref. (Lee, J.W., 1996)

AZ400K photolithographic developer (KOH active ingredient):
AZ400K:H₂O (1:5); AlN selective etch from either GaN or Al₂O₃; little undercut at 65°C; significant undercut at 85°C; etching behavior is rate limited; Ref. (Mileham, J.R., 1995)

2.3.3. Dopant selective etchants

n-GaAs from p-GaAs

HCl:H₂O (1:20); GaAs n-type selective photoetch from GaAs p-type, selectivity > 15,000. GaAs n-type selective etch from GaAs semi-insulating, selectivity ~ 30; Ref. (Khare, R., 1991)

H₂SO₄:H₂O₂:H₂O (3:1:1); GaAs selective n- from p-photoetching; Ref. (Kuhn-Kuhnenfeld, F., 1972)

GaAs; UV illuminated etch for deep features, via holes, etc.; higher etch rates than for visible light UV etch rates at 10 W/cm²
  H₂SO₄:H₂O₂:H₂O (1:1:100); n-type 18 μm/min; Si-type 13 μm/min; p-type 0.8 μm/min
  HNO₃:H₂O (1:20); n-type 12 μm/min; Si-type 10 μm/min; p-type 1.0 μm/min
  KOH:H₂O (1:20); n-type 8 μm/min; Si-type 6 μm/min p-type 0.5 μm/min; Ref. (Podlesnik, D.V., 1984)

HNO₃:H₂O (1:20); GaAs photoetching p–n junction delineation; dopant selective: n-etching under illumination; p-type does not etch; no GaAs dark etching; Ref. (Ruberto, M.N., 1991)

H₂SO₄:H₂O (1:10); GaAs and InP photoetch p–n junction delineation; dopant selective; n-etches under illumination; p-type does not etch; Ref. (Ruberto, M.N., 1991)

Two step thinning: (1) p-GaAs substrate is anodically dissolved down to an n-blocking layer. (2) H₂SO₄:H₂O₂ (3:2) photoetch removes n-blocking layer from the thin p-layer; Ref. (Thrush, E.J., 1974)

p+GaAs from p-GaAs

K₃Fe(CN)₆ at pH = 14; p+GaAs (10²⁰ cm⁻³) selective etch from p-GaAs (1018 cm⁻³); Ref. (Kelly, J.J., 1988)
**p-GaAs from n-GaAs**

Electrochemical etch; GaAs; NaOH electrolyte; removal of p-substrate from n-layer; Ref. (Nuese, C.J., 1970)

Ce(SO$_4$)$_2$:Ce(NO$_3$)$_3$; p-type AlGaAs selective from n-type; Ref. (Tijburg, R.P., 1976a)

Two step thinning: (1) p-GaAs substrate is anodically dissolved down to an n-blocking layer. (2) H$_2$SO$_4$:H$_2$O$_2$ (3:2) photoetch removes n-blocking layer from the thin p-layer; Ref. (Thrush, E.J., 1974)

**p-GaP from n-GaP**

NaOH (3N); electrolyte for electrochemical etching of GaP; selective removal of p-type material from n-type; Ref. (Meek, R.L., 1972)

**n-InP from p-InP**

HCl:HNO$_3$:H$_2$O (1:1:20); InGaAsP and InP p–n junction delineation photoetch; dopant selective: n-etches under illumination; p-type does not etch; very sharp boundaries; Ref. (Williamson, J., 1993)

K$_3$[Fe(CN)$_6$] (10 g):KOH (15 g):H$_2$O (270 ml); photochemical dopant selective n-InP from p-InP; smooth surfaces; Ref. (Kallstenius, T., 1999b)

**n-GaN from p-GaN**

KOH (0.005–0.04 M); photoelectrochemical etch of n-GaN selectively from intrinsic GaN and p-GaN; Ref. (Youtsey, C., 1998)

**Intrinsic Si from n+Si**

KOH (40%) at 60°C and ethylenediamine-pyrocatechol; Application: Si selective etch from B-doped $>1 \times 10^{20}$ cm$^{-3}$ Si layers; Ref. (Rittenhouse, G.E., 1992)

**InGaAsP dopant selectivity**

Photochemical etch; InGaAsP p–n dopant selectivity; Ref. (Kohl, P.A., 1989)

**($Al_xGa_{1-x})_{0.5}In_{0.5}P$ dopant selectivity**

<table>
<thead>
<tr>
<th>(AlGa)$<em>{0.5}$In$</em>{0.5}$P dopant selectivity:</th>
<th>Etch rates (Å/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n = $1 \times 10^{18}$</td>
</tr>
<tr>
<td>H$_2$SO$_4$ (60°C)</td>
<td>148</td>
</tr>
<tr>
<td>H$_2$SO$_4$ (70°C)</td>
<td>181</td>
</tr>
<tr>
<td>HCl:H$_2$O (1:1) (25°C)</td>
<td>483</td>
</tr>
</tbody>
</table>

Ref. (Stewart, T.R., 1992)
2.3.4. Pattern etching: cross-sectional profiles

**InP**

InP photolithography showing vee and dovetail groove cross-section etch profiles for:

- **HCl:** InP etch rate at 25°C ~ 12 μm/min
- **HCl:H2O (1:1):** InP etch rate at 25°C ~ 0.07 μm/min
- **HCl:H2O2 (1:1):** InP etch rate at 25°C ~ 2.3 μm/min
- **HCl:CH3COOH (1:1):** InP etch rate at 25°C ~ 6.0 μm/min
- **HCl:H3PO4 (1:1):** InP etch rate at 25°C ~ 4.0 μm/min
- **HCl:H2O2 (1:1):** InP etch rate at 25°C ~ 0.1 μm/min
- **HCl:CH3COOH:H2O2 (1:1:1):** InP etch rate at 25°C ~ 4.0 μm/min
- **HCl:H3PO4:H2O2 (1:1:1):** InP etch rate at 25°C ~ 2.0 μm/min
- **HCl:HNO3 (1:1):** InP etch rate at 25°C ~ 6.5 μm/min
- **HCl:HNO3 (1:2):** InP etch rate at 25°C ~ 7.0 μm/min
- **HCl:HNO3 (2:1):** InP etch rate at 25°C ~ 8.5 μm/min
- **HCl:HNO3:H2O (1:1:1):** InP etch rate at 25°C ~ 0.1 μm/min
- **HCl:HNO3:H2O2 (1:1:1):** InP etch rate at 25°C ~ 0.5 μm/min
- **HCl:HNO3:CH3COOH (1:1:2):** InP etch rate at 25°C ~ 1.0 μm/min
- **HBr:** InP etch rate at 25°C ~ 6.5 μm/min
- **HBr:H2O2 (1:1):** InP etch rate at 25°C ~ 23 μm/min
- **HBr:CH3COOH (1:1):** InP etch rate at 25°C ~ 3.0 μm/min
- **H3PO4:HBr (1:1):** InP etch rate at 25°C ~ 2.0 μm/min
- **HBr:HNO3 (1:1):** InP etch rate at 25°C ~ 11.0 μm/min
- **HBr:HNO3 (1:2):** InP etch rate at 25°C ~ 9.0 μm/min
- **H2SO4:H2O2 (1:1):** InP etch rate at 60°C ~ 0.2 μm/min
- **H2SO4:H2O2:H2O (1:1:1):** InP etch rate at 60°C ~ 0.17 μm/min
- **H2SO4:H2O2:H2O (3:1:1):** InP etch rate at 60°C ~ 0.12 μm/min
- **K2Cr2O7:H2SO4:HCl (3:1:1):** InP etch rate at 60°C ~ 0.10 μm/min
- **Br/methanol (4%):** InP etch rate at 25°C ~ 0.25 μm/min
- **Br/methanol (2%):** InP etch rate at 25°C ~ 1.5 μm/min
- **Br/methanol (1%):** InP etch rate at 25°C ~ 2.0 μm/min
- **Br/methanol (0.2%):** InP etch rate at 25°C ~ 3.5 μm/min
- **Br/methanol (0.1%):** InP etch rate at 25°C ~ 2.0 μm/min

<table>
<thead>
<tr>
<th>1 M K2Cr2O7:H2SO4:HCl</th>
<th>GaAs (1 0 0) rate (μm/min)</th>
<th>InP (1 0 0) rate (μm/min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(3:1:0) (60°C)</td>
<td>0.03</td>
<td>None</td>
</tr>
<tr>
<td>(3:1:1) (60°C)</td>
<td>12</td>
<td>0.25</td>
</tr>
<tr>
<td>(3:1:2) (25°C)</td>
<td>2.5</td>
<td>0.5</td>
</tr>
<tr>
<td>(3:1:2) (60°C)</td>
<td>20</td>
<td>1.5</td>
</tr>
<tr>
<td>(3:1:3) (60°C)</td>
<td>30</td>
<td>2.3</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>1 M K2Cr2O7:H2SO4:HCl</th>
<th>GaAs (1 0 0) rate (μm/min)</th>
<th>InP (1 0 0) rate (μm/min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(3:1:0) (60°C)</td>
<td>0.03</td>
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<tr>
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<td>12</td>
<td>0.25</td>
</tr>
<tr>
<td>(3:1:2) (25°C)</td>
<td>2.5</td>
<td>0.5</td>
</tr>
<tr>
<td>(3:1:2) (60°C)</td>
<td>20</td>
<td>1.5</td>
</tr>
<tr>
<td>(3:1:3) (60°C)</td>
<td>30</td>
<td>2.3</td>
</tr>
</tbody>
</table>

Gives GaAs and InP groove etch profiles for H2SO4:H2O2:H2O (1:1:1) and all the above concentrations of 1 M K2Cr2O7:H2SO4:HCl; Ref. (Adachi, S., 1981e)
InP photolithography; showing vee and dovetail groove cross-section etch profiles for:

- Br$_2$/methanol; InGaAsP and InP etch rates are similar for the concentration range from 0.1 to 4%
- HBr; InP selective etch from InGaAsP
- HBr:HCl (2:1) to (1:2); InGaAsP and InP etch rates vary with proportions
- HBr:H$_2$O$_2$ (1:1); InGaAsP and InP etch rates are similar
- HBr:CH$_3$COOH (1:1); InP selective etch from InGaAsP
- H$_3$PO$_4$:HBr (1:1); InP selective etch from InGaAsP
- HCl; InP selective etch from InGaAsP
- HCl:H$_2$O (1:1); InP selective etch from InGaAsP
- HCl:H$_2$O$_2$ (1:1); InP selective etch from InGaAsP
- HCl:CH$_3$COOH (1:1); InP selective etch from InGaAsP
- HCl:CH$_3$COOH:H$_2$O$_2$ (1:1:1); InGaAsP and InP etch rates are similar
- HCl:H$_3$PO$_4$:H$_2$O$_2$ (1:1:1); InGaAsP and InP etch rates are similar
- HCl:HNO$_3$ (1:1); InGaAsP and InP etch rates are similar
- HNO$_3$:HBr (1:1); InGaAsP and InP etch rates are similar
- H$_3$PO$_4$:HCl (1:1); InP selective etch from InGaAsP
- H$_2$SO$_4$:H$_2$O$_2$:H$_2$O (1:1:1); InGaAsP selective etch from InP
- H$_2$SO$_4$:H$_2$O$_2$:H$_2$O (3:1:1); InGaAsP selective etch from InP
- K$_2$Cr$_2$O$_7$:H$_2$O$_2$:HCl (3:1:2); InGaAsP selective etch from InP; Ref. (Adachi, S., 1982c)
- HCl:HNO$_3$:H$_2$O (2:3:6); InP etch rate = 1 µm/min; non-preferential
- HCl:HNO$_3$:H$_2$O (2:2:1); InP etch rate = 2 µm/min; non-preferential
- Br$_2$:HBr:H$_2$O (1:17:35); InP etch rate = 2 µm/min; Ref. (Colliver, D.J., 1976)

SiO$_2$ masked InP diffraction grating etch profile study for:

- HCl conc.
  - HCl:H$_3$PO$_4$ (1:3) and HCl:CH$_3$COOH (1:1) give rectangular groove grating
  - HBr:CH$_3$COOH (1:1) gives sawtooth grating; Ref. (Westbrook, L.D., 1983)
  - H$_3$PO$_4$:HCl (3:1); Application: InP (1 0 0) photolithography; rectangular cross-section rib etch; Ref. (Buckmann, P., 1982)
  - HCl:H$_3$PO$_4$ (5:1); InP; vee-groove etchant with photoresist mask; undercut rate is modified by heating substrate; Ref. (Huo, D.T.C., 1988a)
  - HCl:H$_3$PO$_4$ (3:1); InP vee-groove etchant at room temperature with photoresist mask; depth etch rate = 0.083 µm/s; undercut etch rate = 0.042 µm/s; shelf time is about 20 h; undercut may be reduced by heating substrate; Ref. (Huo, D.T.C., 1987)
  - HCl:H$_3$PO$_4$ (5:1); InP vee-groove etch (1 1 0) direction; no undercut
    - HBr:H$_3$PO$_4$:1N K$_2$Cr$_2$O$_7$ (2:1:1); InP vee-groove etch for (1 1 0) direction; attacks photoresist; undercuts; Ref. (Huo, D.T.C., 1990)
  - HCl:H$_3$PO$_4$ (5:1); InP (1 0 0) vee-groove etchant with photoresist mask; undercut is minimized with oxide removal in 48°C HF bath before etch; undercut etch rate = 0.042 µm/s; Ref. (Huo, D.T.C., 1989c)
InP (1 0 0) photoresist undercut study; etch profiles:

- \( \text{H}_3\text{PO}_4:\text{HCl}:\text{H}_2\text{O}_2 \) (1:5:0.1–1)
- \( \text{H}_3\text{PO}_4:\text{HCl}:\text{HF} \) (1:5:0.1–1) (HF causes bad undercut)
- \( \text{H}_3\text{PO}_4:\text{HCl}:\text{HBr} \) (1:5:0.1–1)
- \( \text{H}_3\text{PO}_4:\text{HCl} \) (1:5); Ref. (Huo, D.T.C., 1988b)

HCl: \( \text{H}_3\text{PO}_4 \) (3:1) wet chemical etchant is used for vee-groove in InP (1 0 0) in 20 s at RT; Ref. (Tanahashi, T., 1983)

HCl: \( \text{H}_3\text{PO}_4 \) (5:1); InP masked with Ti or InGaAs for groove etch; no undercutting with InGaAs; dependence of profile shapes on etch time; Ref. (Klockenbrink, R., 1994)

HCl: \( \text{H}_3\text{PO}_4 \) (1:10); Application: InP selective etch from InGaAs using SiN mask for HBT fabrication

HF dilute; Application: SiN passivation layer removal from InP; Ref. (Ouacha, A., 1993)

HCl: \( \text{H}_3\text{PO}_4 \) (5:1); InP (1 0 0) vee-groove etchant with photoresist mask; undercut is minimized with oxide removal in 48°C HF bath before etch; undercut etch rate = 0.042 \( \mu \text{m/s} \); Ref. (Huo, D.T.C., 1989c)

HP\(_3\)O\(_4\):HCl:H\(_2\)O (1:1:1); InP (1 0 0) vee-groove etch; does not erode photoresist

HP\(_3\)O\(_4\):HCl:HBr (1:1:1); InP (1 0 0) vee-groove etch; does not erode photoresist; Ref. (Huo, D.T.C., 1989d)

HCl: \( \text{H}_3\text{PO}_4 \) room temperature etch rate data for (1:19), (1:9), and (1:4)

HCl: \( \text{H}_3\text{PO}_4 \) (1:9); etch rate dependence on temperature; lateral etch behavior at 60°C; Application to self-aligned HBTs; Ref. (Matine, N., 1998)

HCl: \( \text{H}_3\text{PO}_4 \) (1:1); Application: InGaAsP (\( \lambda = 0.997 \mu \text{m} \)) stripe etch

H\(_2\)SO\(_4\):H\(_2\)O\(_2\):H\(_2\)O (3:1:1); InGaAsP (\( \lambda = 1.52 \mu \text{m} \)) stripe etch; Ref. (Imai, H., 1983)

H\(_3\)PO\(_4\):HCl (3:1); Application: InP photolithography; faceted grooves; Ref. (Bhat, R.B., 1991)

H\(_3\)PO\(_4\):HCl (1:1): Application: InP \( \text{Si}_3\text{N}_4 \) masked mesa etch; Ref. (Tamari, N., 1982b)

HCl: \( \text{H}_3\text{PO}_4 \) (0.5:1); at 25°C in light InP rate is 21 nm/s

HCl: \( \text{H}_3\text{PO}_4 \) (5:1); at 25°C in light InP rate is 151 nm/s; for 20 \( \mu \text{m} \) high mesas these give smooth (2 1 1)A side surfaces, but deep pit features on the (1 0 0) bottom surface

HCl: \( \text{H}_3\text{PO}_4 \):lactic acid (\( x:y:z \)); gives etch rate dependence on composition; incorporation of lactic acid reduces size and number of etch pits on bottom (1 0 0) plane; higher lactic acid increases roughness of (2 1 1)A and (1 0 0) surfaces. Requires final 2% Br\(_2\)/methanol polish to reduce roughness

Br\(_2\)/methanol (2%); final polish of 40 \( \mu \text{m} \) mesas etched in HCl: \( \text{H}_3\text{PO}_4 \):lactic acid to reduce surface roughness; Ref. (Eliás, P., 1999)

H\(_3\)PO\(_4\):H\(_2\)O\(_2\):H\(_2\)O (1:1:20); Application; InAlAs/InGaAs/InP mesa etch; Ref. (Tsai, H.H., 1994); (Bélier, B., 2000)

H\(_3\)PO\(_4\):H\(_2\)O\(_2\):H\(_2\)O (1:1:150); gate recess etch in InGaAs/InAlAs/InP HEMTs; Ref. (Duran, H.C., 1999)
H₃PO₄:H₂O₂:H₂O (1:1:38); Application: InGaAs FET channel recess; Ref. (Cheng, C.L., 1984); (Liao, A.S.H., 1982)

H₃PO₄:H₂O₂:H₂O (1:1:8); Application: InGaAs notch etch for FET; etch rate = 0.47 μm/min; Ref. (Gammel, J.C., 1981)

H₃PO₄:H₂O₂ (1:1); InP and InGaAs lattice defect delineation with preferential photoetching
H₂O₂ (30%); InGaAs treatment leaves 8–10 Å In₂O₃ and Ga₂O₃; Ref. (Gottschalch, V., 1982)
H₃PO₄; (1 0 0): InP, GaInP, GaP, GaAsP; Ref. (Gottschalch, V., 1979b)

H₃PO₄:H₂O:saturated bromine water (1:15:2); undercut-mesa etch of InP for MOVPE regrowth following RIE etch
HNO₃:HBr:H₂O (1:1:10); undercut-mesa etch of InP for MOVPE regrowth following RIE etch
H₃PO₄:H₂O:saturated bromine water (5:5:2); undercut-mesa etch of InP for MOVPE regrowth following RIE etch
H₂PO₄:H₂O:saturated bromine water (10:10:1); undercut-mesa etch of InP for MOVPE regrowth following RIE etch; Ref. (Fang, R.Y., 1997)

HCl:HNO₃ (1:3); InGaAsP/InP non-selective mesa etch; data is given on etch wall profiles; Ref. (Coldren, L.A., 1983)

HCl:HNO₃ (1:2); facet etch; equal etch rate on InP and InGaAsP = 0.16 μm/s; Ref. (Furuya, K., 1981)

HCl:HNO₃:H₂O (1:2:1); InP pattern etch for OMVPE regrowth; etch rate ~4 μm/min; Ref. (Blaauw, C., 1986)

HCl:HNO₃; Application: InGaAsP/InP photolithography groove etch profiles for vee-groove laser
HCl:H₃PO₄
Br₂/methanol; Ref. (Imai, H., 1982)

HCl:HNO₃:H₃PO₄ (1:1:5); InP (0 0 1) groove etch; rectangular shaped along (0 1 1)
HCl:H₃PO₄ (1:1); InP (0 0 1) groove etch; partial vee-shaped {1 1 1}B surface along (0 1 1), and vee-shaped {2 1 1} along (0 1 1)
Br₂/methanol (1%); InP (0 0 1) reverse-mesa shaped {1 1 1}A surfaced groove along (0 1 1) and vee-groove {1 1 1}A surface along (0 1 1); Ref. (Westphalen, R., 1992)

HCl conc.; InP photolithography; gives HCl etch orientation dependence of sidewall profiles and InGaAsP mask undercutting following an initial reactive ion dry etch in Cl₂/O₂ which leaves the pattern with an initial 75° wall angle; Ref. (Hemenway, B.R., 1983)

HCl:H₂O (4:1); Application: InP mesa etch for BH laser; Ref. (Kishino, K., 1980)

HNO₃:HCl (1:1); InP rapid etch, but does not selectively attack metal–InP interfaces
HNO₃; oxidizes but does not etch InP; Ref. (Yeats, R.E., 1977)
HCl:ethanol; InP; etch rate concentration and temperature dependence; mesa sidewall profiles; Ref. (das Neves, S., 1993)
HNO₃:HCl:H₂O (1:1:2); InP (1 0 0) etch rate = 5 μm/min
HCl (37%); InP (1 0 0) etch rate = 6.2 μm/min
H₂SO₄:H₂O₂:H₂O (3:1:1); InP (1 0 0) etch rate = 0.25 μm/min
HCl:HO₃₃ (1:1); InP (1 0 0) etch rate = 40 μm/min
HCl:HO₃₃:CH₃COOH (1:1:1); InP (1 0 0) etch rate = 5.5 μm/min
HCl:HO₃₃:CH₃COOH (3:1:5); InP (1 0 0) etch rate = 4 μm/min
HCl:HO₃₃:HClO₄:CH₃COOH (1:6:1:1); InP (1 0 0) etch rate = 2.5 μm/min
HCl:HO₃₃:HClO₄:CH₃COOH (1:3:3:2); InP etch rate = 3.2 μm/min
Br₂/methanol (1%); InP (1 0 0) etch rate = 0.4 μm/min
H₃PO₄ (85%); InP (1 0 0) etch rate at 90°C = 0.15 μm/min; Ref. (Becker, R., 1973)

HCl:CH₃COOH:H₂O₂ (1:2:1) {KKI etch}; Application: InGaAsP/InP (1 0 0) non-selective etch; shows etch profiles; Ref. (Iga, K., 1979a)

HCl:CH₃COOH:H₂O₂ (1:2:1) {KKI etch}; Application: InGaAsP/InP laser mirror etch; Ref. (Miller, B.I., 1980)

HCl:CH₃COOH:H₂O₂ (1:2:1) {KKI etch}; Application: InGaAsP/InP (1 0 0) non-selective mesa etch; Ref. (Iga, K., 1980b, 1982); (Wakao, K., 1981)

HCl:CH₃COOH:H₂O (2:6:1); Application: InP channel etch

HCl:CH₃COOH:H₂O (1:2:1); InP groove etch; Ref. (Moriki, K., 1981)

HCl:CH₃COOH:H₂O₂ (1:2:1) {KKI-121 etch}; InP (1 0 0) etch rate = 1.4 μm/min at 25°C; very smooth, flat etched surfaces

HCl:CH₃COOH:H₂O₂ (1:1:1) {KKI-111 etch}; InP etch rate = 1.1 μm/min at 25°C
H₃PO₄:HCl:H₂O₂; and
HNO₃:HCl:H₂O₂; comparison of surface smoothness; Ref. (Kambayashi, T., 1980)

HCl:CH₃COOH:H₂O₂ (1:1:1) {KKI etch}; Application: InP; SiO₂-masked recess etch at 12°C for selective LPE growth of InGaAs; shows profiles; etch rate ~3000 Å/min; Ref. (Schilling, M., 1986)

HCl:CH₃COOH:H₂O₂ (1:1:1) {KKI etch}; Application: InGaAsP/InP mesa etch; Ref. (Tobe, M., 1980)

HBr:H₂O₂:H₂O:HCl (20:2:20:20); InP (1 0 0) photolithography vertical sidewalls; control of (1 1 1)A versus (1 1 1)B anisotropy; shows effects of changing HBr and HCl concentrations; Ref. (Huo, D.T.C., 1988b)

HBr:HNO₃:H₂O (1:1:30); Application: InGaAsP selective etch from InP
HCl conc.; InP selective etch from InGaAsP mask and stop layer; Ref. (Koch, T.L., 1987)

HBr:H₂O₂:H₂O; InP pattern etch for OMVPE regrowth; for normal and reentrant sidewall profiles
Br₂/methanol (1%); InP; reentrant [1 0 0] direction profiles
HBr:H₃PO₄:H₂O₂:H₂O; InP; reentrant [1 0 0] direction profiles; Ref. (Zilko, J.L., 1991)

HBr:H₂PO₄:H₂O (1:1:8); InGaAs etch at 0°C to define a lithography pattern for the purpose of using the thin InGaAs as an etch mask for underlying InP; eliminates mask undercutting
HCl:H₃PO₄:H₂O (3:1:1); InP etch at 0°C, material selective from InGaAs; shows sidewall deformation for nanometer geometries.

HCl:CH₃COOH (1:4); InP material selective etch from InGaAs; gives near vertical sidewalls for nanometer geometries; Ref. (Inamura, E., 1989)

HCl:H₃PO₄:H₂O (3:1:1); InP etch at 0°C, material selective from InGaAs; shows sidewall deformation for nanometer geometries.

HCl:CH₃COOH (1:4); InP material selective etch from InGaAs; gives near vertical sidewalls for nanometer geometries; Ref. (Inamura, E., 1989)

HBr(37%); InP vee-groove etch using titanium mask, first step to form sharp vees with minimal undercutting; 20 s at 20°C

HBr:K₂Cr₂O₇ (3:1); InP vee-groove sidewall smoothing (step 2) using titanium mask; Ref. (Bönsch, P., 1998)

HBr:CH₃COOH (1:1); Application: InGaAs/InP quantum dot patterning; at 5°C for 3 s (Schmidt, A., 1992)

HBr:CH₃COOH:K₂Cr₂O₇ (2:2:1); InGaAsP/InP laser mirror etch; nearly equal etch rates; (Adachi, S., 1982a)

HBr:HNO₃:H₂O (1:1:4); Application: InP/InGaAs pattern etch with Au mask for quantum wires; etch rate 100–200 Å/min at 33°C; Ref. (Ils, P., 1993)

HNO₃:HBr:H₂O (1:1:5); Application: InGaAsP/InP mesa etch for BH laser cavity; Ref. (Matsuoka, T., 1981)

HBr:CH₃COOH:K₂Cr₂O₇; Application: InP and InGaAs etch with patterned Ti mask for quantum wires; Ref. (Schilling, O., 1993)

HBr:H₂PO₄:K₂Cr₂O₇ (2:2:1); InP vee-groove (1 1 1)A facet etch through SiO₂ mask at 23°C; Ref. (Wang, J.B., 1995)

HBr(46%):H₃PO₄(85%):K₂Cr₂O₇(1N) (2:2:1); Application: etching of beveled surfaces on InGaAsP/InP structures to allow characterization of small angle cross-sections; etchant flow method to form the bevel; Ref. (Srnanek, R., 1997a)

Saturated Br water:HBr:H₂O (1:10:40); InP/InGaAsP photolithography for submicron patterns; InP etch rate = 0.45 μm/min; gives dependence of etch rate and mask undercutting on H₂O + Br₂ concentrations; Ref. (Matsuoka, T., 1986)

Br₂/methanol (3%); Application: via holes in InP FETs; rate ~8 μm/min; Ref. (Trassaert, S., 1998)

Br₂/methanol (2%); vee-groove etching behavior with SiO₂ and photoresist masks

HBr:H₂PO₄:K₂Cr₂O₇ (2:2:1); vee-groove etching behavior with SiO₂ and photoresist masks

HCl:H₂PO₄ (5:1); vee-groove etching behavior with SiO₂, photoresist and InGaAs masks. Shows groove shape dependence on mask alignment; Ref. (Wang, J., 1998)

Br₂/methanol (1%); InGaAsP/InP mesa etch; temperature dependence of etch rate; for T < −58°C there is no undercutting of SiO₂ masks; Ref. (Hou, D.T.C., 1989)
Br₂/methanol (1%); Application: InP (1 1 1)B etch rate = 2.5 μm/min for LPE substrate preparation

Br₂/methanol (3%); InP (1 1 1)B etch rate = 6 μm/min; Ref. (Linh, N.T., 1975)

Br₂/methanol (1%); InGaAsP/InP mesa etch; Ref. (Armiento, C.A., 1979a)

Br₂/methanol (1%); Application: InGaAs mesa etch; Ref. (Lee, T.P., 1981); (Leheney, R.F., 1981)

Br₂/methanol (3 vol.%):H₃PO₄ (1:1); Application: InP mesa etch at 45°C; Ref. (Armiento, C.A., 1979b)

Br₂/methanol (0.1%); InP vee-groove etch, first step; exposes {1 1 1}A sidewalls but leaves surface defects

H₂SO₄:H₂O₂:H₂O (3:1:1); second step of InP vee-groove etch; removes defects from exposed {1 1 1}A surfaces; broadens the radius of the vee

Br₂/methanol (0.1%); third step of InP vee-groove etch; reduces the radius of the vee after H₂SO₄:H₂O₂:H₂O etch; Ref. (Kappelt, M., 1996)

Br₂/methanol (1%); InGaAsP/InP; study of etch temperature on profile geometry and undercutting; Application: InGaAsP/InP double heterostructure laser; zero mask undercutting when etch at or below –58°C

KOH:K₃Fe(CN)₆:H₂O (6 g:4 g:50 g): InGaAsP/InP layer delineation; Ref. (Huo, D.T., 1989e)

Br₂/methanol; Application: photolithography: etch cross-section profiles; laser mirror etch; slight difference in etch rates between InGaAsP and InP; Ref. (Adachi, S., 1981c, 1982b,d)

Br₂/methanol; Application: InGaAsP stripe etch for BH laser fabrication; Ref. (Hirao, M., 1980a,b); (Itaya, Y., 1980); (Kano, H., 1979); (Nagai, H., 1980); (Nelson, R.J., 1981); (Takahashi, S., 1980)

Br₂/methanol; Application: InGaAsP/InP laser cantilever etch for microcleaving

K₂Cr₂O₇:HBr:CH₃COOH
HCl:CH₃COOH:H₂O₂ (1:2:1)
HCl:HNO₃ (1:1.2–2)
HCl:HNO₃:H₂O (1:2:1)
HCl:HNO₃:H₃PO₄ (1:1.2–2:1–1.5)
HCl:HNO₃:H₃PO₄:H₂SO₄ (1:1.2–2:1–1.5:0.005–0.1): Application: InGaAsP/InP laser mirror etching; Ref. (Szaplónczay, A., 1987)

Br₂/methanol (0.05%) and

H₂SO₄:H₂O₂:H₂O (3:1:1); Application: InGaAsP/GaAs etched mirror lasers; Ref. (Ishikawa, J., 1989)

Br₂/methanol (1%); Application: InGaAs mesa etch

H₂SO₄:H₂O₂:H₂O (1:6:10); Application: InGaAs mesa etch at 50°C; etch rate = 20 μm/min; Ref. (Pearsall, T.P., 1978, 1980)
Br$_2$/methanol (0.1–1%); and
H$_2$SO$_4$:H$_2$O$_2$:H$_2$O (2:1:1); GaAs and InP etch procedures to obtain the best morphologies; Ref. (Saletes, A.F., 1988)

HBr (9N); Application: InP photolithography grating at $-15^\circ$C; (1 1 1)A facets; Ref. (Keavney, C.J., 1984)

Lactic acid (CH$_3$CHOHCOOH):Iodic acid (HIO$_3$):H$_2$O (1.5:1:2); InP etch rate of 2 A/s; specular surfaces; diffusion limited, isotropic etch
HCl:H$_2$PO$_4$:CH$_3$COOH (1:1:x, with 0 < x < 6); study of InP etch rate, surface finish and photoresist undercut
HCl:H$_2$PO$_4$:lactic acid (1:1:x, with 0 < x < 6); study of InP etch rate, surface finish and photoresist undercut. Smoother InP surfaces; Ref. (Ikossi-Anastasiou, K., 1995)

Iodic acid:H$_2$O (10% solution); Application: InP groove etch with Si$_3$N$_4$ mask; Ref. (Yu, K.L., 1981)
C$_6$H$_8$O$_7$ (citric acid):H$_2$O$_2$:H$_2$O; 5 s wet etch following reactive ion etch of InP/InGaAlAs/InGaAs heterostructure detectors; removes about 150 Å InGaAs, 70 Å InAlGaAs and <20 Å InP; Ref. (Kollakowski, St., 1998)

Citric acid:H$_2$O$_2$ (10:1); Study: InAlAs selective etch from InP, selectivity > 187; InGaAs selective etch from InP, selectivity > 480. InGaAs selective from InAlAs, selectivity only 2.5. Shows etch profiles. InP etch rate at 20°C = 0.05 Å/s; InAlAs etch rate at 20°C = 10 Å/s; InGaAs etch rate at 20°C = 24 Å/s
Citric acid:H$_2$O$_2$ (1:1); InGaAs selective etch from InAlAs = 25. InGaAs etch rate at 20°C = 25 Å/s; InAlAs etch rate at 20°C = 1 Å/s; Ref. (Tong, M., 1992a)

Citric acid:H$_2$O$_2$ (24:1); Application: In$_{0.53}$Ga$_{0.47}$As FET gates; uses undercutting of photolithography mask to achieve submicron widths; Ref. (Chai, Y.G., 1983, 1985)

Citric acid:H$_2$O$_2$ (5:1); Application InGaAs etch rate = 1000 Å/min; Ref. (O’Conner, P., 1982)

HCl:citric acid (4:5); InP photolithography; forms inverted sidewalls and flat bottoms; Ref. (Yeats, R., 1982)

H$_2$SO$_4$:H$_2$O$_2$:H$_2$O (1:1:1); Application: InP etch at 50°C using SiO$_2$ pattern mask; Ref. (Osaka, F., 1980)

H$_2$SO$_4$:H$_2$O$_2$:H$_2$O (1:1:20); Application: InGaAs slow etch, etch rate = 0.25 μm/min at 20°C; photolithography gives positively tapered sidewalls for both (0 1 1) and (0 1 1); Ref. (Dambkes, H., 1984)

H$_2$SO$_4$:H$_2$O$_2$:H$_2$O (10:1:1); Application: InGaAs mesa etch for photodiode fabrication
Br$_2$/methanol; InP mesa etch; Ref. (Kanbe, H., 1980)

H$_2$SO$_4$:H$_2$O$_2$:H$_2$O; InGaAsP first-order grating etch for laser; Ref. (Kawanishi, H., 1979)

H$_2$SO$_4$:H$_2$O$_2$:H$_2$O (1:8:1); Application: InGaAs InP mesa etch; Ref. (Matsushima, Y., 1979)
HF buffered (5N H$_3$F:1 HF) is used to etch windows in SiO$_2$ mask on InP.

HCl (conc.) is preferential vee-grooved etchant for InP (1 0 0) but shows damage on vee-groove walls due to high etch rate (7.33 µm/min at 22°C).

H$_3$PO$_4$:HCl (1:1) is preferred vee-grooved etchant for InP with smaller etch rate (0.1 µm/min at 22°C); Ref. (Edwards-Shea, L., 1985)

HF:H$_2$O (1:1); InP etch rate enhanced by mg ion bombardment damage for maskless patterning; Ref. (Inada, T., 1984)

III–V semiconductor mask patterning by focused Ga ion beam damage; using photoelectrochemical etching of non-damaged areas on n-type GaAs, InP, InGaAs, InGaAsP

H$_2$SO$_4$ (2 M); Photoelectrochemical etch electrolyte; Ref. (Cummings, K.D., 1986)

Saturated bromine water (SBW):HBr:H$_2$O (1:10:40); Application; InP grating fabrication; dependence of etch depth on pattern spacing; Ref. (Nishida, T., 1993)

Saturated Br$_2$ water:H$_2$O:H$_3$PO$_4$ (2:15:5); InAlAs etch rate = 4000 Å/min for photolithography of second-order gratings; Ref. (Meneghini, G., 1989)

Saturated Br$_2$ water:H$_3$PO$_4$:H$_2$O (2:1:15); Application: InGaAsP and InP vee-groove grating etch; does not attack photoresists

H$_2$O:H$_2$O$_2$:HF (8:3:2) to remove SiO$_2$ mask and In droplets from first LPE step; Ref. (Prince, F.C., 1980)

K$_2$Cr$_2$O$_7$:HBr:CH$_3$COOH (3:1:1); Application: InGaAsP tilted laser facet etch

Saturated Br$_2$ water:HBr:H$_2$O; InGaAsP/InP laser surface grating etch; Ref. (Itaya, Y., 1984)

1N K$_2$Cr$_2$O$_7$:HBr:CH$_3$COOH (3:1:1); Application: InP (1 0 0) grating etch for BH laser; Ref. (Matsuoka, T., 1982)

Br$_2$:HBr:H$_2$O (1:17:1000); Application: InP FET channel etch preparation for Schottky contact; Ref. (Chevrier, J.M., 1980)

Etchant undercutting of SiO$_2$ masks on InP (1 0 0) for the following:

Br$_2$ in dimethylformamide (5%), etch rate = 1.9 µm/min
HCl, etch rate = 8.2 µm/min
HCl:H$_3$PO$_4$ (1:1), etch rate = 2.6 µm/min
HCl:CH$_3$COOH (1:1), etch rate = 4.0 µm/min
HCl:HNO$_3$ (1:1), etch rate = 6.0 µm/min
HBr, etch rate = 1.5 µm/min
HBr:H$_3$PO$_4$ (1:1), etch rate = 7.3 µm/min
HBr:CH$_3$COOH (1:1), etch rate = 0.9 µm/min
HNO$_3$:HCl:HClO$_4$:CH$_3$COOH (6:1:1:1), etch rate = 3.1 µm/min
HNO$_3$:HCl:H$_2$O:CH$_3$COOH (3:1:1:1), etch rate = 2.5 µm/min
All etchants show no undercutting in the \(\{110\}\)A direction and are suitable for self-limiting vee-grooves. Only the anhydrous \(\text{Br}_2\) etch shows no undercutting in the \(\{110\}\)B direction; Ref. (Vozmilova, L.N., 1985)

KOH 45% solution; used for InP native oxide removal prior to acid etch; does not attack InP

- \(\text{Br}_2\)/methanol (1 vol.%); InP (1 0 0) etch rate = 3000 Å/min
- \(\text{Br}_2\)/methanol (3 vol.%); InP (1 0 0) etch rate = 2000 Å/min
- \(\text{HBr}\); InP (1 0 0) etch rate = 4–8 µm/min, highly pitted surface
- \(\text{HBr}:\text{H}_2\text{O} (1:10)\); InP (1 0 0) etch rate = 167 Å/min
- \(\text{HBr}:\text{H}_2\text{O} (1:5)\); InP (1 0 0) etch rate = 250 Å/min
- \(\text{H}_2\text{PO}_4:\text{H}_2\text{O}_2 (1:1)\); InP (1 0 0) etch rate = 10 0 Å/min
- \(\text{H}_2\text{O}:\text{AgNO}_3:\text{CrO}_3:\text{HF} (10 \text{ml}:40 \text{mg}:5 \text{g}:8 \text{ml}) \{\text{A–B etch}\}; \text{InP} (1 0 0) \text{etch rate} = 600 Å/min at 20°C
- \(\text{Citric acid}:\text{H}_2\text{O}_2 (3:1)\); InP (1 0 0) etch rate = 10 Å/min
- \(\text{Tartaric acid (40 w/o solution)}:\text{H}_2\text{O}_2 (1:1)\); InP (1 0 0) etch rate = 6 Å/min
- \(\text{Tartaric acid (40 w/o solution):H}_2\text{O}_2 (3:1)\); InP (1 0 0) etch rate = 120 Å/min
- \(\text{Iodic acid (5 w/o solution)}\); InP (1 0 0) etch rate = 67 Å/min; smooth, uniform surfaces; thinning etch
- \(\text{Iodic acid (10 w/o solution)}\); InP (1 0 0) etch rate = 350 Å/min; does not attack photoresists; leaves a black residue on InAs and InGaAs
- \(\text{Iodic acid (20 w/o solution)}\); InP (1 0 0) etch rate = 750 Å/min
- \(\text{Lactic acid}:\text{HNO}_3 (10:1)\); InP (1 0 0) etch rate < 8 Å/min
- \(\text{Oxalic acid}:\text{H}_2\text{O}_2\); InP (1 0 0) etch rate < 8 Å/min; Ref. (Clawson, A.R., 1978)

- \(\text{Tartaric acid}:\text{H}_2\text{O}_2:\text{H}_2\text{O} (1:1:10)\); InGaAs etch rate = 1000 Å/min
- \(\text{Tartaric acid}:\text{H}_2\text{O}_2:\text{H}_2\text{O} (1:1:20)\); InGaAs etch rate = 700 Å/min
- \(\text{HF}:\text{H}_2\text{O}_2:\text{H}_2\text{O} (1:1:10)\); InGaAs etch rate = 6300 Å/min
- \(\text{HF}:\text{H}_2\text{O}_2:\text{H}_2\text{O} (1:1:20)\); InGaAs etch rate = 2750 Å/min
- \(\text{H}_2\text{SO}_4:\text{H}_2\text{O}_2:\text{H}_2\text{O} (1:1:10)\); InGaAs etch rate = 9500 Å/min
- \(\text{H}_2\text{SO}_4:\text{H}_2\text{O}_2:\text{H}_2\text{O} (1:1:20)\); InGaAs etch rate = 4500 Å/min
- \(\text{H}_2\text{SO}_4:\text{H}_2\text{O}_2:\text{H}_2\text{O} (1:1:60)\); InGaAs etch rate = 700 Å/min
- \(\text{Citric acid}:\text{H}_2\text{O}_2 (25:1)\); InGaAs etch rate = 1200 Å/min
- \(\text{Citric acid}:\text{H}_2\text{O}_2 (25:1)\); \text{p-InGaAs etch rate} = 450 Å/min
- \(\text{Citric acid}:\text{H}_2\text{O}_2:\text{H}_2\text{O} (1:1:10)\); InGaAs etch rate = 700 Å/min
- \(\text{Lactic acid}:\text{H}_2\text{O}_2:\text{HF} (50:8:2)\); InGaAs etch rate = 7200 Å/min; Ref. (Elder, D.I., 1983)

- \(\text{H}_2\text{PO}_4 (10\%)\); InP etch rate = 0.27 µm/min with no mask undercutting
- \(\text{H}_2\text{SO}_4 (10\%)\); InP etch rate ~ 8 µm/min; undercutting
- \(\text{HCl (10\%)}\); InP etch rate = ~ 40 µm/min; undercutting
- \(\text{HF}:\text{NH}_4\text{F} (45:500) \{\text{buffered HF}\}; \text{InP etch rate} + 0.04 \mu\text{m/min with no mask undercutting}; \text{Ref. (Schmitt, F., 1983)}

- \(\text{Br}_2/:\text{methanol} 1 \text{vol.\%}; \text{InGaAs (1 0 0), MBE-grown, etch rate} = 6 \mu\text{m/min, InAlAs (1 0 0) etch rate} = 8 \mu\text{m/min}
- \(\text{H}_2\text{SO}_4:\text{H}_2\text{O}_2:\text{H}_2\text{O} (3:1:1)\); InGaAs etch rate = 2.5 µm/min; InAlAs etch rate = 3 µm/min
- \(\text{H}_2\text{SO}_4:\text{H}_2\text{O}_2:\text{H}_2\text{O} (5:1:1)\); InGaAs etch rate = 1.9 µm/min; InAlAs etch rate = 2.5 µm/min
- \(\text{H}_2\text{SO}_4:\text{H}_2\text{O}_2:\text{H}_2\text{O} (8:1:1)\); InGaAs etch rate = 1.2 µm/min; \{selective from InP\}
H$_3$PO$_4$:H$_2$O$_2$ (2:1); InGaAs etch rate = 3.3 μm/min; InAlAs etch rate = 3 μm/min
H$_3$PO$_4$:H$_2$O$_2$ (5:1); InGaAs etch rate = 2.4 μm/min; InAlAs etch rate = 1.5 μm/min
H$_3$PO$_4$:H$_2$O$_2$ (10:1); InGaAs etch rate = 0.7 μm/min; InAlAs etch rate = 0.5 μm/min
H$_3$PO$_4$:H$_2$O$_2$:H$_2$O (8:1); InGaAs etch rate = 1.6 μm/min; InAlAs etch rate = 1.5 μm/min
H$_3$PO$_4$:H$_2$O$_2$:H$_2$O (8:1:40); InGaAs etch rate = 0.4 μm/min; InAlAs etch rate = 0.6 μm/min
H$_3$PO$_4$:H$_2$O$_2$:H$_2$O (8:1:60); InGaAs etch rate = 0.2 μm/min; InAlAs etch rate = 0.16 μm/min

Gives InGaAs (1 0 0) etch rate dependence on orientation; shows etch profiles: for InGaAs only

Br$_2$/methanol (1%); Application: InGaAs mesa photodiode etch, shows high dark current compared to peroxide etch

H$_2$SO$_4$:H$_2$O$_2$:H$_2$O (1:1:x) \{10 < x < 500\}; InGaAs mesa photodiode etch; low dark current; InGaAs surface behavior depends on solution pH
H$_2$SO$_4$:H$_2$O$_2$:H$_2$O (1:1:50); InGaAs etch rate = 2200 Å/min; Ref. (Stocker, H.J., 1983)

Br$_2$/methanol (1 vol.%); InP, etch rate = 3000 Å/min; (0.5 vol.%) etch rate = 2000 Å/min

<table>
<thead>
<tr>
<th>Etch rates (mg/cm$^2$/s)</th>
<th>(1 1 1)B</th>
<th>(1 0 0)</th>
</tr>
</thead>
<tbody>
<tr>
<td>HCl:HNO$_3$</td>
<td>0.27</td>
<td>0.08</td>
</tr>
<tr>
<td>HCl conc.</td>
<td>0.15</td>
<td>0.08</td>
</tr>
<tr>
<td>0.4N Fe$^{3+}$</td>
<td>0.03</td>
<td>0.03</td>
</tr>
<tr>
<td>Br$_2$/methanol (1%)</td>
<td>0.016</td>
<td>0.03</td>
</tr>
</tbody>
</table>

Ref. (Tuck, B., 1973)

H$_3$PO$_4$:HCl (4:1); Application: InP groove etch; gives etch rate dependence on composition; selective from InGaAsP; gives SiO$_2$ masked profiles
Br$_2$/methanol (0.5%); InP etch rate = 2 μm/min; gives SiO$_2$ masked profiles
HCl conc.; InP etch rate $\approx$ 12 μm/min at 25°C; gives SiO$_2$ masked profiles; Ref. (Turley, S.E.H., 1982)

HCl:H$_3$PO$_4$ (5:95); InP (1 0 0) etch rate = 0.09 μm/min at 23°C
HCl:H$_3$PO$_4$ (10:90); InP (1 0 0) etch rate = 0.24 μm/min
HCl:H$_3$PO$_4$ (15:85); InP (1 0 0) etch rate = 0.40 μm/min
HCl:H$_3$PO$_4$ (20:80); InP (1 0 0) etch rate = 0.70 μm/min
HCl:H$_3$PO$_4$ (25:75); InP (1 0 0) etch rate = 1.05 μm/min
HCl:H$_3$PO$_4$ (20:80); InP (1 1 0) etch rate = 3.4 μm/min
HCl:H$_3$PO$_4$ (20:80); InP (1 1 1) etch rate = 2.6 μm/min; Ref. (Uekusa, S., 1985)

Etch mask, transparent low melting point wax (Gatan Inc., USA); Ref. (Kallstenius, T., 1999a)

Apiezon W black wax etch mask; Ref. (Sasaki, Y., 1999)
GaAs

<table>
<thead>
<tr>
<th>1 M K₂Cr₂O₇:H₂SO₄:HCl</th>
<th>GaAs (100) rate (µm/min)</th>
<th>InP (100) rate (µm/min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(3:1:0) (60°C)</td>
<td>0.03</td>
<td>None</td>
</tr>
<tr>
<td>(3:1:1) (60°C)</td>
<td>12</td>
<td>0.25</td>
</tr>
<tr>
<td>(3:1:2) (25°C)</td>
<td>2.5</td>
<td>0.5</td>
</tr>
<tr>
<td>(3:1:2) (60°C)</td>
<td>20</td>
<td>1.5</td>
</tr>
<tr>
<td>(3:1:3) (60°C)</td>
<td>30</td>
<td>2.3</td>
</tr>
</tbody>
</table>

Gives GaAs and InP groove etch profiles for H₂SO₄:H₂O₂:H₂O (1:1:1) and all the above concentrations of 1 M K₂Cr₂O₇:H₂SO₄:HCl; Ref. (Adachi, S., 1981e)

HCl:CH₃COOH:H₂O₂ (1:1:1); masked pattern etch profiles on (001) GaAs

HCl:H₂PO₄:H₂O₂ (1:1:1)
HCl:CH₃COOH:(1N K₂Cr₂O₇) (1:1:1)
HCl:H₂PO₄:(1N K₂Cr₂O₇) (1:1:1)
HNO₃:H₂O₂ (1:1)
HNO₃:CH₃COOH: (1:1)
HNO₃:H₂PO₄ (1:1)
HNO₃:CH₃COOH:H₂O₂ (1:1:1)
HNO₃:H₂PO₄:H₂O₂ (1:1:1)
HBr:HNO₃ (1:1)
HBr:HNO₃:H₂O (1:1:1)
HBr:CH₃COOH:(1N K₂Cr₂O₇) (1:1:1)
HBr:H₂PO₄:(1N K₂Cr₂O₇) (1:1:1)
H₂PO₄:H₂O₂:H₂O (1:1:1)
H₂PO₄:CH₃COOH:H₂O₂ (1:1:1)
H₂PO₄:CH₃OH:H₂O₂ (1:1:1)
H₂PO₄:C₂H₅OH:H₂O₂ (1:1:1)
H₂SO₄:H₂O₂:H₂O (1:1:1)
H₂SO₄:CH₃COOH:H₂O (1:1:1)
H₂SO₄:H₂PO₄:H₂O (1:1:1)
H₂SO₄:HCl:(1N K₂Cr₂O₇) (1:1:1)
HF:HNO₃:H₂O (1:1:1)
HF:HNO₃:H₂O₂ (1:1:1)
HF:HNO₃:CH₃COOH (1:1:1)
HF:HNO₃:H₂PO₄ (1:1:1)
HF:H₂SO₄:H₂O₂ (1:1:1)
Br₂:CH₃OH (4%)
Br₂:CH₃OH (1%)
[Br₂:CH₃OH (1%)]:CH₃COOH (1:1)
[Br₂:CH₃OH (1%)]:H₂PO₄ (1:1)
NaOCl (aqueous solution)
NaOCl (aqueous solution):HCl (1:1)
1N NaOH:H₂O₂:H₂O (1:1:10)
1N NaOH:H₂O₂:NH₄OH (5:1:1)
NH₄OH:H₂O₂:H₂O (1:1:5)
1N KOH:H₂O₂:H₂O (1:1:10)
1N KOH:H₂O₂:NH₄OH (5:1:1)
Ref. (Adachi, S., 1983)

H₂SO₄:H₂O₂:H₂O (3:1:1); GaAs etch rate = 3.1 μm/min

H₂SO₄:H₂O₂:H₂O (18:1:1); GaAs etch rate = 2.1 μm/min
H₂SO₄:H₂O₂:H₂O (8:1:1); GaAs etch rate = 2.8 μm/min
H₂SO₄:H₂O₂:H₂O (9:9:2); GaAs etch rate = 8.7 μm/min
H₂SO₄:H₂O₂ (1:1); GaAs etch rate = 5.0 μm/min
NH₄OH:H₂O₂:H₂O (1:4:20) GaAs etch rate = 1.8 μm/min
H₂O₂:AgNO₃:CrO₃:HF (2 ml:8 mg:1 g:1 ml) {A–B etch}; GaAs etch rate = 4 μm/min at 65°C;
Ref. (Colliver, D.J., 1976)

H₂SO₄:H₂O₂:H₂O (3:1:1); Application: AlGaAs mesa etch at 50°C; Ref. (Zhu, Y., 1991)

H₂SO₄:H₂O₂:H₂O (1:8:1); Application: GaAs etch; Ref. (Hurwitz, C.E., 1975)

H₂SO₄:H₂O₂:H₂O (1:8:40); Application: GaAs (1 0 0) photolithography [0 1 1] channel etch; Ref. (Kapon, E., 1987)

CH₃OH:H₃PO₄:H₂O₂ (3:1:1); Application: GaAs mesa etch

H₂O₂:NaOH (1:5); GaAs etch gives rough surface texture
H₂SO₄:H₂O₂:H₂O (10:15:15); destroys the Au mask layer
Br₂/methanol; destroys the Au mask layer; Ref. (Merz, J.L., 1976)

GaAs (1 0 0); study of etch rate dependence on temperature; etch rates and surface morphologies at
0°C are given as a ternary diagram:

H₂SO₄:H₂O₂:H₂O (1:4:0); GaAs (1 0 0) etch rate = 10 μm/min at 20°C
H₂SO₄:H₂O₂:H₂O (1:1:1); GaAs (1 0 0) etch rate = 8.8 μm/min at 20°C
H₂SO₄:H₂O₂:H₂O (5:1:1); GaAs (1 0 0) etch rate = 1.4 μm/min at 20°C
H₂SO₄:H₂O₂:H₂O (5:1:20); GaAs (1 0 0) etch rate = 0.60 μm/min at 20°C
H₂SO₄:H₂O₂:H₂O (40:1:1); GaAs (1 0 0) etch rate = 0.37 μm/min at 20°C; Ref. (Iida, S., 1971)

HCl:H₂O₂:H₂O (40:4:1); tip formation on GaAs by etching through square mask patterns

HCl (37%):CH₃COOH (99.8%):H₂O (31:62:7); mesa etchant for AlGaInP/GaAs LED structures; 2.2
μm/min; gives etch rate dependence on etchant composition; Ref. (Schineller, B., 1998)H₂SO₄:-
H₂O₂:H₂O (10:2.8:10); GaAs (1 0 0) photolithography ridge and groove etch showing profiles; Ref. (Arent, D.J., 1989)
H$_2$SO$_4$:H$_2$O$_2$:H$_2$O (1:8:11) and (1:8:40); GaAs (1 0 0) photolithography substrate patterning etch profiles; Ref. (Demeester, P., 1988)

H$_2$SO$_4$:H$_2$O$_2$:H$_2$O (1:8:40); Application: GaAs (1 0 0) photolithography channel etch at 24°C; [0 1 1] and [0 1 1] cross-sectional profiles; Ref. (Tsang, W.T., 1977)

Orientation dependence of etch rate and etch profiles are given for:

H$_2$SO$_4$:H$_2$O$_2$:H$_2$O (1:8:1); GaAs (1 0 0) etch rate = 8.8 μm/min at 20°C

H$_2$SO$_4$:H$_2$O$_2$:H$_2$O (8:1:1); GaAs (1 0 0) etch rate = 1.3 μm/min at 20°C; Ref. (Iida, S., 1971)

H$_2$SO$_4$:H$_2$O$_2$:H$_2$O (4:1:1); Application: AlGaAs/GaAs mesa etch; Ref. (Maranowski, S.A., 1993)

H$_2$SO$_4$:H$_2$O$_2$:H$_2$O (1:8:40); Application: GaAs vee-groove etch; 90 min for 1.2 μm wide stripe with (1 1 1)A sidewalls; Ref. (Kim, T.G., 1997)

H$_2$SO$_4$:H$_2$O$_2$:H$_2$O (1:8:40); GaAs dovetail mesa etch; Ref. (Colas, E.A., 1990, 1991)

H$_2$SO$_4$:H$_2$O$_2$:H$_2$O (8:1:40); Application: mesa etch for {1 1 1}A sidewalls on GaAs [1 –1 0] stripe patterns

H$_2$SO$_4$:H$_2$O$_2$:H$_2$O (1:8:80); Application: vee-groove etch of GaAs, quasi (1 1 1)A sidewalls; with Si$_3$N$_4$ mask; Ref. (Constantin, C., 1999)

HF:H$_2$O$_2$:H$_2$O (1:9:5); Application: mesa etch for concave sidewalls of ~70° near mesa top on GaAs (1 0 0) stripe patterns; Ref. (Konkar, A., 1998)

H$_2$SO$_4$:H$_2$O$_2$:H$_2$O (4:1:1); Application: AlGaAs/GaAs mesa etch; Ref. (Sugg, A.R., 1993)

H$_2$SO$_4$:H$_2$O$_2$:H$_2$O (1:8:1); Application: anisotropic GaAs etch for forming micromachined triangular cross-section structures; depth etch rate is 7 μm/min; undercutting etch rate is 4 μm/min

H$_2$SO$_4$:H$_2$O$_2$:H$_2$O (1:8:0); Application: anisotropic GaAs etch for forming micromachined triangular cross-section structures; depth etch rate is 10 μm/min; undercutting etch rate is 6 μm/min

H$_3$PO$_4$:H$_2$O$_2$:H$_2$O (1:13.8:13.2) at 0°C; Application: anisotropic GaAs etch for forming micromachined triangular cross-section structures; depth etch rate is 1 μm/min; undercutting etch rate is 0.25 μm/min; etch becomes isotropic with increasing temperature

NH$_4$OH:H$_2$O$_2$:H$_2$O (20:7:973); Application: anisotropic GaAs etch for forming micromachined triangular cross-section structures; depth etch rate is 0.5 μm/min; undercutting etch rate is 0.15 μm/min

NH$_4$OH:H$_2$O$_2$:H$_2$O (20:7:73); Application: anisotropic GaAs etch for forming micromachined triangular cross-section structures; depth etch rate is 0.6 μm/min; undercutting etch rate is 0.6 μm/min; Ref. (Ribas, R.P., 1998)

GaAs photolithography etch profiles for:

HCl:H$_2$O$_2$:H$_2$O (160:4:1)

HCl:H$_2$O$_2$:H$_2$O (80:4:1)
1 M NaOCl:HCl (5:1)
1 M NaOCl in 0.1 M NaOH
0.1 M Na₂CO₃
0.05 M K₃Fe(CN)₆ pH = 13
0.5 M K₃Fe(CN)₆ pH = 13; Ref. (Notten, P.H.L., 1986)

Br₂/methanol (1 wt.%)
GaAs (1 1 0), etch rate = 7.5 μm/min
GaAs (1 1 1), etch rate = 8.5 μm/min
GaAs (1 1 1), etch rate = 2 μm/min
GaAs (1 1 0), etch rate = 10 μm/min

Gives etch profile orientation dependence; Ref. (Tarui, Y., 1971)

Br₂:KBr solution; GaAs groove etch profile dependence on temperature; Ref. (Kelly, J.J., 1988)

Br₂:methanol: GaAs etching anisotropy is dependent on concentration; shows \{1 1 1\} plane terminated features for Br₂ < 1%; shows \{3 3 2\} plane terminated features for Br₂ > 1%; Application of negative bias increases etch rate and eliminates etch anisotropy; Ref. (Koszi, L.A., 1975)

H₃PO₄:H₂O₂:H₂O (1:9:3); GaAs (1 0 0) groove etch, reverse-mesa shaped groove along \{0 1 1\}
H₂SO₄:H₂O₂:H₂O (3:1:1); GaAs (1 0 0) vee-groove \{1 1 1\}A surface along \{0 1 1\}; Ref. (Westphalen, R., 1992)
H₂PO₃:H₂O₂:H₂O (1:1:25); Application: GaAs mesa etch; Ref. (Li, F., 1993)

H₃PO₄:H₂O₂:H₂O (1:1:100); Application: GaAs slow recess etch; showing etch profiles with little anisotropy; Ref. (Demeester, P.P., 1988)

H₃PO₄:H₂O₂:H₂O (3:1:50); Application: GaAs MESFET mesas; Ref. (Hashemi, M.M., 1992)

H₃PO₄:H₂O₂:CH₃OH (28:16:84); Application: AlGaAs mesa etch; Ref. (Fricke, K., 1994)

H₃PO₄:H₂O₂:H₂O (2:1:10); anisotropic etch of GaAs substrate supporting cantalever stripes; Ref. (Arslan, D., 1999)

H₃PO₄:H₂O₂:H₂O (10:1:1); shaping of GaAs microtips for scanning tunneling microscopy; shape dependence on H₃PO₄ concentration and etch temperature; Ref. (Yamaguchi, K., 1996)

H₃PO₄:H₂O₂:H₂O (7:3:3)

H₃PO₄:H₂O₂:H₂O (3:1:6)
H₃PO₄:H₂O₂:H₂O (3:1:10)
H₃PO₄:H₂O₂:H₂O (3:1:50)
Chemical beveling of GaAs by lifting a sample through a constant flow of etchant; Ref. (Srnanek, R., 1997b)
H$_3$PO$_4$:H$_2$O$_2$:H$_2$O (3:1:50); GaAs etch rate = 0.18 μm/min at 24°C

H$_3$PO$_4$:H$_2$O$_2$:H$_2$O (1:9:210); GaAs etch rate = 0.2 μm/min at 24°C
H$_3$PO$_4$:H$_2$O$_2$:H$_2$O (7:3:3); GaAs etch rate = 2 μm/min at 24°C
H$_3$PO$_4$:H$_2$O$_2$:H$_2$O (1:9:1); GaAs etch rate = 3 μm/min at 24°C

No dependence on GaAs doping is seen; shows etch rate dependence on concentration, temperature and GaAs orientation; Ref. (Mori, Y., 1978)

H$_3$PO$_4$:H$_2$O$_2$:H$_2$O (3:4:1); GaAs; uniform, high, isotropic etch rate for etching via holes; Ref. (Yenigalla, S.P., 1982)

Br$_2$/methanol
Br$_2$/ethylene glycol
H$_3$PO$_4$:H$_2$O$_2$:H$_2$O; Application: first step stairstep groove etchant for AlAs/GaAs multilayer structures for quantum wire MOCVD growth
Citric acid:H$_2$O$_2$; Application: second step stairstep groove etchant for shaping grooves in AlAs/GaAs multilayer structures for quantum wire MOCVD growth; Ref. (Kicin, S., 1999)

NH$_4$OH:H$_2$O$_2$:H$_2$O (1:1:20); selective removal of polycrystalline GaAs from Si mask; Ref. (Peake, G.M., 1999)

NH$_4$OH:H$_2$O$_2$:H$_2$O (5:3:80); Application: GaAs/AlGaAs for 6 s; photolithography isolation of Hall bars; Ref. (Ghanbari, R.A., 1992)

KOH (11 M); selective etch of Si mask on GaAs from STM direct write oxidized Si pattern; 2 s at 60°C. Does not attack GaAs

HF 10%; second step (after KOH) to remove Si mask from GaAs
NH$_4$OH:H$_2$O$_2$:H$_2$O (1:2:1 by weight), diluted 1:100 by H$_2$O; GaAs pattern etch through Si mask; Ref. (Snow, E.S., 1993)

NH$_4$OH:H$_2$O$_2$:H$_2$O (20:7:973); GaAs (1 1 1)B etch rate = 0.12 μm/min; GaAs (1 0 0) etch rate = 0.037 μm/min; shows much less SiO$_2$ mask undercutting than with NaOH:H$_2$O$_2$ etchant; Ref. (Gannon, J.J., 1974)NH$_4$OH:H$_2$O$_2$:H$_2$O (20:7:1000); GaAs vee-grooves through a Si$_3$N$_4$ mask; Ref. (Yeats, R.E., 1977)

NaOH:H$_2$O$_2$:NH$_4$OH (5:1:1); Application: GaAs/AlGaAs laser mirror etch

H$_2$SO$_4$:H$_2$O$_2$:H$_2$O; comparison profiles; Ref. (Itoh, K., 1977)
HF:H$_2$O$_2$:H$_2$O mixtures; GaAs; etch rate and sidewall profile dependence on etchant composition; Ref. (Takebe, T., 1993)

HCl:H$_2$O$_2$:H$_2$O (40:4:1); field emitter tip formation on GaAs by etching through square mask patterns

HF:H$_2$O$_2$:H$_2$O (1:10:21.2); field emitter tip formation on GaAs by etching through square mask patterns
HF:HNO₃:H₂O (1:1:2); field emitter tip formation on GaAs by etching through square mask patterns
HF:H₂O₂:H₂O (1:20:100); field emitter tip formation on GaAs by etching through square mask patterns
NH₄OH:H₂O₂:H₂O (1:1:8); field emitter tip formation on GaAs by etching through square mask patterns
H₃PO₄:H₂O₂:H₂O (3:1:50); sharpening of dry etched field emitter tips
Reactive ion etch of GaAs field emitter tips using Ar + SiCl₄; Ref. (Ducroquet, F., 1999)

GaAs etch rate study shows proportional dependence on H₂O₂ concentration; low etch rates are surface reaction limited and show flat bottomed profiles; high etch rates are H₂O₂-diffusion limited and show enhanced etching at mask edges:

- NaOH:H₂O₂:H₂O (2:x:100), 1 < x < 10
- NH₄OH:H₂O₂:H₂O (1:1:x), 16 < x < 50
- H₂SO₄:H₂O₂:H₂O (x:1:1), 10 < x < 250
- Citric acid:H₂O₂:H₂O (50:x:50), 1 < x < 10
- H₃PO₄:H₂O₂:H₂O (1:1:x), 18 < x < 50; Ref. (Kohn, E., 1980)

AlGaAs etch inhibition by oxygen implantation; Ref. (Reynolds, C.L., 1992)

HNO₃:H₂O₂ (1:1); attacks photoresists

NH₄OH:H₂O₂:H₂O; attacks photoresists
Br₂/methanol; attacks photoresists
Citric acid:H₂O₂ (25:1); GaAs etch rate = 20 Å/s; does not attack photoresists; Ref. (Otsubo, M., 1976)

HCl:H₂O (1:1); InGaP mesa etch

- H₃PO₄:H₂O₂:H₂O (1:1:1); GaAs and AlGaAs mesa etch. ECR etch; Ref. (Pearson, S.J., 1993e)
- H₂SO₄:H₂O₂:H₂O; GaAs; discussion of reaction chemistry; Ref. (Ruberto, M.N., 1991)
- H₂SO₄:H₂O₂:H₂O (3:1:1); Application: InGaAs/GaAs mesa etch; Ref. (Susa, N., 1980b)

GaAs etching anisotropy and cross-sectional profiles for:

- H₂SO₄:H₂O₂:H₂O (1:8:1)
- H₂SO₄:H₂O₂:H₂O (1:8:40)
- H₂SO₄:H₂O₂:H₂O (1:8:80)
- H₂SO₄:H₂O₂:H₂O (1:8:160)
- H₂SO₄:H₂O₂:H₂O (1:8:1000)
- H₂SO₄:H₂O₂:H₂O (4:1:5)
- H₂SO₄:H₂O₂:H₂O (8:1:1)
- H₂SO₄:H₂O₂:H₂O (3:1:1)
- HCl:H₂O₂:H₂O (1:1:9)
- HCl:H₂O₂:H₂O (1:4:40)
HCl:H2O2:H2O (40:4:1)  
HCl:H2O2:H2O (80:4:1); Ref. (Shaw, D.W., 1981)

Saturated Br2 water:H3PO4:H2O (4:15:2); Application: InGaAs submicron photolithography for quantum well dots

Citric acid:H2O2 (1:1); GaAs/AlGaAs/InGaAs blanket etch; AlGaAs etch rate is ~1/3 that of GaAs and InGaAs; Ref. (Tan, I.-H., 1992)

H2SO4:H2O2:H2O (1:8:1); GaAs photolithography; use of undercutting of a metal layer as a fabrication step; Ref. (Wada, O., 1976)

InAs

Br2/methanol (0.5%); InAs (1 1 1)B etch rate = 1 µm/min; Ref. (Sharma, B.I., 1966)

GaSb

CH3COOH:HNO3:HF (40:18:2); GaSb mesa etch; room temperature for 40 s

Br2/methanol (2%); GaSb mesa etch; room temperature 1 min  
CH3COOH:HNO3:HF (40:18:2), followed by HCl:HNO3 (30:1) at 5°C for 10 s; GaSb mesa etch for oxygen-free, low p–n junction leakage; Ref. (Kodama, M., 1994)

Citric acid:H2O2:H2O (3:15:150); GaAs gate recess etch for FETs. Electrochemical effects induced by electrical contact materials cause etch rate non-uniformities; Ref. (Metze, G.M., 1995)

H2SO4:H2O2:H2O (3:1:1); GaAs etch rate ~1000 Å/s at 0°C; Ref. (Müller, H., 1975)

Br2/methanol (2%); GaSb; study and modeling of diffusion limited etching; Ref. (Tan, S.S., 1995)

HCl:H2O2:H2O (1:1:2); anisotropic stripe pattern etch on GaSb (1 0 0) at 5°C; Ref. (Wissmann, H., 1999)

GaP

H3PO4 (85%); GaP (1 1 1)B etch rate at 180°C = 15 µm/min; gives etch rate dependence on temperature, time, and orientation; gives cross-sectional profiles; Ref. (Uragaki, T., 1976)

Br2/methanol; p-type GaP; etch mechanism study; Ref. (Strubbe, K., 1993a,b)

HCl:CH3COOH:H2O2 (1:1:1); etch for GaP photolithographic patterning; polish on (−1,−1,−1); complex relief on (1 1 1) at room temperature. Fresh solution needed; shows time dependent etch rate; discusses etch mechanism

HCl:HNO3 (3:1) (aqua regia); GaP polish on (−1,−1,−1); pitted on (1 1 1) for T = 40°C, complex relief for T = 65°C  
HCl:HNO3:H2O (2:1:2); GaP polish on (−1,−1,−1); pitted on (1 1 1) for T = 60°C; Ref. (Berdinskikh, T., 1998)
KOH:K₃Fe(CN)₆; etch for GaP; etch rate dependence on solution concentrations and temperature; Ref. (Plauger, L.R., 1974)

Br₂/methanol (5%); GaP etch rate at 20°C = 0.8 µm/min

Br₂/methanol (1%); GaP etch rate at 20°C = 0.3 µm/min
Br₂/methanol (0.5%); GaP etch rate at 20°C = 0.2 µm/min
KOH:K₃Fe(CN)₆ (1:5); GaP etch rate at 21°C = 0.2 µm/min
KOH:K₃Fe(CN)₆ (2:1); GaP etch rate at 21°C = 0.3 µm/min
KOH:K₃Fe(CN)₆:H₂O (3:1:60); GaP etch rate at 21°C = 0.03 µm/min
HCl:HNO₃ (3:1); GaP etch rate at 30°C = 2 µm/min
HCl:HNO₃ (3:1); GaP etch rate at boiling = 6 µm/min
HCl:HNO₃:H₂O (2:1:2); GaP etch rate at 60°C = 1 µm/min
HCl:HNO₃:H₂O (1:1:2); GaP etch rate at 60°C = 0.45 µm/min
HCl:HNO₃:CH₃COOH (3:1:5); GaP etch rate at 21°C = 1.15 µm/min
HCl:HNO₃:CH₃COOH (1:1:1); GaP etch rate at 21°C = 1.2 µm/min fresh solution
HCl:HNO₃:CH₃COOH (1:1:1); GaP etch rate at 21°C = 0.25 µm/min, 30 min stabilized solution
HCl:HNO₃:CH₃COOH:HClO₄ (1:3:2:3); GaP etch rate at 21°C = 6 µm/min from fresh solution
HCl:HNO₃:CH₃COOH:HClO₄ (1:3:2:3); GaP etch rate at 21°C = 0.6 µm/min for 30 min from stabilized solution
HCl:HNO₃:CH₃COOH:HClO₄ (1:6:1:1); GaP etch rate at 21°C = 1.8 µm/min
HCl:HNO₃:H₂SO₄:H₂O (2:1:2:2); GaP etch rate at 30°C = 1.2 µm/min
HCl:HNO₃:H₂SO₄:H₂O (2:1:2:2); GaP etch rate at 50°C = 3.2 µm/min; Ref. (Kaminska, E., 1981)

Saturated Cl₂ water; GaP etch rate temperature dependence is given; iodine solution etch rates were negligible; Ref. (Milch, A., 1976)

Cl₂/methanol (Cl₂ saturated solution): H₃PO₄ (1:1); GaP non-preferential chemical polish; Ref. (Oldham, W.G., 1965)

GaN

NaOH:H₂O (1:1); GaN etch at 5–90°C; Ref. (Chu, T.L., 1971)

KOH (5 g in 200 cm³ H₂O); electrolyte for electrochemical pattern etching of GaN and AlGaN; Ref. (Yoshida, S., 1997)

KOH (0.1 M) electrolyte for photoenhanced electrochemical etching of GaN; Ref. (Stocker, D.A., 1999)

H₃PO₄ (85%); AlN dissolution; Ref. (Pauleau, Y., 1982)

H₃PO₄ (85%); AlN etch rate at 60°C is dependent on layer quality; Ref. (Sheng, T.Y., 1988)

H₃PO₄ (85%); GaN etchant at T = 100–200°C; gives etch rate and morphology dependence on temperature; Ref. (Morimoto, Y., 1974)
H$_3$PO$_4$ (14.61 M); study of etching Al$_2$O$_3$ dielectric films; etch rate dependence on temperature and concentration; Ref. (Zhou, B., 1996)

AZ400K photolithographic developer (active ingredient KOH); etch study of AlN and InAlN between 20 and 80°C; Ref. (Vartuli, C.B., 1996d)

InN wet chemical etching study; no etch in acid:H$_2$O$_2$ solutions

KOH:H$_2$O (33 wt.% solution); InN etch rate at 50°C = 220 Å/min
NaOH:H$_2$O (33 wt.% solution); InN etch rate at 50°C = 65 Å/min; Ref. (Guo, Q., 1992)

KOH (molten); transverse (i.e. sidewall) etch for GaN; no etch in the (0 0 0 1) direction

KOH (30%) in ethylene glycol; transverse (i.e. sidewall) etch for GaN; no etch in the (0 0 0 1) direction
H$_3$PO$_4$; transverse (i.e. sidewall) etch for GaN; no etch in the (0 0 0 1) direction
TEAH (tetraethylammonium hydroxide) (40%):H$_2$O; transverse (i.e. sidewall) etch for GaN; no etch in the (0 0 0 1) direction; Ref. (Stocker, D.A., 2000)

Si

HF:HNO$_3$:H$_2$O (15:10:300) {p-etch (Si)}; Application: SiO$_2$ selective etch of electron beam irradiated pattern mask on Si; irradiated area etch rate is 3 × non-irradiated area

KOH:H$_2$O (5 g:20 ml); Si anisotropic etch at 65°C, stops at {1 1 1} planes; Ref. (Hoole, A.C.F., 1992)

HF:HNO$_3$:H$_2$O; Germanium etch rate dependence on composition; Ref. (McKeown, P.J.A., 1962)

HF:HNO$_3$:H$_2$O (15:10:300) {p-etch (Si)}; Application: patterning of electron beam irradiated SiO$_2$ mask; Ref. (Pan, X., 1992)

KOH (40%) at 60°C and ethylenediamine-pyrocatechol; Application: Si selective etch from B-doped $> 1 \times 10^{20}$ cm$^{-3}$ Si layers

HF:H$_2$O (1:50); Si$_3$N$_4$ removal

NH$_4$OH:H$_2$O$_2$ Si surface cleaning; Ref. (Rittenhouse, G.E., 1992)

HF:HNO$_3$:H$_2$O; Silicon etch kinetics; dependence on concentrations; Ref. (Schwartz, B., 1976b)

Modeling

Modeling of masked pattern etching; Ref. (Kuiken, H.K., 1984)

Modeling of profiles for photolithographic etching using diffusion limited etchants; Ref. (Kuiken, H.K., 1986)

Modeling of resist pattern etching; Ref. (Vuik, C., 1985)
2.4. Wet chemical surface preparation

2.4.1. Thinning

**InP**

HCl:HNO₃:CH₃COOH:HClO₄ (1:6:1:1); InP (1 0 0) jet thinning etch; Ref. (Armiento, C.A., 1979b)

HCl:HNO₃:CH₃COOH:HClO₄ (3:2:1:3); InP thinning etch; etch rate = 7 μm/min; Ref. (Aytac, S., 1983)

Cl₂/methanol; GaAs, InP, GaP, AlGaAs jet thinning of electron microscope specimens; Ref. (Bicknell, R.W., 1973)

Iodic acid (5 w/o solution in H₂O; InP (1 0 0) etch rate = 67 Å/min; smooth, uniform surfaces; thinning etch

Iodic acid (10 w/o solution in H₂O; InP (1 0 0) etch rate = 350 Å/min; does not attack photoresists; leaves a black residue on InAs and InGaAs

Iodic acid (20 w/o solution in H₂O; InP (1 0 0) etch rate = 750 Å/min; Ref. (Clawson, A.R., 1978)

H₂SO₄:H₂O₂:H₂O (5:1:1); Application: InP(Zn) thinning etch for two-step MOVPE regrowth in InGaAs/InP pin-FET; Ref. (Ebbinghaus, G., 1991)

H₂SO₄:H₂O₂:H₂O (5:1:1); InP(Fe) thinning, etch rate = 500 Å/min at 25°C to remove damage from Si-implanted InP prior to MBE regrowth; Ref. (Praseuth, J.P., 1991)

HCl:H₂O₂:H₂O (40:4:1); III–V non-preferential thinning for TEM specimens; Ref. (Narayanan, H., 1974)

HBr:H₃PO₄:1N.K₂Cr₂O₇ (2:2:1), dilute (1:1) with H₂O; Application: InP uniform thinning etch for incremental Hall measurements; etch rate ~ 300 Å/s; Ref. (Whitney, P.S., 1988)

Br₂:HBr:H₂O; etch rate is linearly proportional to the Br₂ concentration; rate is diffusion limited; Ref. (Notten, P.H.L., 1987)

o-H₃PO₄:HNO₃:H₂O₂:H₂O; InP thinning etch; with concentration dependent etch rates from 5 to 110 nm/min; Ref. (Faur, M., 1991b)

Anodization; InGaAsP/InP anodize/strip thinning of InP; Ref. (Ito, N., 1980)

Br₂/methanol; InP thinning etch for measuring diffusion profile

Br₂/isopropanol; InP thinning etch for measuring diffusion profile

Br₂/methanol (0.5%); InP etch rate = 1.37 μm/min at −10°C

Br₂/methanol (1%); InP etch rate = 2.7 μm/min at −10°C

Br₂/methanol (1.5%); InP etch rate = 0.5 μm/min at −10°C
Br₂/isopropanol (1.5%); InP etch rate = 0.5 μm/min at −10°C
Br₂/isopropanol (2.5%); InP etch rate = 0.86 μm/min at −10°C; Ref. (Aytac, S., 1982)

**InGaAs**

H₃PO₄:H₂O₂:H₂O (3:1:50); InGaAs and InAlAs thinning etch for differential Hall measurement profiles; Ref. (Mori, Y., 1988)

H₃PO₄:H₂O₂:H₂O (3:1:50); InGaAs thinning, etch rate = 10 Å/s at 20°C; for differential Hall measurements; Ref. (Kamada, M., 1989); (Mori, Y., 1988)

H₃PO₄:H₂O₂:H₂O (1:1:38); Application: InGaAs slow thinning etch; Ref. (Silberg, E., 1982)

**InGaAsP**

Br₂/methanol; Application: InGaAsP thinning for X-ray lattice parameter profile; Ref. (Feng, M., 1980)

**GaAs**

NaOCl:H₂O (1:5); GaAs jet etch thinning; etch gives a grainy structure

HCl:H₂O₂:H₂O (40:4:1); GaAs jet etch thinning; gives smooth, uniform etch; Ref. (Biedermann, E., 1966)

HCl:CH₃COOH:H₂O₂ (1:20:x); 0 < x < 5; etch rates for GaAs, InP and InGaP

HCl:CH₃COOH:H₂O₂ (1:y:1); y > 20 gives slow etch rates and smooth surfaces
HCl:CH₃COOH:H₂O₂ (1:40:1); etch rate dependence on the age of the solution; Ref. (Flemish, J.R., 1993)

H₂SO₄:H₂O₂:H₂O (8:1:100); GaAs thinning etch; Ref. (Sin, Y.K., 1991)H₂SO₄:H₂O₂:H₂O (2:1:1); Application: rapid GaAs substrate thinning, 300 μm under continuous swirling at 60°C for <15 s; Ref. (Dimroth, F., 1997)

H₂SO₄:H₂O₂:H₂O (3:1:1); polishing etch for thinning GaAs; Ref. (Novák, J., 1996)

H₂SO₄:H₂O₂:H₂O (5:1:1); jet thinning of GaAs for TEM; Ref. (Weyher, J.L., 1998)

Anodization; H₃PO₄:H₂O, pH = 2.6–3.0, electrolyte; GaAs thinning

NH₄OH:H₂O (1:1); oxide stripping etch

HCl; alternative oxide stripping etch; Ref. (Niehaus, W.C., 1976)

Light controlled anodization; Application: GaAs anodize-strip thinning for MESFETs; Ref. (Shimano, A., 1979)
Anodic etching with a mechanically scanned jet of KOH (20%) electrolyte with the etching current controlled by IR transmitted intensity to achieve uniform thickness; Ref. (Thrush, E.J., 1978)

Two step thinning: (1) p-GaAs substrate is anodically dissolved down to an n-blocking layer. (2) H₂SO₄:H₂O₂ (3:2) photoetch removes n-blocking layer from the thin p-layer; Ref. (Thrush, E.J., 1974)

Real-time etch rate monitoring by optical interferometry of AlGaAs/GaAs and InGaAsP/InP structures

\[ \text{NH}_4\text{OH}:\text{H}_2\text{O}_2:\text{H}_2\text{O} \ (3:1:50); \text{AlGaAs/GaAs thinning etch; Ref. (Chand, N., 1993)} \]

Etch thickness monitoring by use of ECV profiling with spaced marker layers; Ref. (Somogyi, K., 1990)

Citric acid (3 g in 100 ml H₂O):ethylene glycol (1:2), with pH adjusted to 6 using ammonia; electrolyte for anodizing AlₓGa₁₋ₓAs. HCl:H₂O (1:10); anodic oxide removal from AlₓGa₁₋ₓAs (to thin AlₓGa₁₋ₓAs by repeated discrete incremental steps); Ref. (Buda, M.E., 1998)

**GaP**

Cl₂/methanol; GaP jet thinning for TEM samples; Ref. (Chase, B.D., 1972a,b)

**InP**

Br₂/methanol for (100) substrates; Ref. (Chin, B.H., 1988)

Br₂/methanol; dependence on Br concentration; Ref. (Chin, B.H., 1990)

**GaAs**

NH₄OH:H₂O₂; chemi-mechanical polishing solution; Ref. (Dyment, J.C., 1971)

Br₂/methanol; chemi-mechanical polishing solution; Ref. (Dyment, J.C., 1971); (Sullivan, M.V., 1963)

NaOCl; GaAs etch-polish to remove surface polish damage; Ref. (Fronius, H., 1987)

NaOCl:H₂O; chemi-mechanical polishing solution; Ref. (Rideout, V.L., 1972)

NaOCl:H₂O; GaAs chemomechanical polishing; Ref. (Khoukh, A., 1987)

NaOCl: HCl:H₂O (2:2:16); scanning jet polishing of GaP

NaOCl: HCl:H₂O (10:20:170); scanning jet polishing of GaAs; Ref. (Unvala, B.A., 1972)
Br$_2$/methanol; GaAs and GaP

$I_2$/methanol; InSb
$Cl_2$/methanol Ref. (Fuller, C.S., 1962)

$KMnO_4$:H$_2$SO$_4$:H$_2$O (100 mg:10 ml:40 ml); polish etch for ZnSe; etch rate $\sim 1 \mu$m/min; Ref. (Tamura, H., 1994)

AlGaAs

NaClO:(CH$_3$CO)$_2$O:KOH:H$_2$O; solution for mechano-chemical polishing of AlGaAs (1 1 1)A flat surfaces; Ref. (Sawafuji, Y., 1999)

GaN

KOH (10–1N)

$NaOH$

Free etch and mechano-chemical polishing of GaN; Ref. (Weyher, J.L., 1997)

2.4.3. Surface cleaning

InP

CH$_3$COOH:HClO$_4$:HNO$_3$:HCl (1:1:5:1); Application: n-InP substrate preparation etch for ion implantation; Ref. (Armiento, C.A., 1979a)

H$_2$SO$_4$:H$_2$O (1:5); InP surface cleaning for photoresist ash removal following O$_2$ plasma prior to InP regrowth; Ref. (Kim, J.S., 1992)

H$_2$SO$_4$:H$_2$O$_2$ (5:1); InP substrate cleaning; removal of surface contaminants and oxides prior to reactive ion etching; Ref. (van Roejen, R., 1991)

H$_2$SO$_4$:H$_2$O$_2$:H$_2$O (3:1:1); followed by Br$_2$/methanol (0.5%); InP substrate cleaning for MBE growth; Ref. (Bahl, S.R., 1991)

H$_2$SO$_4$:H$_2$O$_2$:H$_2$O (5:1:1); InP substrate cleaning prior to OMVPE growth; 3 min at 60°C; Ref. (Kamada, M., 1989)

H$_2$SO$_4$:H$_2$O$_2$:H$_2$O (5:5:1); Application: surface cleaning for ion implantation; InP and InGaAs 2 min followed by 5 min 1% Br$_2$/methanol; Ref. (Kamiya, Y., 1986)

H$_2$SO$_4$:H$_2$O$_2$:H$_2$O (5:1:1); InP substrate cleaning, first step, followed by Br$_2$/methanol second step, followed by KOH third step, followed by DI water rinse; Ref. (Narayan, S.Y., 1981)

H$_2$SO$_4$:H$_2$O$_2$:H$_2$O (1:8:1); InP 1 min substrate cleaning followed by 3 min Br$_2$/methanol (0.6%); Ref. (Sakai, K., 1981)
H₂SO₄:H₂O₂:H₂O (100:0.92:5); InP surface cleaning prior to Br₂/methanol removal of surface polish damage; (1 0 0) etch rate = 0.02 μm/min; (1 1 1)B etch rate = 0.06 μm/min; gives etch rate dependence on H₂O₂ concentration; Ref. (Nishitani, Y., 1979)

H₂SO₄:H₂O₂:H₂O (5:1:1); InP surface cleaning following 30 min Br₂/methanol (0.7%); followed by (5:1:1); Ref. (Olsen, G.H., 1981)

H₂SO₄:H₂O₂:H₂O (4:1:1); Application: InP substrate cleaning for LPE followed by surface treatment in Br₂:HBr:H₂O (1:17:300); etch rate = 0.8 μm/min for 2–4 min; Ref. (Saxena, R.R., 1980)

H₂SO₄:H₂O₂:H₂O (7:1:1); Application: InP substrate cleaning for MBE; oxidizing etch shows little or no carbon contamination (C < 1% monolayer); oxide is removed in MBE by heating above 500°C in As flux; Ref. (Davies, G.J., 1980)

H₂SO₄:H₂O₂:H₂O (7:1:1); InP surface preparation etch for flat, damage-free surface; Ref. (Katsura, S., 1993)

H₂SO₄:H₂O₂:H₂O (7:1:1); InP surface cleaning for MBE; Ref. (Katsura, S., 1993)

H₂SO₄:H₂O₂:H₂O (4:1:1); InP surface cleaning; Ref. (Hyder, S.B., 1979)

H₂SO₄:H₂O₂:H₂O (10:1:1); Application: InP substrate cleaning for LPE; needs careful H₂O rinse to remove S contamination; Ref. (Trapp, K.D.C., 1983)

H₂SO₄:H₂O₂:H₂O (3:1:1); Application: InP substrate cleaning first step for MBE, followed by:

- Br₂/methanol, followed by 5 min DI water rinse to form protective oxide; Ref. (Maruno, S., 1987)

H₂SO₄:H₂O₂:H₂O (5:1:1) {Caro’s etch}; Application: InP substrate cleaning first step, followed by Br₂/methanol (1%) second step for VPE; Ref. (Towe, E.D., 1982)

H₂SO₄:H₂O₂:H₂O (5:1:1); Application: InP surface cleaning prior to oxidation; 4 min

HNO₃; 50 Å anodic oxide growth on InP; Ref. (Eftekhari, G., 1993)

Optimum polishing treatment to obtain optical smooth and oxide free (1 0 0) and (1 1 1) InP:

1. Rinse with trichlorethylene, acetone and methanol pre-etch with (NH₄)₂S₂O₈:H₂SO₄:H₂O (15:73:15) at RT for 1 min
2. Rinse with methanol
3. Br₂/methanol polishing etch (1% at RT for 1 min)
4. Rinse with methanol for 90 min
5. Etch with HCl:methanol (1:10) at RT for 10 s
6. Rinse with methanol; Ref. (Kurth, E., 1988)

H₂SO₄ (0.25 M); oxide-free interface for STM surface imaging

HNO₃ InP oxidation; 200 Å under illumination; then
HF oxide dissolution; Ref. (Robach, Y., 1992)
H$_2$SO$_4$:H$_2$O$_2$:H$_2$O (8:1:1); InP surface cleaning; room temperature for 5 min to remove native oxide overlayer; longer times does not improve oxide removal but causes contamination and roughening; Ref. (Losurdo, M., 1996)

H$_2$SO$_4$; treatment to remove RIE etch polymer by-products

(NH$_4$)$_2$S$_x$ (6.0–7.5% sulfur concentration); room temperature for 10 min; followed by H$_2$SO$_4$ treatment to reduce surface impurities; process acronym is (ACE); surface preparation of InP mesa devices for InP MOVPE regrowth; study of regrown interface quality; Ref. (Yamamoto, N., 1998)

Br$_2$:HBr:H$_2$O (1:17:300); InP surface treatment following H$_2$SO$_4$:H$_2$O$_2$:H$_2$O (4:1:1) for 2–4 min; etch rate = 0.8 $\mu$m/min; Ref. (Hyder, S.B., 1979)Br$_2$/methanol; Application: InP substrate cleaning for LPE; Ref. (Nakajima, K., 1979); (Chen, P.C., 1981); (Pearsall, T.P., 1977); (Rezek, E.A., 1980); (Sankaran, R., 1976)

Br$_2$/methanol (5%); Application: InP substrate cleaning for VPE; Ref. (Kanbe, H., 1979)

Br$_2$:HBr:H$_2$O (1:17:35); 90 s InP wafer etch after Br$_2$/methanol chemi-mechanical polishing; Ref. (Guivarc’h, A., 1984)

Br$_2$/methanol (0.5%); InP substrate cleaning for MBE growth; Ref. (Bahl, S.R., 1991)

Br$_2$/methanol (0.5%); 2–3 s etch to remove ion damage; Ref. (Boudma, N.J., 1987)

HBr:H$_2$O$_2$:H$_2$O removal of RIE damage before MOCVD regrowth; Ref. (Ahn, J.-H., 1996)

HCl:H$_2$O (1:10); InP substrate cleaning to introduce chloride ion absorbed layer for surface protection prior to LPE growth; Ref. (Nelson, A.W., 1982)

HCl (1 M); InP surface etch and oxide removal prior to STM study in sulfuric acid solution; Ref. (Yao, H., 1998)

KOH:methanol (2.5 g:200 ml); InP surface cleaning study for Schottky contacts; Ref. (Dunn, J., 1988)

KOH:H$_2$O (100 g:500 ml), boiling; Application: InP pre-etch surface cleaning; Ref. (Aytac, S., 1982)

Iodic acid:H$_2$O (10 wt.% solution); InP surface preparation AES study for Schottky contacts; Ref. (Hökelek, E., 1982)

Surface treatment scanning photoluminescence study:

HF; InP oxide removal
H$_2$O$_2$; InP surface oxidation
NH$_4$OH; InP oxide removal
HNO$_3$; InP surface oxidation; Ref. (Krawczyk, S.K., 1986)
HF: ethanol (1:9); GaAs and InP deoxidization post etch solution; Ref. (Saletes, A., 1988); (Massies, J., 1986)

HF: methanol (1:10); Application: InP native oxide removal; 2 min ultrasonic; Ref. (Hu, Y.Z., 1993)

HF: H₂O (1:30); InP surface oxide cleaning in N₂ dry box; Ref. (Kwok, R.W.M., 1995)

HF: H₂O (1:1); InP substrate cleaning; low C and O contamination. Auger analysis comparing:
  Br₂/methanol; H₂SO₄:H₂O₂:H₂O (5:1:1); CH₃COOH:H₂O₂ (3:1); Ref. (Singh, S., 1982)

HF: H₂O₂ (1:20); InP surface cleaning for MBE regrowth gives high surface defect density

Citric acid:H₂O₂ (1:1); InP surface cleaning for MBE regrowth gives high surface defect density
  Br₂/methanol (1%); InP surface cleaning for MBE regrowth gives high surface defect density
  H₂SO₄:H₂O₂:H₂O (1:4:50); InP surface cleaning for MBE regrowth; best morphology
  UV light/ozone InP surface oxidation; surface cleaning for MBE regrowth; Ref. (Passenberg, W., 1997)

HF (5%) for 10 s followed by H₂SO₄ (80%) for 60 s to clean InP vee-grooved surface prior to MOVPE regrowth without affecting vee-groove shape; Ref. (Schrimpf, T., 1999)

Buffered HF, {NH₄F:HF (10:1)}; InP etch rate after 60 min at 20°C is negligible; Ref. (Elder, D.I., 1987)

(NH₄)₂Sₓ InP surface cleaning for MOVPE regrowth; followed by hydrogen gas anneal at 450°C

HF; InP surface cleaning for MOVPE regrowth; impurities at interface
  H₂SO₄:H₂O₂:H₂O (1:1:40); InP surface cleaning for MOVPE regrowth; impurities at interface;
  Ref. (Miyamoto, Y., 1991)

In–Ga–As metal solution; Application: LPE in situ etch of InP for surface cleaning; Ref. (Nelson, A.W., 1982)

In–As metal solution; Application: LPE melt back in situ cleaning of mesa stripe prior to regrowth of InP encapsulant layers; Ref. (Kano, H., 1979)

Indium metal solution etch; Application: for InP LPE in situ substrate cleaning; Ref. (Wrick, V., 1976); (Rezek, E.A., 1980); (Wright, P.D., 1977)

**InGaAsP**

H₂SO₄:H₂O₂:H₂O (5:1:1); InGaAs surface cleaning for OMVPE InP regrowth; Ref. (Frei, M.R., 1991); (Mori, Y., 1988)

H₂SO₄:H₂O₂:H₂O (5:1:1); Application: InGaAsP surface preparation for Schottky contact; Ref. (Yamazoe, Y., 1981)

H₂SO₄:H₂O₂:H₂O (5:5:1); Application: surface cleaning for ion implantation; InP and InGaAs 2 min followed by 5 min 1% Br₂/methanol; Ref. (Kamiya, Y., 1986)
H₂SO₄:H₂O₂:H₂O (1:8:100); InGaAs/InP mesa p–n junction surface treatment to reduce excess surface recombination; Ref. (Frei, M.R., 1991)

H₂SO₄:H₂O₂:H₂O (1:1:40); step 1 in damage removal from RIE etched InGaAsP/InP; 0°C for 70 s

HCl:H₂O (1:10); step 2 in damage removal from RIE etched InGaAsP/InP 1 min at room temperature; Ref. (Madhan Raj, M., 1999)

Buffered HF [NH₄F:HF (10:1)]; InGaAsP oxide removal; Ref. (Iga, K., 1980a)

H₂O₂:NH₄OH (10:1); InGaAs surface cleaning prior to anodization; Ref. (Shirafuji, J., 1982)

NH₄OH:H₂O₂:H₂O (4:1:2000); 30 Å surface etch following dry etch of InGaAs/AlGaAs; Ref. (Ko, K.K., 1992)

Br₂/methanol (1%); Application: InGaAsP surface cleaning for Schottky contacts; Ref. (Morgan, D.V., 1980); (Naitoh, M., 1982)

Br₂/methanol (1:2000); InGaAs surface cleaning for InP OMVPE regrowth, or alternative:

Saturated Br₂ water:HBr:H₂O (1:1:10); Ref. (Yablonovitch, E., 1992)

Br₂/methanol; InGaAs surface treatment followed by H₂O rinse and H₂O₂:NH₄OH (1:1) gives best contaminant-free interface; Ref. (Aspnes, D.E., 1982a)H₂O₂ (30%); InGaAs surface treatment leaves 8–10 Å of In₂O₃ and Ga₂O₃; Ref. (Aspnes, D.E., 1982a)

HCl:HNO₃:H₂O (1:2:3); step 1, 15 s, RIE damage removal from InGaAsP/InP grooves prior to MOVPE regrowth

HCl:CH₃COOH (1:4); step 2, 5 s, selective RIE damage removal from InP in InGaAsP/InP grooves prior to MOVPE regrowth

H₂SO₄:H₂O₂:H₂O (1:1:40); step 3, 15 s, selective RIE damage removal from InGaAsP in InGaAsP/InP grooves prior to MOVPE regrowth; Ref. (Nunoya, N., 1999)

H₂SO₄:H₂O₂:H₂O (1:1:50); Application: removal of REI residual InGaAs at bottom corner recesses

H₂SO₄:HCl (3:1); Application: mesa preparation for InP regrowth; Ref. (Ojha, S.M., 1994)

InGaP

CH₃COOH:HCl:H₂O₂ (20:1:1); GaInP surface cleaning; 10 s; prior to photoluminescence measurements; Ref. (Arent, D.J., 1996)
GaAs

H$_2$SO$_4$:H$_2$O$_2$:H$_2$O (3:1:1); Application: GaAs substrate cleaning for MBE; at 48°C for 1 min followed by heating in air at 250–300°C for 3–5 min to form a protective stable oxide as protection against contamination; Ref. (Fronius, H., 1987)

H$_2$SO$_4$:H$_2$O$_2$:H$_2$O (4:1:1); GaAs patterned substrate cleaning for MBE; Ref. (Kapon, E., 1987)

H$_2$SO$_4$:H$_2$O$_2$:H$_2$O (4:1:1); GaAs surface preclean prior to H oxide reduction; Ref. (Petit, E.J., 1994)

H$_2$SO$_4$:H$_2$O$_2$:H$_2$O (5:1:1); GaAs substrate cleaning for MBE; surface analysis; Ref. (Massies, J., 1985)

H$_2$SO$_4$:H$_2$O$_2$:H$_2$O (5:1:1); Application: GaAs surface cleaning for CVD and LPE overgrowth on carbon film masked substrate; Ref. (Olsen, G.H., 1976)

H$_2$SO$_4$:H$_2$O$_2$:H$_2$O (5:1:1); GaAs substrate cleaning for 20 s at 20°C; Ref. (El Jani, B., 1982a)

H$_2$SO$_4$:H$_2$O$_2$:H$_2$O (7:1:1); Application: GaAs substrate cleaning for MBE, 1 min; Ref. (Akatsu, Y., 1987)

H$_2$SO$_4$:H$_2$O$_2$:H$_2$O; GaAs surface cleaning for electrical contacts inferior to low energy Ar ion beam cleaning

Ar ion beam etch; GaAs surface cleaning for low resistance contacts; Ref. (Starkeev, G., 1993)

H$_2$SO$_4$:H$_2$O$_2$:H$_2$O (7:1:1); GaAs surface cleaning for MBE growth of GaSb layers; Ref. (Tadayon, B., 1995)

H$_2$SO$_4$:H$_2$O$_2$:H$_2$O (5:5:1); Application: GaAs 5 min surface cleaning for ion implantation. InP and InGaAs 2 min surface cleaning followed by 5 min 1% Br$_2$/methanol; Ref. (Kamiya, Y., 1986)

H$_2$SO$_4$:H$_2$O$_2$:H$_2$O (10:1:1); GaAs substrate cleaning for MOCVD; Ref. (Biefeld, R.M., 1986)

H$_2$SO$_4$:H$_2$O$_2$:H$_2$O (3:1:1); study of sulfur contamination of GaAs from etchant. HCl:H$_2$O; removal of sulfur contamination from GaAs following etch in H$_2$SO$_4$:H$_2$O$_2$:H$_2$O; Ref. (Butcher, K.S.A., 1996)

H$_2$SO$_4$:H$_2$O (1:8); GaAs deoxidation for 1 min; Ref. (Hue, X., 1998)

H$_2$SO$_4$:H$_2$O (1:80); GaAs surface cleaning for MOCVD regrowth; Ref. (Jones, A.M., 1998)

H$_2$SO$_4$:H$_2$O$_2$:H$_2$O (5:1:1); GaAs native oxide removal, 2 min; Ref. (Kaneshiro, C., 1997)

H$_2$SO$_4$:H$_2$O$_2$:H$_2$O (1:8:500); GaAs etched surface contains elemental As; Ref. (Shun, J., 1991)

HCl:H$_2$O (1:3); oxide removal; from AlGaAs/GaAs; Ref. (Green, D.L., 1993b)
HCl (36%); GaAs 10–20 min etch shows monolayer flat surface; 10 s H₂O rinse dissolves oxides leaving an As-rich surface; Ref. (Song, Z., 1995)

HCl:H₂O (1:10); GaAs native oxide removal at 25°C; Ref. (Watanabe, H., 1993a,b)

HCl:H₂O (1:1); GaAs deoxidation, 1 min; Ref. (Sik, H., 1996)

HCl:HF:H₂O:H₂O₂ (10 ml:10 ml:40 ml:5 drops); Application: GaAs surface cleaning for deposition of metal Schottky contacts; Ref. (Christou, A., 1976)

HNO₃:HCl:H₂O; Application: GaP (1 0 0) substrate cleaning for OMVPE followed by:

(NH₄)₂Sₓ solution surface treatment to remove oxide; Ref. (Wang, X.-L., 1993)

NH₄OH:H₂O₂:H₂O (1:1:20); Application: GaAs; for removal of surface damage after annealing, prior to Schottky contact; Ref. (Hirota, Y., 1993)

NH₄OH:H₂O₂:H₂O (2:1:10); GaAs substrate cleaning for OMVPE; Ref. (Olson, J.M., 1989)

NH₄OH:H₂O₂:H₂O (10:1:10); Application: GaAs (1 0 0) substrate cleaning for MBE; Ref. (Arent, D.J., 1989)

NH₄OH:H₂O₂:H₂O (3:1:120); Application: GaAs surface cleaning, 1 min followed by H₂O rinse followed by HCl:H₂O (1:1); 2 min oxide removal; Ref. (Auret, F.D., 1992)

NH₄OH:H₂O (1:10–50); Application: GaAs patterned substrate cleaning prior to OMVPE regrowth; attacks primarily surface oxides

H₃PO₄:H₂O₂:H₂O; alternative etch attacks both GaAs and oxides; Ref. (York, P.K., 1992)

NH₄OH:H₂O (1:15); Application: GaAs native oxide removal, 15 s; Ref. (Jeong, Y.-H., 1994)

NH₄OH:H₂O (1:18); GaAs surface oxide removal prior to MBE overgrowth; Ref. (Reed, J.D., 1995)

NH₄OH:H₂O₂:H₂O (1:1:20); GaAs surface treatment to remove damage, 2 min at room temperature; Ref. (Hirota, Y., 1995)

NH₄OH:H₂O (3%); native oxide removal from GaAs to demonstrate that plasma etch rates do not depend on initial presence of oxides; Ref. (Bailey III, A.D., 1995a)

NH₄OH:H₂O (1:10); GaAs surface oxide removal prior to other etching; Ref. (Carter-Coman, C., 1997)

NH₄OH:H₂O (1:20); Application: GaAs surface cleaning for Ohmic contact deposition; 30 s then spin dried for native oxide removal; Ref. (Ren, F., 1994)

NH₄OH:H₂O₂:H₂O (2:1:12); Application: GaAs substrate cleaning for OMVPE growth, 1 min; Ref. (Lee, S.H., 1997)
NH₄OH:H₂O (1:1) deoxidation of GaAs, GaSb and InAs surfaces, 10 min, N₂ dried; Ref. (Lin, J.-L., 1995)

H₂SO₄:H₂O₂:H₂O (3:1:1); GaAs planar surface etch prior to study of HCl treatment

HCl (36%); GaAs treatment to remove surface oxide; study of dependence on HCl temperature and H₂O rinse; Ref. (Matsushita, K., 1998)

NH₄OH:H₂O (1:20); oxide removal from GaAs for bonding to Si; Ref. (Peake, G.M., 1999)

NH₄OH:H₂O (1:5); initial oxide removal from GaAs prior to etching; Ref. (Schneider, M., 1987)

Monoethanolamine solution with NH₄OH:H₂O (1:5); treatment of GaAs prior to Ohmic contact metallization

H₂SO₄ (10%); oxide removal from GaAs
Atomic hydrogen; in situ cleaning of GaAs prior to Ohmic contact metallization; Ref. (Kagadei, V.A., 1999)

KCN (20%) solution; Application: GaAs, Si, Ge; cleaning of metallic ions from surface prior diffusion; Ref. (Hall, R.N., 1964)

Review of GaAs etching and surface preparation; discusses etching mechanisms, diffusion and reaction rate limiting etching, anodic etching, and surface preparation

Gives GaAs etching summaries for:
- Citric acid:H₂O₂
- H₃PO₄:H₂O₂:H₂O
- HN₄OH:H₂O₂:H₂O
- H₂SO₄:H₂O₂:H₂O
- H₂O:AgNO₃:CrO₃:HF {A–B etch}
- HCl:H₂O₂:H₂O; Ref. (Mukherjee, S.D., 1985)

GaAs (1 0 0) surface cleaning XPS study:

NH₄OH:H₂O₂:H₂O (10:5:1 0 00)
HCl conc.; GaAs (1 0 0) (leaves a nearly stoichiometric surface)
HF (50%); GaAs (1 0 0)
H₂SO₄:H₂O₂:H₂O (5:1:1); Ref. (Olivier, J., 1990)

GaAs surface cleaning study by Auger analysis and Au layer epitaxy behavior:

H₂SO₄:H₂O₂:H₂O (3:1:1)
NH₄OH:H₂O₂:H₂O (1:1:2)
HF:HNO₃:H₂O (2:2:1); Ref. (Vermaak, J.S., 1977)

H₂O₂ (30%); oxidation of GaAs followed by

HCl:H₂O (1:1); oxide removal agent from GaAs
Citric acid (1 M); oxide removal agent from GaAs
\[
\begin{align*}
\text{H}_2\text{PO}_4: \text{H}_2\text{O} & \ (1:4); \ \text{oxide removal agent from GaAs} \\
\text{H}_2\text{SO}_4: \text{H}_2\text{O} & \ (1:10); \ \text{oxide removal agent from GaAs} \\
\text{HF}:\text{NH}_4\text{F} & \ (1:7); \ \text{oxide removal agent from GaAs}; \ \text{Ref. (DeSalvo, G.C., 1996)} \\
\text{H}_2\text{O}; \ \text{GaAs (0 0 1) surfaces treated with ultrasonic running deionized water} & \ \text{show complete removal of arsenic and gallium oxides following etch in H}_2\text{SO}_4 \ or \ \text{NH}_4\text{OH}; \ \text{Ref. (Hirota, Y., 1992)} \\
\text{H}_2\text{O}; \ \text{dissolution of oxides from GaAs}; \ \text{Ref. (Hirota, Y., 1991)} \\
\text{H}_2\text{O}; \ \text{photochemical reaction on GaAs to unpin the Fermi level}; \ \text{Ref. (Ives, N.A., 1987)} \\
\text{AlGaAs} \\
\text{NH}_4\text{OH}:\text{H}_2\text{O}_2: \text{H}_2\text{O} & \ (1:1:400); \ \text{AlGaAs surface cleaning 15 s etch prior to loading for AlGaAs regrowth}; \ \text{Ref. (Guel, G., 1992)} \\
\text{H}_3\text{PO}_4; \ \text{AlGaAs native oxide removal at 60°C}; \ \text{Ref. (Watanabe, H., 1993a)} \\
\text{Thermochemical vapor etch}; \ \text{HCl/H}_2/\text{AsH}_3; \ \text{Application: GaAs and AlGaAs in situ etch in OMVPE reactor at 550°C}; \ \text{Ref. (Guel, G., 1992)} \\
\text{Thermochemical etch of AlGaAs/GaAs in HCl with H}_2 \ \text{at 710°C}; \ \text{Application: for OMVPE regrowth}; \ \text{Ref. (Shimoyama, K., 1991)} \\
\text{HCl}:\text{H}_2\text{O} & \ (1:10); \ \text{anodic oxide removal from Al}_x\text{Ga}_{1-x}\text{As (to thin Al}_x\text{Ga}_{1-x}\text{As by repeated discrete incremental steps)} \ \text{Ref. (Buda, M.E., 1998)} \\
\text{NH}_4\text{OH}:\text{H}_2\text{O} \ \text{with DI water rinse}; \ \text{removal of dry etch residues from AlGaAs/InGaAs}; \ \text{Ref. (Pearton, S.J., 1993c)} \\
\text{InSb} \\
\text{InSb cleaning for Auger surface studies:} \\
\text{Lactic acid}:\text{HNO}_3 & \ (10:1) \\
\text{HF}:\text{H}_2\text{O}_2: \text{H}_2\text{O} & \ (1:1:4) \\
\text{HF}:\text{HNO}_3:\text{CH}_3\text{COOH}:\text{Br} & \ (15:25:15:0.3) \\
\text{HF}:\text{HNO}_3:\text{CH}_3\text{COOH} & \ (1:2:5) \\
\text{Br}_2/\text{methanol} (1%) \\
\text{KOH}:\text{tartaric acid}:\text{ethylenediamine tetra-acetic acid}:\text{H}_2\text{O} & \ (70 g:4 g:8 g:78 g), \ \text{mixed with H}_2\text{O}_2 \ (5:2) \\
\text{CH}_3\text{COOH}:\text{HNO}_3:\text{HF} & \ (15:30:15) \ \{\text{CP-4 etch}\}; \ \text{Ref. (Auret, F.D., 1982)} \\
\text{Lactic acid}:\text{HNO}_3:\text{HF} & \ (50:8:2); \ \text{InSb surface cleaning for LPE}; \ \text{no carbon contamination}; \ \text{Ref. (Holmes, D.E., 1980)} \\
\text{Lactic acid}:\text{HNO}_3 & \ (10:1); \ \text{InSb substrate cleaning for MOCVD}; \ \text{Ref. (Biefeld, R.M., 1986)}
\end{align*}
\]
NH₄OH:H₂O₂ (1:1); Application: InAs and InSb substrate cleaning; used boiling to remove organic residues; Ref. (Holmes, D.E., 1980)

**GaP**

HNO₃:HCl:H₂SO₄:H₂O (1:2:2:2); GaP [1 1 1]B, 5 min to remove mechanical polish damage. Etch rate is dependent on carrier concentration; Ref. (Hajkova, E., 1972)

HCl:HNO₃:H₂O (2:1:2); GaP substrate etch to remove polish damage; Ref. (Uragaki, T., 1976)

**GaSb**

HCl:H₂O (1:1); p-GaSb surface cleaning first step, 30 s, followed by:

Buffered HF:H₂O (1:1); p-GaSb surface cleaning, 30 s, for low resistance Au contacts; Ref. (Tadayon, B., 1995)

**InAs**

HF:H₂O (1:1); InAs substrate cleaning for MOCVD; Ref. (Biefeld, R.M., 1986)

HNO₃:H₂O₂ (1:5); InAs cleaning; 1–2 min at 75°C; Ref. (Sharma, B.I., 1966)

**InAl(Ga)As**

HF conc.; InAlAs pre-etch to remove surface oxides; Ref. (Meneghini, G., 1989)

NH₄OH:H₂O (1:10); oxide removal from InAlAs; 20 s; prior to deposition of silicon nitride passivation layer; Ref. (Decorby, R.G., 1997)

C₆H₈O₇ (citric acid):H₂O₂:H₂O; 5 s wet etch following reactive ion etch of InP/InGaAlAs/InGaAs heterostructure detectors; removes about 150 Å InGaAs, 70 Å InAlGaAs and <20 Å InP; Ref. (Lemm, Ch., 1997)HF; InGaAlAs/InP surface cleaning for MOCVD regrowth

...HF:2-propanol; InGaAlAs/InP surface cleaning for MOCVD regrowth; Ref. (Kollakowski, St., 1998)

**GaN**

Surface treatment of GaN, AlN, and AlGaN to remove air-exposure overlayers; studied by spectroscopic ellipsometry; Ref. (Edwards, N.V., 1996)

HCl:HNO₃ (3:1); 10 min in boiling aqua regia to remove surface oxide from p-type GaN prior to (NH₄)₂Sₓ surface treatment for Pd low resistivity Ohmic contact

(NH₄)₂Sₓ; 10 min treatment of p-type GaN surface for Pd low resistivity Ohmic contact; Ref. (Kim, J.K., 1999)
HCl:H₂O (1:1); GaN surface cleaning; good removal of O and C

HCl:methanol (1:1); GaN surface cleaning; good removal of O and C

HF:H₂O (1:20); GaN surface cleaning; good removal of O and C

HF:H₂O (1:1); GaN surface cleaning; good removal of O and C

HF:methanol (1:1); GaN surface cleaning; best removal of O and C; Ref. (Smith, L.L., 1996)

Wet chemical cleaning; study for AlN and GaN

HF (buffered, 7 NH₄F:1 HF): H₂O (10:1); surface oxide removal from AlN and GaN

HCl:H₂O (1:1); surface oxide removal from AlN and GaN; Ref. (King, S.W., 1998)

ZnSe

Citric acid (100 g in 100 ml H₂O):H₂O₂ (30%) (3:1); surface cleaning of ZnSe (1 0 0) substrates; etch rate 400 Å/min

CS₂; rinse of ZnSe surface to remove residual Se; Ref. (Kobayashi, M., 1999)

Si

HF:H₂O (1:3); Application: Si-removal of thermal oxide as a step in Si substrate cleaning for GaAs MBE growth, followed by NH₄OH:H₂O (1:10) for 30 s, followed by HCl:H₂O (1:10) for 30 s, followed by HF dip, followed by DI water rinse and N₂ blow dry; Ref. (Christou, A., 1987)

HF:HNO₃:CH₃COOH (8:2:1); Application: Si substrate cleaning for GaAs MBE growth; Ref. (Koch, S.M., 1987)

HF:H₂O (1:5); Silicon substrate contaminant removal step, 2 min

HCl:H₂O₂:H₂O (3:3:5); Silicon substrate oxidation step, 2 min followed by HF:H₂O step for three times prior to loading for CBE growth of GaAs; Ref. (Xing, Y.R., 1993)

HF:HNO₃:CH₃COOH (8:2:1); Application: Si substrate cleaning for GaAs MBE growth; Ref. (Koch, T.L., 1987)

Sapphire

H₃PO₄:H₂SO₄ (1:3); hot solution to clean sapphire substrates for MOVPE growth of GaN; Ref. (Akasaki, I., 1989)

H₃PO₄:H₂SO₄ (1:3); Surface cleaning (hot) of Al₂O₃ (0 0 0 1) substrates for GaN growth by MOVPE; Ref. (Asaki, I., 1989)

H₂SO₄:H₃PO₄ (3:1); sapphire substrate cleaning: 140°C for 10 min; Ref. (Kim, J.-H., 1999)

H₂SO₄:H₃PO₄ (3:1); surface preparation of Al₂O₃ (0 0 0 1) substrates at 160°C for GaN growth by MBE; Ref. (Xiao, H.Z., 1994)
2.4.4. Surface characterization studies

InP

KOH:methanol (2.5 g:200 ml); InP surface cleaning study for Schottky contacts; Ref. (Dunn, J., 1988)

Iodic acid:H_2O (10 wt.% solution); InP surface preparation AES study for Schottky contacts; Ref. (Hökelek, E., 1982)

Surface treatment scanning photoluminescence study:

HF; InP oxide removal
H_2O_2; InP surface oxidation
NH_4OH; InP oxide removal
HNO_3; InP surface oxidation; Ref. (Krawczyk, S.K., 1986)

H_2SO_4:H_2O

H_2SO_4:H_2O_2:H_2O; identification of composition and crystalline phases of surface oxides on etched InP using X-ray diffraction; H_2O_2 plays no significant role in etch of InP; Ref. (Liu, H.C., 1999)

H_2SO_4:H_2O_2:H_2O (2:1:1); InP etch rate = 500 Å/min at 20°C; surface study

HF–ethanol (10%): InP surface cleaning; surface deoxidation etch; Ref. (Massies, J., 1986)

HF:H_2O (1:1); InP substrate cleaning; low C and O contamination. Auger analysis comparing:

Br_2/methanol
H_2SO_4:H_2O_2:H_2O (5:1:1)
CH_3COOH:H_2O_2 (3:1); Ref. (Singh, S., 1982)

H_2SO_4:H_2O_2 (5:1); InP substrate cleaning; removal of surface contaminants and oxides prior to RIE

Reactive ion etching; Cl_2; InP; Ref. (van Roejen, R., 1991)

Iodic acid:H_2O (10 wt.% solution); InP surface preparation AES study for Schottky contacts; Ref. (Hökelek, E., 1982)

Ellipsometry measurements to assess cleanest and smoothest etched surfaces:

NH_4OH:H_2O (1:1); III–V pre-etch surface oxide removal
Br_2:methanol (0.05%), followed by H_2O rinse gives most abrupt surface
HF (buffered)
HF (5% in methanol); Ref. (Aspnes, D.E., 1981)

GaAs and InP XPS surface study giving binding energies and Ga/As and In/P surface compositions after etching in:
HCl conc.
Br<sub>2</sub>/methanol
H<sub>2</sub>SO<sub>4</sub>; Ref. (Bertrand, P.A., 1981)

XPS study of InP surface oxides following chemical treatment:

NaOH:H<sub>2</sub>O<sub>2</sub> (1 M:0.8 M)
Br<sub>2</sub>:HBr:H<sub>2</sub>O (1:17:35)
HNO<sub>3</sub>; Ref. (Hollinger, G., 1985)

XPS surface study of InP with different etch treatments:

(a) Residual oxide
(b) Residual Br dependence on methanol rinse time following Br<sub>2</sub>/methanol etch
(c) Time dependence of oxide growth on surfaces for different etch treatments
H<sub>2</sub>SO<sub>4</sub>:H<sub>2</sub>O<sub>2</sub>:H<sub>2</sub>O; discusses time dependence of secondary reaction products after initial mixing of the etchant; Ref. (Kurth, E., 1988)

Study of oxide formation on Br<sub>2</sub>/methanol etched InP; Ref. (Wager, J.F., 1981)

InP surface oxide (XPS) and Schottky contact study following chemical treatment in:

NaOH:H<sub>2</sub>O (1 M:0.8 M); 20 min at 80°C, pH = 9.6
NH<sub>4</sub>OH:H<sub>2</sub>O<sub>2</sub>:H<sub>2</sub>O (5:1:100); 80°C for 1, 5, 20, and 80 min; pH = 11
H<sub>2</sub>O<sub>2</sub> at 80°C; pH = 4.4
HF (49%)
H<sub>2</sub>SO<sub>4</sub>:H<sub>2</sub>O<sub>2</sub>:H<sub>2</sub>O (3:1:1); pH = 2
Br<sub>2</sub>:methanol (1:100)
Br<sub>2</sub>:HBr:H<sub>2</sub>O (1:17:35); pH = 0
Br<sub>2</sub>:HBr:H<sub>2</sub>O (0.3:10:100); pH = 0.2; Ref. (Guivarc’h, A., 1984)

GaAs

Surface cleaning effects on GaAs light emission from Schottky contacts; assessment of etching on electronic surface behavior for:

NH<sub>4</sub>OH
HCl:H<sub>2</sub>O (1:1)
HCl:H<sub>2</sub>O<sub>2</sub>:H<sub>2</sub>O (1:20:50)
NH<sub>4</sub>OH:H<sub>2</sub>O (1:1)
H<sub>2</sub>SO<sub>4</sub>:H<sub>2</sub>O<sub>2</sub>:H<sub>2</sub>O (20:1:1)
H<sub>2</sub>SO<sub>4</sub>:H<sub>2</sub>O<sub>2</sub>:H<sub>2</sub>O (1:1:250)
NaOH:H<sub>2</sub>O (1:2)
NaOH:H<sub>2</sub>O<sub>2</sub>:H<sub>2</sub>O (1:3:30)
NaOH:H<sub>2</sub>O<sub>2</sub>:H<sub>2</sub>O (1:3:150)
H<sub>3</sub>PO<sub>4</sub>:H<sub>2</sub>O (10:1)
H<sub>3</sub>PO<sub>4</sub>:H<sub>2</sub>O<sub>2</sub>:H<sub>2</sub>O (10:1:1); Ref. (Adachi, H., 1981a)
Evaluation of GaAs surface oxides for various cleaning methods. Cleanest surface has $\sim 8$ Å film which grows due to air oxidation to $\sim 30$ Å; Ref. (Adams, A.C., 1973)

$\text{H}_2\text{SO}_4: \text{H}_2\text{O}_2: \text{H}_2\text{O} (5:1:1)$; GaAs substrate cleaning for MBE; surface analysis; Ref. (Massies, J., 1985)

GaAs (1 0 0) surface cleaning XPS study:

- $\text{NH}_4\text{OH}: \text{H}_2\text{O}_2: \text{H}_2\text{O} (10:5:1000)$
- $\text{HCl}$ conc.; GaAs (1 0 0); leaves a nearly stoichiometric surface
- HF (50%); GaAs (1 0 0)
- $\text{H}_2\text{SO}_4: \text{H}_2\text{O}_2: \text{H}_2\text{O} (5:1:1)$; Ref. (Olivier, J., 1990)

GaAs surface cleaning study by Auger analysis and Au layer epitaxy behavior:

- $\text{H}_2\text{SO}_4: \text{H}_2\text{O}_2: \text{H}_2\text{O} (3:1:1)$
- $\text{NH}_4\text{OH}: \text{H}_2\text{O}_2: \text{H}_2\text{O} (1:1:2)$
- $\text{HF}: \text{HNO}_3: \text{H}_2\text{O} (2:2:1)$; Ref. (Vermaak, J.S., 1977)

Surface study by AES and XPS of GaAs etched with:

- $\text{H}_2\text{SO}_4: \text{H}_2\text{O}_2: \text{H}_2\text{O} (5:1:1)$ at 50°C for 1 min
- $\text{NaOH}$ (1N):$\text{H}_2\text{O}_2$ (1:1) at 30°C for 1 min; Ref. (Yoon, H.J., 1992)

$\text{H}_3\text{PO}_4: \text{H}_2\text{O}_2: \text{H}_2\text{O} (3:1:40)$; GaAs etch rate = 100nm/min; isotropic etch

Ar ion milling and plasma etch; cathodoluminescence study of surface damage; best surface combines ion milling with 1 min wet etch; Ref. (Papadopoulo, A.C., 1990)

$\text{H}_2\text{O}$; GaAs photowash surface passivation; reduces surface state density; Ref. (Shen, H., 1990)

Measurement of GaAs residual surface oxide:

- Etchant A = $\text{H}_2\text{SO}_4 : \text{H}_2\text{O}_2 : \text{H}_2\text{O} (4:1:1)$
- Etchant B = HF conc.
- Etchant C = $\text{NaOH} : \text{H}_2\text{O}_2$ (1:1)

<table>
<thead>
<tr>
<th>Surface characteristics</th>
<th>Residual oxide (Å)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A at 50°C for 3 min</td>
<td>50</td>
</tr>
<tr>
<td>A + B for 5 min</td>
<td>30</td>
</tr>
<tr>
<td>A + B + C at 30°C for 1 min</td>
<td>$&lt;10$</td>
</tr>
<tr>
<td>C at 55°C for 10 min</td>
<td>60</td>
</tr>
<tr>
<td>C + B</td>
<td>25</td>
</tr>
<tr>
<td>C + B + C at 30°C for 1 min</td>
<td>10</td>
</tr>
</tbody>
</table>

Ref. (Shiota, I., 1977)

GaAs and InP XPS surface study giving binding energies and Ga/As and In/P surface compositions after etching in:
HCl conc.
Br$_2$/methanol
H$_2$SO$_4$; Ref. (Bertrand, P.A., 1981)

H$_2$SO$_4$:H$_2$O$_2$:H$_2$O (4:1:1); GaAs (1 0 0), AFM surface study shows undulations; HCl (36%); GaAs 10–20 min etch shows monolayer flat surface; 10 s H$_2$O rinse dissolves oxides leaving an As-rich surface; Ref. (Song, Z., 1995)

Citric acid:H$_2$O$_2$ (x:1, for 1 < x < 10); study of GaAs and etched surface interface layers and roughness by variable angle spectroscopic ellipsometry; Ref. (Snyder, P.G., 1998)

HCl; deoxidation of GaAs surface; photoluminescence degradation caused by surface oxide; Ref. (Suzuki, T., 1977)

**InGaAs**

H$_2$SO$_4$:H$_2$O$_2$:H$_2$O (1:1:x) {10 < x < 100}; InGaAs surface study; behavior depends on solution pH; Ref. (Aspnes, D.E., 1982b)

Br$_2$/methanol (1:2000); InGaAs best surface cleaning for InP OMVPE regrowth on patterned InGaAs, or alternative:

- Saturated Br$_2$ water:HBr:H$_2$O (1:1:10); InGaAs surface cleaning (etch rate = 80 Å/s; does not attack photoresist)
- HCl conc.; InP cap layer removal
- H$_2$SO$_4$:H$_2$O$_2$:H$_2$O (1:8:500); InGaAs etch rate = 20 Å/s; for 30 s
- H$_2$SO$_4$:H$_2$O$_2$:H$_2$O (1:8:500)
- H$_2$SO$_4$:H$_2$O$_2$:H$_2$O (1:8:50)

{Compares surface recombination velocity of regrown InP/InGaAs for various cleaning methods}; Ref. (Yablonovitch, E., 1992)

**InGaP**

InGaP/GaAs surface recombination study:

- HCl:H$_2$O (11:1); Application: InGaP mesa etch
- H$_2$PO$_4$:H$_2$O$_2$:H$_2$O (1:1:1); Application: GaAs and AlGaAs mesa etch
- (NH$_4$)$_2$S$_x$; Application: surface passivation of InGaP; Ref. (Pearton, S.J., 1993d)

**InSb**

InSb cleaning for Auger surface studies:

- Lactic acid:HNO$_3$ (10:1)
- HF:H$_2$O$_2$:H$_2$O (1:1:4)
- HF:HNO$_3$:CH$_3$COOH:Br (15:25:15:0.3)
HF:HNO₃:CH₃COOH (1:2:5)
Br₂/methanol (1%)
KOH:tartaric acid:ethylene diamine tetra-acetic acid:H₂O (70 g:4 g:8 g:78 g), mixed with H₂O₂ (5:2)
CH₃COOH:HNO₃:HF (15:30:15) {CP-4 etch}; Ref. (Auret, F.D., 1982)

InAs

InAs surface contaminant studies:

(A) Br₂/methanol (2%); InAs surface cleaning 5 min first step followed by:
HF conc.; InAs surface cleaning 5 min second step; followed by DI water rinse; leaves residual Br₂, and F; demonstrates need for high purity water rinse to reduce ionic contaminants
(B) HCl:H₂O₂:H₂O (150:1:100); InAs surface cleaning 5 min; leaves surface pitting and chloride contamination; Ref. (Brown, A., 1986)

2.4.5. Surface oxidation, anodization, passivation

InP

Anodization: InP; defect delineation; Ref. (Elliott, C.R., 1981)
Anodization; InP and GaAs; Ref. (Kohl, P.A., 1983)
Anodization; InP; Application: antireflective coating on InGaAsP/InP photodiodes; Ref. (Sakai, S., 1979c)
Anodization; Application: InP for InGaAsP/InP stripe laser; tartaric acid (3%):propylene glycol (1:3), pH = 7.2 adjusted with NaOH; Ref. (Sakai, S., 1979b)
Anodization; InP with tartaric acid (3%):propylene glycol (1:3) electrolyte; Ref. (Schmitt, F., 1983)
Anodization; InP and InGaAsP; Ref. (Williams, J.O., 1978)
Anodic oxidation; InP; study of oxidation mechanism; Ref. (Besland, M.P., 1993)
KOH (0.1 M), electrolyte for anodic oxidation of n-InP; Ref. (Quinlan, K.P., 1994)
Study of oxide formation on Br₂/methanol etched InP; Ref. (Wager, J.F., 1981)
HNO₃; 50 Å anodic oxide growth on InP; Ref. (Eftekhari, G., 1993)
HNO₃; InP oxidation; 200 Å under illumination; Ref. (Robach, Y., 1992)
o-H₃PO₄:HNO₃:H₂O (5:30:1); Application: chemical growth of native oxide on InP for use as solar cell surface coating; Ref. (Faur, M., 1994a)
Anodization: InP; study of surface passivation; Ref. (Hollinger, G., 1987)

(NH₄)₂Sₓ; InP surface passivation study; Ref. (Maeda, F., 1993)

Na₂S:H₂O (1:9); sulfide passivation of GaAs, InP, GaP; Ref. (Bessolov, V.N., 1995b)

(NH₄)₂Sₓ; InP surface passivation, study of Schottky contact stability; Ref. (Ahaitouf, A., 1998)

(NH₄)₂Sₓ; sulfidation of GaAs and InP; study of surface roughness and oxygen content; Ref. (Choy, W.H., 1999)

S passivation of InP in S₂Cl₂ (NH₄)₂S, and sulfide-containing Br₂:methanol solutions; Ref. (Gao, L.J., 1995)

Sulfur passivation of InP; anodization in (NH₄)₂Sₓ solution; study of surface stability; Ref. (Han, I.K., 1997)

(NH₄)₂Sₓ; sulfidization of InP surfaces; ammonium polysulfide solution prepared by dissolving about 2–2.5 g free sulfur into 25 ml of commercially available ammonium sulfide solution, then oxidizing by bubbling pure oxygen through it for about 30–45 min. This solution is then diluted with water, 20 drops in 15 ml H₂O, and heated with intermittent stirring to 50–60°C with previously etched InP in it; Ref. (Iyer, R., 1991b)

(NH₄)₂Sₓ; sulfidization of InP surfaces; ammonium polysulfide solution prepared by dissolving about 2–2.5 g free sulfur into 25 ml of commercially available ammonium sulfide solution, then oxidizing by bubbling pure oxygen through it for about 30–45 min. This solution is then diluted with water, 20 drops in 15 ml H₂O, and heated with intermittent stirring to 50–60°C with previously etched InP in it; Ref. (Iyer, R., 1991a)

(NH₄)₂Sₓ-treated InP; study of surface S atoms; most S atoms on InP (0 0 1) form In–S–In bridge bonds in the first layer; Ref. (Sugiyama, M., 1996)

Anodization; InP with tartaric acid (3%):propylene glycol (1:3) electrolyte; Ref. (Schmitt, F., 1983)

InGaAs(P)

InGaAs anodization; electrolyte is tartaric acid (3%) with pH adjusted to 7 by adding NH₄OH

H₂O₂:NH₄OH (10:1); InGaAs surface cleaning prior to anodization; Ref. (Shirafuji, J., 1982)

Anodization; InGaAsP/InP anodize/strip thinning of InP; Ref. (Ito, N., 1980)

Anodization; InGaAsP in 0.1 M ammonium phosphate dibasic solution electrolyte; Ref. (Law, H.D., 1980)

Anodization; InP and InGaAsP; Ref. (Williams, J.O., 1978)

(NH₄)₂S; Application: InGaAsP laser facet passivation; Ref. (DeChiaro, L.F., 1992)
Na$_2$S: isopropanol (saturated solution); sulfur passivation of InGaAsP/InP laser diodes; reduced surface recombination; Ref. (Hakimi, R., 1997)

H$_2$SO$_4$: 1 min cleaning step for InP/InGaAlAs/InGaAs heterostructure detectors prior to sulfide passivation in preparation for MOCVD regrowth step

(NH$_4$)$_2$S$_x$ (ammonium polysulfide); passivation of InP/InGaAlAs/InGaAs heterostructures for MOCVD regrowth Ref. (Kollakowski, St., 1998; Lemm, Ch., 1997)

Polysulfide solution (50 ml (NH$_4$)$_2$S, dissolving 5 g sulfur into the solution, then flowing oxygen through the solution, bubbling for 45 min); first step in passivation of InP/InGaAs MSM photodetectors

(NH$_4$)$_2$S (8.9% S); second step in passivation of InP/InGaAs MSM photodetectors; Ref. (Pang, Z., 1999)

InGaAs/InP photodiode surface passivation:

First step: place device wafer in OCG OPD 4262 positive photoresist developer
Second step: mix 2-propanol:H$_2$SO$_4$ (1:1) (an exothermic reaction; color changes from clear to amber)
Third step: immediately ultrasonically agitate fresh mixture for 15 s and add to developer containing the wafer; agitate this fuming mixture for 1 min
Fourth step: decant the bath and spray rinse the wafer with 2-propanol; remove wafer and N$_2$ blow dry; Ref. (Porkolab, G.A., 1997)

(NH$_4$)$_2$S$_x$ (3.5 ml supersaturated solution; Ref. (Iyer, R., 1991); 45 ml H$_2$O; InP passivation; 15 min at 50°C under illumination of a 250 W tungsten lamp; reduction in dark current of MSM photodetectors; good stability; Ref. (Schade, U., 1994)

GaAs

Anodization of InP for successive anodization/stripping thickness profile van der Pauw measurements using N-methylacetamide electrolyte; Ref. (Kamiya, Y., 1986)

Anodization; InP and GaAs; Ref. (Kohl, P.A., 1983)

Anodization; GaAs using H$_2$O$_2$ electrolyte with pH adjusted by H$_3$PO$_4$ or NH$_4$OH; Ref. (Logan, R.A., 1973b)

Anodization; H$_3$PO$_4$:H$_2$O, pH = 2.6–3.0, electrolyte; GaAs thinning

NH$_4$OH:H$_2$O (1:1); oxide stripping etch
HCl; alternative oxide stripping etch; Ref. (Niehaus, W.C., 1976)

Anodization; H$_2$O$_2$ electrolyte; Application: GaAs anodize-strip thinning of layers for FETs; Ref. (Rode, D.L., 1974)

Light controlled anodization; Application: GaAs anodize-strip thinning for MESFETs; Ref. (Shimano, A., 1979)
GaAs anodization in:

- $\text{H}_3\text{PO}_4$:$\text{H}_2\text{O}$ (acidic electrolyte)
- $\text{NH}_4\text{OH}$:$\text{H}_2\text{O}$ (basic electrolyte)
- $\text{(NH}_4\text{)}_2\text{HPO}_4$:$\text{H}_2\text{O}$ (neutral electrolyte); Ref. (Schwartz, B., 1976a)
- $\text{KMnO}_4$:$\text{acetone}$ (1:25); anodization electrolyte for GaAs and GaAs$_{0.6}$P$_{0.4}$; Ref. (Stoneham, E.B., 1974)
- $\text{H}_2\text{O}_2$:$\text{H}_2\text{O}_2$:$\text{NH}_4\text{OH}$, $\text{pH } \approx 7$; and $\text{H}_2\text{O}$; Application: GaAs surface oxidation for study of effects on laser degradation; Ref. (Schwartz, B., 1972)
- $\text{H}_2\text{O}_2$:$\text{H}_2\text{O}$ (1:1); 2 min oxidation of GaAs surface features, followed by $\text{HCl}$:$\text{H}_2\text{O}$ (1:1) 2 min etch removal of oxide; Ref. (Moran, P.D., 1999)
- $\text{HNO}_3$ (65%); GaAs oxidation under illumination
  - $\text{HNO}_3$ (without water) vapor etch; GaAs oxidation; Ref. (Michel, C., 1982)
- $\text{N}$-methyacetamide ($\text{CH}_3\text{CONHCH}_3$); electrolyte for anodization of GaAs; Ref. (Müller, H., 1975)
- Passivation; ultrasonic running deionized water; GaAs; Ref. (Hirota, Y., 1992)
- $\text{H}_2\text{O}$ (deoxygenated, deionized); GaAs treatment for oxide-free surface; Ref. (Hirota, Y., 1995)
- $\text{Na}_2\text{S}$:$\text{H}_2\text{O}$ (1:9); sulfide passivation of GaAs, InP, GaP; Ref. (Bessolov, V.N., 1995b)
- $\text{(NH}_4\text{)}_2\text{S}_x$:$\text{H}_2\text{O}$ (1:1); Application: GaAs sulfide passivation; 20 min at 40°C; Ref. (Jeong, Y.-H., 1994)
- $\text{(NH}_4\text{)}_2\text{S}_x$ (10 ml solution with added 1 g sulfur and 2 g phosphorus pentasulfide); GaAs surface passivation, followed by deposition of SiN$_x$ overlayer; Ref. (Kapila, A., 1995)
- $\text{(NH}_4\text{)}_2\text{S}$; surface passivation of GaAs; chemical structure study; Ref. (Lu, Z.H., 1993)

$\text{(NH}_4\text{)}_2\text{S}$ alcohol solutions

- Study of passivation efficiency; Ref. (Bessolov, V.N., 1997a)

Sulfide passivation study on GaAs; dependence on sulfur activity and solvent dielectric constant

- $\text{(NH}_4\text{)}_2\text{S}$ (20%)
- $\text{Na}_2\text{S}$:$\text{H}_2\text{O}$ (60%)
- $\text{S}_2\text{Cl}_2$:$\text{CCl}_4$ (1:10)
- $\text{(NH}_4\text{)}_2\text{S}$:$i$-$\text{C}_3\text{H}_7\text{OH}$ (20 v/o in isopropanol)
- $\text{(NH}_4\text{)}_2\text{S}$:$t$-$\text{C}_4\text{H}_9\text{OH}$ (10 v/o in tert-butanol)
\( \text{Na}_2\text{S}:i\text{-C}_3\text{H}_7\text{OH} \)
\( \text{Na}_2\text{S}:t\text{-C}_4\text{H}_9\text{OH}; \text{Ref. (Bessolov, V.N., 1998)} \)

\((\text{NH}_4)_2\text{S}_x \) sulfidation of GaAs and InP; study of surface roughness and oxygen content; Ref. (Choy, W.H., 1999)

\((\text{NH}_4)_2\text{S}_x \) sulfidation of GaAs for contact metalization; Ref. (Shoji, D., 1999)

\((\text{NH}_4)_2\text{S}_x \) GaAs surface passivation; Ref. (Eftekhari, G.R., 1996)

\((\text{NH}_4)_2\text{S}_x \) GaAs surface treatment for MBE regrowth; Ref. (Furuhata, N., 1998)

\((\text{NH}_4)_2\text{S}_x \) sulfidation of GaAs XPS study; Ref. (Kang, M.-G., 1999)

\((\text{NH}_4)_2\text{S}_x \) solution; sulfur passivation of GaAs; 10 min at 60°C; XPS study of surface bonding states; Ref. (Kang, M.-G., 1997)

\((\text{NH}_4)_2\text{S}_x \) solution; GaAs surface treatment to reduce carbon and oxide contamination prior to CBE regrowth, 40°C for 30 min; Ref. (Sik, H., 1996)

\((\text{NH}_4)_2\text{S}_x \) solution; GaAs passivation by dipping in solution and annealing at 400°C; Ref. (Yamaguchi, K., 1996)

Study of GaAs barrier height shift with surface sulfidization using:

\((\text{NH}_4)_2\text{S} (20\%):\text{ethanol (1:9)} \)
\((\text{NH}_4)_2\text{S}(20\%):\text{isopropanol (1:9)} \)
\((\text{NH}_4)_2\text{S}(20\%):t\text{ert-butanol (1:9)}; \text{Ref. (Bessolov, V.N., 1997b)} \)
\(\text{Na}_2\text{S}:\text{H}_2\text{O (2 M:0.4 M)} \) sulfide passivation of GaAs; Ref. (Berkovits, V.L., 1998)

\(\text{Na}_2\text{S}:\text{isopropanol (1:9)} \) surface passivation of GaAs; reduces surface recombination and increases photoluminescence efficiency; comparison to passivation with:

\(\text{Na}_2\text{S}:\text{H}_2\text{O (1:9)} \)
\(\text{Na}_2\text{S}:\text{ethylene glycol (1:9)}; \text{Ref. (Bessolov, V.N., 1995a)} \)

\(\text{Na}_2\text{S} \) solution passivation of GaAs surfaces; dependence on the solvent dielectric constant; comparison of water, ethylene glycol, ethanol, isopropanol, butanol and tert-butanol. Photoluminescence efficiency increases as surface oxygen is replaced with sulfur; Ref. (Bessolov, V.N., 1996)

\(\text{NaS} \) solution GaAs sulfidization

\((\text{NH}_4)_2\text{S} \) solution GaAs sulfidization; Ref. (Shun, J., 1991)

\(\text{HCl}:\text{H}_2\text{O}_2:\text{H}_2\text{O (1:1:50)} \) GaAs surface cleaning prior to S passivation

\(\text{CH}_3\text{CSNH}_2/\text{NH}_4\text{OH} \) solution; GaAs surface passivation
\(\text{CH}_3\text{CSNH}_2/\text{H}^+ \) solution; GaAs surface passivation; Ref. (Lu, E.D., 1996)
P2S5:(NH4)2S:Sx solution; Application: sulfur passivation of GaAs

(NH4)2Sx + 6% S solution; Application: sulfur passivation of GaAs; Ref. (Wu, D., 1997)

H2S dry passivation of GaAs surface using excimer laser at room temperature; Ref. (Yoshida, N., 1993)

Se passivation of GaAs surfaces; Ref. (Scimeca, T., 1993)

SeS2 solution passivation of GaAs surfaces; study of bonding and electrical properties; Ref. (Sun, J., 1999)

Surface passivation; GaAs; nitridation with hyrazine; Ref. (Vogt, K.W., 1993)

HCl (36% aqueous solution):methanol (from 1:10 to 1:1000); protects GaAs surface from oxidation to improve photoluminescence intensity; Ref. (Akita, K., 1990)

AlGaAs

Citric acid (3 g in 100 ml H2O):ethylene glycol (1:2), with pH adjusted to 6 using ammonia; electrolyte for anodizing AlxGa1-xAs; Ref. (Buda, M., 1998)

NaS2:isopropanol (1:9); sulfidization to reduce optical degradation in InGaAs/AlGaAs laser mirrors; Ref. (Bessolov, V.N., 1995c)

(NH4)2Sx solution; study of AlGaAs and InGaP surface passivation; Ref. (Seo, J.M., 1996)

AlGaInP

(NH4)2Sx; Application: surface passivation of AlGaInP laser mirror facets; Ref. (Kamiyama, S., 1991)

InSb

(NH4)2Sx sulfidation study of InSb surfaces; Ref. (Ichikawa, S., 1999)

InAs

(NH4)2Sx passivation of InAs/InAsPb photodetectors; Ref. (Gong, X.Y., 1998)

(NH4)2Sx; InAs; study of surface structure; S replaces outermost As atoms; all S desorbs above 500°C; Ref. (Katayama, M., 1991)

GaSb

Citric acid (1 mol l⁻¹):thiourea (1/3 mol l⁻¹):isopropanol; electrolyte for anodic passivation of GaSb; Ref. (Salesse, A., 1997)
HCl:H$_2$O (3:7); GaSb surface treatment to provide Sb surface termination prior to sulfidation

$(\text{NH}_4)_2\text{S}:\text{H}_2\text{O}$ (1:4) and (1:45); sulfur passivation of GaSb; Ref. (Lin, C.L., 1998)

**GaP**

HNO$_3$; GaP oxidation/etching under illumination; chemical kinetics; Ref. (Hsieh, H.F., 1992)

Na$_2$S:H$_2$O (1:9); sulfide passivation of GaAs, InP, GaP; Ref. (Bessolov, V.N., 1995b)

**InGaP**

$(\text{NH}_4)_2\text{S}_x$; InGaP surface passivation; Ref. (Pearton, S.J., 1993e)

$(\text{NH}_4)_2\text{S}_x$; Application: surface passivation of InGaP; Ref. (Pearton, S.J., 1993d)

$(\text{NH}_4)_2\text{S}_x$ solution; study of AlGaAs and InGaP surface passivation; Ref. (Seo, J.M., 1996)

$(\text{NH}_4)_2\text{S}_x$ sulfur passivation of InGaP/GaAs structures; study of dependence on S concentration in the solution; Ref. (Sik, H., 1994)

**GaN**

$(\text{NH}_4)_2\text{S}_x$; 10 min treatment of p-type GaN surface for Pd low resistivity Ohmic contact; Ref. (Kim, J.-K., 1999)

2.4.6. Metal layer removal

KI:I$_2$:H$_2$O; etchant for Au/Zn contact layer from InP; Ref. (Adachi, S., 1981c)KI:I$_2$:H$_2$O; Au implantation mask from InGaP; Ref. (Hamisch, Y., 1992)

KI:I$_2$:H$_2$O; Au contact and masklayer removal from GaAs; Ref. (Merz, J.L., 1976, 1979)

I$_2$:KI:H$_2$O; GaP photolithographic pattern etch in deposited Au layer; Ref. (Uragaki, T., 1976)

KI:I$_2$:H$_2$O; Au mask removal from InP; Ref. (Ils, P., 1993)

HF (1%); Ti mask removal from InP; Ref. (Schilling, O., 1993)

HF:H$_2$O (1:4); Ti/SiN mask removal from InP/InGaAsP; Ref. (Qian, Y.H., 1999)

HF conc.; removal of Ti from InGaAs; Ref. (Kallstenius, T., 1999a)

Buffered HF (i.e. HF:NH$_4$F, 1:6):H$_2$O (1:4); Ti removal from InP; 30 s at room temperature removes ~200 Å; Ref. (Liao, H.-H., 1996)

HF buffered; Ti mask removal from vee-groove patterned InP; Ref. (Schrimpf, T., 1999)
HF (40%):HNO₃ (65%):H₂O (5:24:64); selective removal of titanium mask from InP; 10 s at 20°C; Ref. (Bönsch, P., 1998)

HCl:H₂O (1:1); Ni mask removal from InGaAs/AlGaAs structure; Ref. (Ko, K.K., 1992)

HCl conc.; removal of Cr mask from GaAs; Ref. (Tihanyi, P., 1987)

HCl:HNO₃:H₂O (7:1:8); Pt mask removal from GaN; 85°C for 4 min; Ref. (Bardwell, J.A., 1999)

Ceric sulfate (saturated solution):HNO₃ (9:1); chromium etchant from semiconductor surface; etch rate ~ 800 Å/min

I₂:KI:H₂O (100 g:400 g:400 ml); gold etchant from semiconductor surface
NaOH (20%); Al etchant; 60–90°C; Ref. (Glang, R., 1970)

Ceric sulfate (saturated solution):HNO₃ (9:1); chromium etchant from semiconductor surface

I₂:KI:H₂O (56 g:112 g:500 ml); gold etchant from semiconductor surface; Ref. (Park, S., 1997)

H₃PO₄:HBF₄:H₂O (2:1:10); Al contact removal from GaAs; Ref. (Christou, A., 1976)

H₂SO₄:H₂O₂:H₂O (1:1:10); removal of iron nitride pattern mask from GaN; Ref. (Lee, H., 1998)

ECR plasma etch; NF₃; Ti/W metal removal from mesa sidewalls; Ref. (Lee, W.S., 1992)

HgCl₂:dimethylformamide (100 g:500 ml); In droplet removal from LPE InP surfaces; use ultrasonic agitation to free Hg reaction by-product from surface; Ref. (Astles, M.G., 1973)

2.5. Wet chemical photo- and electro-chemical techniques

2.5.1. Photochemical wet etching

InP

Review: laser-assisted etching of InP; with summary table of etchants, etch conditions, and etch rates; Ref. (Matsushita, K., 1990d)

Treatise on photochemical behavior of semiconductors; discusses thermodynamics and kinetics of photodecomposition and function of electrolyte junction solar cells; Ref. (Gerischer, H., 1979)

Relationship of semiconductor etching to the Fermi level; Ref. (Gerischer, H., 1978)

Electrochemical C–V profiling; HCl:methanol electrolyte; Ref. (Akita, K., 1991b)

Electrochemical C–V profiling; HCl electrolyte; Ref. (Ambridge, T., 1979b); (Cabaniss, G.E., 1988)
Electrochemical C–V profiling; HCl:HNO₃:isopropanol electrolyte; Ref. (Green, R.T., 1986)

Electrochemical C–V profiling; Ref. (Jackson, N.F., 1992)

HCl:H₂O (1:20); Application: InP n-type photoelectrochemical etch with sample biased to form a surface depletion layer; forms deep narrow grooves; Ref. (Bowers, J.E., 1985)

HCl; photochemical; InAs and GaP etch characteristics under illumination; reaction kinetics dependence on semiconductor band structure; Ref. (Hsieh, H.F., 1993)

HCl:H₂O (1:20); electrolyte for photoelectrochemical etching of GaAs and InP; etch rates and profiles for via hole fabrication are given; Ref. (Khare, R., 1993a)

HCl (1 M); electrolyte for photo-anodic etching and pulsed avalanche etching of InP (0 0 1); formation of pore arrays; Ref. (Hamamatsu, A., 1999)

HCl (1 M); photoelectrochemical etch study of InP; etch anisotropy dependence on etch conditions; Ref. (Soltz, D., 1996a)

HCl (1 M); monitoring of grating depth during photoelectrochemical etching on n-InP; Ref. Soltz, D., 1996b)

HCl:HNO₃:H₂O (1:3:x); InP photoetching through thin layer electrolyte; etch rate is dependent on x; Ref. (Grebel, H., 1989)

HCl:HNO₃:H₂O (1:3:30); laser-induced etch in Fe-doped InP; Ref. (Osgood, R.M., 1982)

HNO₃:HCl:H₂O (1:1:100); InP photoetch p–n junction delineation; Ref. (Ruberto, M.N., 1991)

Photoelectrochemical etch of InP using HCl:HNO₃:H₂O (1:1:20) electrolyte; Application: maskless diffraction grating fabrication; Ref. (Matz, R., 1988)

Laser controlled photochemical etch of InP

HNO₃:HCl:H₂O (1:1:20); (negligible dark etch rate)
H₂O:H₂O (1:10); at incident laser power of 40 W/cm² InP (1 0 0) etch rate = 2.8 μm/min; (1 1 1A) InP = 1.1 μm/min and (1 1 1B) InP = 2.3 μm/min; under ultraviolet p-InP is etched about 18 times slower than n-InP; in visible light, p-InP is not etched at all; laser etching rate can be controlled externally by secondary light source; Ref. (Willner, A.E., 1988)

HNO₃; photoelectrochemical etching of p-InP; dependence on carrier concentrations and etch pit densities; study of photoetch mechanism; Ref. (Quinlan, K.P., 1997)

HNO₃:H₂O; study of photoelectrochemical etching of p-InP; dependence on light intensity, HNO₃ concentration, and potential; Ref. (Quinlan, K.P., 1996)

H₂O₂ acidic solutions; etch and photoetch mechanism study on n- and p-InP; Ref. (Theuwis, A., 1996)
Analysis of resolution for light defined patterns in photoelectrochemical etching of InP; Ref. (Ostermayer, F.W., 1985)

Light intensity controlled etch to form spherical lenses on n-InP LED substrates; Ref. (Ostermeyer, F.W., 1983)

HF:H₂O (1:10); GaAs and InP photoetch p–n junction delineation; dopant selective; Ref. (Ruberto, M.N., 1991)

Light activated Pd deposition on InP (Zn) on which electroless gold contacts will deposit; Ref. (Stremdoerfer, G., 1986)

Iodic acid solutions; InP etch and photoetch chemical kinetics; Ref. (Vermeir, I.E., 1992)

I₂:KI:HCl; study of etch and photoelectrochemical etch of InP (0 0 1); Ref. (Vermeir, I.E., 1996)

CrO₃:HF:H₂O {Sirtl etch}; InP defect delineation under white light or laser light; Ref. (Weyher, J.L., 1985)

H₃PO₄:H₂O (1:9); n-InP photoetch study; etch rates are enhanced two to five times by added Cu metal ions; Ref. (Lowes, T.D., 1993a)

H₃PO₄:H₂O (1:9); n-InP photochemical etching study using 488 nm Ar + laser; photoetch rate for via holes is 300 times greater for 0.002% duty cycle than for 100%; photoetch rate is controlled by local saturation; Ref. (Lowes, T.D., 1993b)

FeCl₃ (21% diluted); laser scanned photochemical etch for vee-grooves in InP (1 0 0); Ref. (Moutonnet, D., 1988)

FeCl₃:H₂O (40% w/v); Application: InP photoetching of mesas; etch rate = 0.5 µm/min under illumination, followed by cleanup etch of Br:HBr:H₂O; Ref. (Lubzens, D., 1977)

H₂SO₄:H₂O₂:H₂O; photoelectrochemical etch electrolyte for n- and p-GaAs; etch study; Ref. (Plieth, W.J., 1989)

Photoelectrochemical etching of n-GaAs with H₂SO₄:H₂O₂:H₂O and KOH electrolytes and n-InP with HCl:HNO₃:H₂O electrolyte; Ref. (Svorcik, V., 1988)

Maskless photoetching of InP and GaAs using ion implantation damage mask patterning; (Chi, G.C., 1986)

n-InP photoetch with HeNe laser in:

FeNH₄(SO₄)₂:H₂O (1:12)
FeSO₄(NH₄)₂SO₄:H₂O (1:6)
FeCl₃
HCl:HNO₃:H₂O (5:8:10)
HCl:HNO₃:H₂O (5:2:10)
HCl:HNO₃:H₂O (3:8:10); Ref. (Svorcik, V., 1991)

AZ-303 developer; photochemical etchant for n-InP laser-induced maskless grating etching; Ref. (Aoyagi, Y., 1985)

Comparison of electrolyte for C–V profiling of InP and GaAs materials:

HCl
Tiron
Pear etch
EDTA
Ammonium tartarate
FAP; Ref. (Faur, M., 1994c)

0.3 M N-n-Butylpyridinium Chloride (C₉H₁₄ClN):1 M NH₃F₂ (1:4); electrolyte for Electrochemical C–V profiling; does not destroy calomel electrodes (in BIORAD/Polaron proflers); useful on InP, GaAs, InGaAs, AlGaAs, GaP, InGaAsP, Si and Ge; Ref. (Faur, M., 1996)

InP; light intensity controlled etch to form spherical lenses on n + InP LED substrates; Ref. (Ostermayer, F.W., 1983)

HNO₃ (12 M)

HNO₃ (12 M): sulfamic acid (0.1 M); photoelectrochemical p-InP etch mechanism study; Ref. (Quinlan, K.P., 1999)

InAs

H₂SO₄ (0.2 M); electrolyte for photo-selective etch of n-InAs

HCl (0.2 M); electrolyte for photoelectrochemical etch of InAs; Ref. (Harris, D., 1994)

InGaAs(P)/InP

KF:HF; Application: InGaAs/InP photoetch; deep hole etch for detector structures; Ref. (Forrest, S.R., 1982)

HF:KOH solution electrolyte; InP and InGaAsP holographic photoetch for diffraction gratings; Ref. (Lum, R.M., 1985)

HF:H₂O₂:H₂O; Application: InGaAs diffused junction p–n junction cross-section delineation; Ref. (Yamamoto, Y., 1980)

Acid electrolytes for InAsP for liquid junction solar cells; Ref. (Menezes, S., 1984)

HCl:HNO₃:H₂O; p–n junction delineation; Ref. (Williamson, J., 1993)
H₃PO₄:H₂O₂ (1:1); InP and InGaAs lattice defect delineation by selective photoetching; Ref. (Gottschalch, V., 1982)

Photochemical etching review: p–n dopant selectivity; surface relief etching; InGaAsP/InP and GaAs; Ref. (Kohl, P.A., 1989)

KOH:Fe(CN)₆:H₂O (6 g:4 g:50 ml); Application: p–n junction photochemical delineation for Zn diffusion assessment in InGaAsP/InP structures; Ref. (Hou, D.T.C., 1990)

**GaAs**

Review: laser-assisted etching of GaAs; with table of etchant, etch conditions, and etch rates; Ref. (Ashby, C.I.H., 1990d)

Electrochemical C–V profiling; GaAs; Ref. (Jackson, N.F., 1992)

3 M ammonium tartarate; GaAs, electrolyte for electrochemical C–V profiling; Ref. (Akatsu, Y., 1987)

HNO₃:H₂O (1:10–100); GaAs and AlGaAs non-selective; Ref. (Fink, Th., 1993a)

HNO₃:H₂O (1:200); GaAs selective etch from AlGaAs; Ref. (Fink, Th., 1993a)

HNO₃:H₂O; GaAs n-type; similar etch rates for AlGaAs; Ref. (Fink, Th., 1993b)

HNO₃ (10%); GaAs semi-insulating; laser-induced etch; Ref. (Tisone, G.C., 1983)

HNO₃:H₂O (1:20); GaAs and AlGaAs photoetch with AlAs stop layer; Ref. (Ruberto, M.N., 1989)

HNO₃:H₂O (1:20); GaAs p–n junction delineation; Ref. (Ruberto, M.N., 1991)

HNO₃:H₂O (1:20); Photoetching of deep features in GaAs; role of optical waveguiding; Ref. (Podlesnik, D.V., 1986)

HNO₃:HCl:H₂O (1:4:50); GaAs photoinduced etching to taper the thickness by varying pattern of the UV intensity; Ref. (Hu, M.H., 1997)

HCl:HNO₃:H₂O (4:1:50); GaAs photoelectrochemical electrolyte for high aspect ratio features; Ref. (Khara, R., 1992)

HCl:H₂O (1:20); GaAs n-type selective photoetch from GaAs p-type; Ref. (Khare, R., 1991)

HCl:H₂O (1:20); electrolyte for photoelectrochemical etching of GaAs and InP; etch rates and profiles for via hole fabrication are given; Ref. (Khare, R., 1993a)

HCl:H₂O (1%); Photoetch of GaAs; Ref. (Mottet, S., 1983)
Photoelectrochemical dopant selective and bandgap selective etch; HCl:H$_2$O (1:20) electrolyte; GaAs/AlGaAs structures; dependence on band structure; Ref. (Khare, R., 1993b)

HCl (0.5 M); photoelectrochemical depth profile etch for AlGaAs/GaAs; Ref. (Wei, C., 1992)

H$_2$SO$_4$:H$_2$O$_2$:H$_2$O (3:1:1); GaAs selective n- from p-photoetching; Ref. (Kuhn-Kuhnenfeld, F., 1972)

H$_2$SO$_4$:H$_2$O$_2$:H$_2$O (1:1.3:25); GaAs semi-insulating, laser-induced etching for via holes and diffraction gratings; Ref. (Osgood, R.M., 1982)

H$_2$SO$_4$:H$_2$O$_2$:H$_2$O; GaAs n-type photoetching behavior; Ref. (van de Ven, J., 1991)

H$_2$SO$_4$:H$_2$O$_2$:H$_2$O; (1:1:100); maskless grating etch; Ref. (Podlesnik, D.V., 1983)

H$_2$SO$_4$:H$_2$O$_2$:H$_2$O (1:1:50); photochemical, maskless grating etch; Application: GaAs submicrometer optical gratings; Ref. (Matz, R., 1986)

H$_2$SO$_4$:H$_2$O$_2$:H$_2$O (1:1:n, 10 < n < 50); laser-induced photochemical wet etching of GaAs; formation of ripples; Ref. (Tsukada, N., 1983)

H$_2$SO$_4$:H$_2$O$_2$:H$_2$O (10:13:250); Photoetch of GaAs; Ref. (Mottet, S., 1983)

H$_2$O$_2$/H$_2$SO$_4$ and S$_2$O$_8^{2-}$/H$_2$SO$_4$ aqueous solution electrolytes; GaAs photoetch behavior; Ref. (van de Ven, J., 1990b)

H$_2$SO$_4$:NaSCN solution electrolyte for GaAs p-type photoetch; Ref. (Ostermayer, F.W., 1981)

HF:H$_2$O (1:10); GaAs p–n junction delineation; Ref. (Ruberto, M.N., 1991)

HF:HNO$_3$:H$_2$O (4:1:50); Application: GaAs photoetch for waveguide fabrication; Ref. (Willner, A.E., 1989)

H$_3$PO$_4$:H$_2$O$_2$; GaAs etch pit and layer delineation; Ref. (Gottschalch, V., 1979a)

CrO$_3$:HF; photoetch chemical kinetics; Ref. (van de Ven, J., 1986b)

NaOH:EDTA electrolyte; use of N-ion surface damage as an etch mask; Ref. (Yamamoto, A., 1975)

I$_2$:KI:H$_2$O (1:10:89); photochemical etchant for n-GaAs laser-induced maskless grating etching; Ref. (Aoyagi, Y., 1985)

I$_2$:KI:H$_2$O (0.1:10:90); n-GaAs photoetchant for maskless laser-induced patterning; Ref. (Haynes, R.W., 1980)

I$_2$:KI:H$_2$SO$_4$; study of etch and photoelectrochemical etch of Al$_{0.25}$Ga$_{0.75}$As and GaAs on etch conditions; Ref. (Verpoort, P.J., 1995)
Br₂:KBr:H₂O (1:10:89); n-GaAs photoetchant for maskless laser-induced patterning; Ref. (Haynes, R.W., 1980)

Maskless laser-induced etching of GaAs in KOH; Ref. (Lee, C., 1990)

KOH:H₂O (1:10); GaAs n-type laser-induced etch; Ref. (Osgood, R.M., 1982)

KOH 1 M solution; voltage controlled photoetching of GaAs, self limiting to depletion layer for n-type for FETs; Ref. (Hoffmann, H.J., 1981)

KOH:H₂O (1 and 5%); Photooetch of n-GaAs; no etch without illumination; does not attack AuGe contacts; Application: focused laser beam microetching; Ref. (Mottet, S., 1983)

KOH (1 M); selective photoetch of n-GaAs from stop layer of low-temperature MBE grown GaAs:As; Ref. (Chen, E.H., 1995)

1 M KOH aqueous solution; GaAs n-type voltage-controlled photoetching at 26°C; self-limiting to thickness of the depletion layer for FETs; Ref. (Hoffmann, H.J., 1981)

Tiron (0.5 M); electrolyte for photoelectrochemical enhancement of defect structure on GaAs surfaces

Sodium dihydrogen orthophosphate (0.3 M); electrolyte for photoelectrochemical enhancement of defect structure on GaAs surfaces; Ref. (Faktor, M.M., 1978)

NiSO₄ (0.8 M) with pH adjusted to 2–3 with H₂SO₄, H₂O diluted; nanoscale photoelectrochemical etch of GaAs with STM; Ref. (Kaneshiro, C., 1997)

UV illuminated etch for deep features, via holes; Ref. (Podlesnik, D.V., 1984)

Anodize-strip thinning, GaAs; Ref. (Shimano, A., 1979)

Anodic thinning, GaAs; Ref. (Thrush, E.J., 1974)

GaAs n-type photoetching study; Ref. (van de Ven, J., 1990a)

Relationship of semiconductor etching to the Fermi level for electrochemical and photochemical techniques; GaAs and GaP; Ref. (Gerischer, H., 1978)

Laser-induced etching in CH₃Br; Ref. (Osgood Jr., R.M., 1983)

Electrochemical C–V profiling:

p–n AlGaAs with 1 M NaOH electrolyte (gives poor results)

p–n GaAs with 0.1 M EDTA/0.2 M NaOH electrolyte (gives good results); Ref. (Cabaniss, G.E., 1988)

Photoelectrochemical etching of n-GaAs with H₂SO₄:H₂O₂:H₂O and KOH electrolytes and n-InP with HCl:HNO₃:H₂O electrolyte; Ref. (Svorcik, V., 1988)
Maskless photoetching of InP and GaAs using ion implantation damage mask patterning; (Chi, G.C., 1986)

Ferric sulfate (non-ahydrate):EDTA (disodium salt of ethylenediaminetetraacetic acid):H₂O (5 g:3 g:100 ml); GaAs photoelectrochemical p–n junction delineation; Ref. (Greene, P.D., 1977)

Photoelectrochemical etching of n-GaAs; dependence on orientation and doping concentration; 0.5 M Tiron electrolyte (4,5-dihydroxy-1,3-benzenedisulfonic acid); shows cross-sectional profiles; Ref. (Carrabba, M.M., 1987)

Photoelectrochemical etch of GaAs using electrolytes of either 1 M KCl or 0.5 M Tiron (4,5-dihydroxy-1,3-benzenedisulfonic acid, disodium salt); pH = 7, non-corrosive, compatible with photoresists; Application: sawtooth grating fabrication; Ref. (Carrabba, M.M., 1986)

Photoetching of n-GaAs in KCl, KOH, and HCl electrolytes; Ref. (Haisty, R.W., 1961)

Photoelectrochemical etch; KCl electrolyte; GaAs; Application: sawtooth gratings using photoresist mask; Ref. (Li, J., 1988)

High resolution photoelectrochemical etch of GaAs with scanning tunneling microscope; Ref. (Lin, C.L., 1998)

Photoetch of micrometer size features in GaAs using a scanned focused laser beam; KOH electrolyte; Ref. (Rauh, R.D., 1985)

Review: Photochemical processing of semiconductors; Ref. (Rauth, D.R., 1992)

**GaSb**

Photochemical etching of n-GaSb; NaOH and HCl electrolytes; aerated solution to oxidize Sb; matte gray, faceted surface; Ref. (Propst, E.K., 1993)

EDTA:NH₄OH (0.2 M ethylene diamine tetraacetic acid disodium salt with ammonium hydroxide for pH control); electrolyte for photoelectrochemical etching of GaAs and GaSb; Ref. (Elliott, C.R., 1980)

**GaP**

HNO₃; GaP oxidation/etching kinetics; Ref. (Hsieh, H.F., 1992)

H₃PO₄:H₂O₂ (1:1); GaP etch pit and layer delineation; Ref. (Gottschalch, V., 1979a)

HCl; photochemical; InAs and GaP etch characteristics under illumination; reaction kinetics dependence on semiconductor band structure; Ref. (Hsieh, H.F., 1993)

Relationship of semiconductor etching to the Fermi level for electrochemical and photochemical techniques; GaAs and GaP; Ref. (Gerischer, H., 1978)
GaN

KOH solution + 0.02 M K₂S₂O₈; photoenhanced etching of GaN using a Pt mask; Ref. (Bardwell, J.A., 1999)

Tartaric acid (3 w/o) buffered with NH₄OH:ethylene glycol (1:2); electrolyte for GaN photoassisted anodic etch; rate dependence on current and pH; Ref. (Lu, H., 1997)

HCl:H₂O (1:10); photoelectrochemical etch of GaN; rates of a few hundred Å/min

KOH:H₂O (1:3); photoelectrochemical etch of GaN; rates of several μm/min; Ref. (Minsky, M.S., 1996)

NaOH (0.1 mol l⁻¹):NaCl (0.03 mol l⁻¹); electrolyte for photoinduced electrochemical etching of GaN; Ref. (Ohkubo, M., 1999)

KOH (0.5 M); electrolyte for photoinduced electrochemical smoothing-etch for GaN surfaces; Ref. (Rotter, T., 1999)

KOH (0.1 M); electrolyte for photoenhanced electrochemical etching of GaN; Ref. (Stocker, D.A., 1999)

Si

HF:H₂O; Si photoetch; Ref. (Hoffman, H.J., 1989)

HF:HNO₃:CH₃COOH (1:3:1); Si dislocation etch pit delineation; Ref. (Schimmel, D.G., 1976)

HF:HNO₃ (155:1); Si dislocation etch pit delineation; Ref. (Schimmel, D.G., 1976)

2.5.2. Electrochemical etching

InP

Review of electrochemical behavior of semiconductor electrodes; Ref. (Gerischer, H., 1959)

HCl:H₂O; Shows data for InP etch rate dependence on dilution. InP electrochemical behavior shows HCl etching is purely chemical; Ref. (Notten, P.H.L., 1984)

HCl dilute (pH = 1.0); electrolyte for electrochemical etching of InP; study of reaction using voltammetry, XPS and STM; Ref. (Kaneshiro, C., 1998)

Anodization: InP; defect delineation; Ref. (Elliott, C.R., 1981)

Plasma anodic oxidation; InP; Ref. (Fujuki, T., 1983)

Electrochemical etch of InP in aqueous bromine solutions
CH₃COOH:HBr:Br₂; mechanism of p-InP etch rate in dark and under illumination; Ref. (Notten, P.H.L., 1987)

NH₃F₂:o-H₃PO₄ (UNIEL); Electrolyte for EC-V profiling InP and GaAs; Ref. (Faur, M., 1994b)

ECV profiling; InP; unidentified electrolyte compared with HCl; Ref. (Faur, M., 1991a)

o-H₃PO₄:HNO₃:H₂O₂:H₂O; InP thinning etch; with concentration dependent etch rates from 5 to 110 nm/min; Ref. (Faur, M., 1991b)

Electrochemical C–V profiling; III–V semiconductor carrier concentrations; Ref. (Jackson, N.F., 1992)

Analysis of resolution for light defined patterns in photoelectrochemical etching of InP; Ref. (Ostermayer, F.W., 1985)

HCl:H₂O; Application: InP n-type photoelectrochemical etch with the sample biased to form a surface depletion layer; forms deep narrow grooves; Ref. (Bowers, J.E., 1985)

HCl (1.2 M); electrolyte (pH = 0) for study of anodic dissolution of InP; Ref. (Erné, B.H., 1993)

Tartaric acid (40%):H₂O₂ (30%) (3:1); InP; rate =~ 2000 Å/h; used as Schottky contact for C–V carrier concentration profiling; Ref. (Lile, D.L., 1978)

**InGaAsP**

Anodization; InGaAsP in 0.1 M ammonium phosphate dibasic solution electrolyte; Ref. (Law, H.D., 1980)

2 M HF:0.5 M KOH solution electrolyte; InP and InGaAsP holographic photoetch for diffraction gratings on a biased sample with a depletion region at its surface; Ref. (Lum, R.M., 1985)

Br-containing alkylate electrolytes; study of electrochemical mechanism; selectivity of InGaAs over InP; Ref. (Theuwis, A., 1999a)

H₂SO₄ (1.3 mol/l); (photo)electrochemical and etching properties of n- and p-In₀.₅₃Ga₀.₄₇As

H₂SO₄:H₂O₂ (1.3 mol/l); electrochemical and etching properties and mechanism of n- and p-In₀.₅₃Ga₀.₄₇As and InP; conduction band studies; Ref. (Theuwis, A., 1997)

**GaAs**

3 M ammonium tartarate; GaAs, electrolyte for electrochemical C–V profiling; Ref. (Akatsu, Y., 1987)
HNO₃:H₂O (1:10–100); GaAs and AlGaAs non-selective etch under illumination

HNO₃:H₂O (1:200); GaAs selective etch from AlGaAs under illumination
HNO₃:H₂O (1:300–1000); weak etching for both GaAs and AlGaAs with trench at boundary between illuminated and dark regions; Ref. (Fink, Th., 1993a)

HNO₃:H₂O (1:20); GaAs n-type photoelectrochemical etch; no measurable etch without illumination; similar etch rates for AlGaAs; applied bias shows a current minimum as a GaAs/AlGaAs interface is crossed during etching; surface roughness limits assessment of MQWs; Ref. (Fink, Th., 1993b)

HCl:H₂O (1:20); GaAs n-type selective photoetch from GaAs p-type, selectivity > 15,000. GaAs n-type selective etch from GaAs semi-insulating, selectivity ~ 30; Ref. (Khare, R., 1991)

Relationship of semiconductor etching to the Fermi level for electrochemical and photochemical techniques; GaP, GaAs; Ref. (Gerischer, H., 1978)

KOH aqueous solution; GaAs n-type voltage-controlled photoetching at 26°C; self-limiting to thickness of the depletion layer for FETs; Ref. (Hoffmann, H.J., 1981)

Review of GaAs etching, GaAs electrochemical etching, GaAs thermochemical etching; Ref. (Kern, W., 1978a)

Electrochemical etch; GaAs; NaOH electrolyte; removal of p substrate from n-layer; Ref. (Nuese, C.J., 1970)

Anodic etching with a mechanically scanned jet of KOH (20%) electrolyte with the etching current controlled by IR transmitted intensity to achieve uniform thickness; Ref. (Thrush, E.J., 1978)

Two step thinning: (1) p-GaAs substrate is anodically dissolved down to an n-blocking layer. (2) H₂SO₄:H₂O₂ (3:2) photoetch removes n-blocking layer from the thin p-layer; Ref. (Thrush, E.J., 1974)

H₂O₂/H₂SO₄ and S₂O₈²⁻/H₂SO₄ aqueous solution electrolytes; Study: GaAs photochemical etch behavior; Ref. (van de Ven, J., 1990b)

Electrochemical etch study on GaAs; redox processes and photoeffects on III–V etchant selectivity; Ref. (Hollan, L., 1979)

NH₃F₂:o-H₃PO₄ (UNIEL); Electrolyte for EC-V profiling InP and GaAs; Ref. (Faur, M., 1994b)

Electrochemical C–V profiling; GaAs carrier concentration and electron mobility using Tiron electrolyte (1,2-dihydroxybenzene-3,5-disulphonic acid, disodium salt, aqueous solution); Ref. (Ambridge, T., 1979a)

KOH; electrolyte for Schottky contact in ECV profiling; Ref. (Ambridge, T., 1974a,b,c, 1975, 1980)

GaAs etch and electrochemical etch mechanism study; Ref. (Minks, B.P., 1989)
GaP

Electrochemical dissolution study of GaP in electrolytes of NaOH, K\textsubscript{3}Fe(CN)\textsubscript{6}, H\textsubscript{2}SO\textsubscript{4}; Ref. (Memming, R., 1968)

GaN

NaOH (0.1 mol/l); anodic etching of GaN films results in accumulated gallium oxide deposits and slow etch rates

NaOH (0.1 mol/l):NaCl (0.2 mol/l); anodic etching of GaN films with reduced surface deposits and accelerated etch rates; Ref. (Ohkubo, M., 1998)

NaOH (0.1N) electrolyte for etching GaN; Ref. (Pankove, J.I., 1972)

Si

Review of Si and Ge etching and photoetching; Ref. (Kern, W., 1978a)

2.6. Rate monitoring

Etch rate monitoring; in situ optical interferometric technique

H\textsubscript{2}SO\textsubscript{4}:H\textsubscript{2}O\textsubscript{2}:H\textsubscript{2}O (1:4:60); AlGaAs/GaAs; in situ measurement of growth rate temperature dependence

NH\textsubscript{4}OH:H\textsubscript{2}O\textsubscript{2}:H\textsubscript{2}O (20:2:100); AlGaAs/GaAs; in situ measurement of growth rate dependence on solution stirring; Ref. (Wipiejewski, T., 1993)

Real time monitoring control of etch depth using spectroscopic ellipsometry; Ref. (Cho, S.-J., 1999)

HCl (1 M); monitoring of grating depth during photoelectrochemical etching on n-InP; Ref. Soltz, D., 1996b)

Real-time etch rate monitoring by optical interferometry of AlGaAs/GaAs and InGaAsP/InP structures

NH\textsubscript{4}OH:H\textsubscript{2}O\textsubscript{2}:H\textsubscript{2}O (3:1:50); AlGaAs/GaAs thinning etch; Ref. (Chand, N., 1993)

Etch depth monitoring with laser reflectometry; Ref. (Cho, H.K., 1999)

2.7. Etch safety

Lactic acid:HNO\textsubscript{3}:HF (50:8:2); Safety caution: This etchant evolves heat and gas when stored which can explosively burst capped containers; Ref. (Bubar, S.F., 1966)Br/methanol; Safety

1. Protect against skin contact; capable of severe burns
2. Strong oxidizer; keep away from organic materials which can ignite; keep away from reducing agents (sodium, zinc, ammonium compounds) to avoid explosion
3. Spilled Br or Br/methanol can be neutralized with 5–10% sodium thiosulfate solution; Ref. (Walker, D.M., 1980)

HCl-based etchants; dissolution of InP leads to formation of phosphine (PH\textsubscript{3}) gas; Ref. (Notten, P.H.L., 1984) (use proper ventilation for personnel protection)
3. Dry etch applications

3.1. Dry etch reviews

Review: InP etching overview; wet chemical and dry etching; Ref. (Adachi, S., 1990a)
Review: GaAs etching overview; wet and dry etching; Ref. (Ashby, C.I.H., 1990a)

Review of plasma etching and reactive ion etching principles; Si; Ref. (Coburn, J.W., 1982)

Plasma etch; CCl₄, CHCl₃, CF₂Cl₂, BCl₃; InP and GaAs review; Ref. (Donnelly, V.M., 1983)

Dry etch review: description of process mechanisms for ion etching and plasma etching; Ref. (Melliar-Smith, C.M., 1978)

Review: ion beam milling and sputtering of InP; with summary table of ion beam etching giving etch conditions and etch rates; Ref. (Matsushita, K., 1990b)

Review: laser-assisted etching of InP; with summary table of etchants, etch conditions, and etch rates; Ref. (Matsushita, K., 1990d)

Review: plasma etching of InP; with table of typical etchants, etch conditions and etch rates; Ref. (Matsushita, K., 1990a)

Review: reactive ion etching and ion-beam etching of InP; with summary table of etchants, etch conditions, and etch rates; Ref. (Matsushita, K., 1990c)

Review: ion-assisted etching of GaAs; RIE, RIBE, IBAE, and RBIBE techniques; with tables of etchants, etch conditions, and etch rates; Ref. (Ashby, C.I.H., 1990b)

Review: ion-beam milling and sputter etching of GaAs; with table of etchants, etch conditions, and etch rates; Ref. (Ashby, C.I.H., 1990c)

Review: laser-assisted etching of GaAs; with table of etchant, etch conditions, and etch rates; Ref. (Ashby, C.I.H., 1990d)

Review: plasma etching of GaAs; with table of etchants, etch conditions, and etch rates; Ref. (Ashby, C.I.H., 1990e)

Review: dry etching of InP; Ar ion milling, reactive ion etching and ion beam-assisted I₂ and Cl₂ etching; gives comparison of results; Ref. (Doughty, G.F., 1986)

Review: dry etching processes; classification of dry etching as: physical, chemical, chemical-physical, and photochemical; tabulates the approaches and their characteristics; Ref. (Fonash, S.J., 1985)

Review: projection lithography using excimer laser; includes photochemical etching; Ref. (Rothschild, M., 1988)
Review: ion beam-assisted etching of semiconductors; Ref. (Zalm, P.C., 1986)

Review: plasma etching; Ref. (Flamm, D.L., 1989)

Review: dry etch processes for InP-based materials; Ref. (Niggebrügge, U., 1991)

Review: plasma etching of III–Vs; Ref. (Hu, E.L., 1987)

Review of dry etch damage in III–V semiconductors; techniques for differentiating sidewall damage from surface damage. Damage is greatest when neutral ions are present; Ref. (Murad, S., 1996b)

Review: high ion density dry etching; ECR; ICP; of GaAs, GaSb, InP, AlGaAs, GaN, InGaN, InGaAs; Ref. (Pearton, S.J., 1996d)

ECR plasma etch; BCl₃, CCl₂F₂/O₂, SF₆/Ar, CH₄/H₂/Ar; processing for GaAs/AlGaAs and InP/InGaAs structures; Ref. (Pearton, S.J., 1994e)

ECR plasma etch with CH₄/H₂/Ar under various conditions for InP/GaP/GaAs/InGaAs/AlGaAs/InGaAsP; Ref. (Pearton, S.J., 1996b)

ECR high power plasma etch; CH₄/H₂/Ar; of InP, GaAs, GaP, AlGaAs, InGaAs, InGaAsP; Ref. (Pearton, S.J., 1996c)

Review: dry etching of GaAs (plasma, RIE, RIBE, ion milling); Ref. (Williams, R.F., 1990)

Review: chlorine-based dry etching of III–V semiconductors; advantages of ECR/RIBE over conventional RIE; Ref. (Asakawa, K., 1998)

Reactive ion etching; modeling of ion-induced damage in III–V semiconductors; Ref. (Hu, E.L., 1997a)

3.2. Dry etch-ion sputtering, plasma, and reactive ion etching

InP

Review: ion beam milling and sputtering of InP; with summary table of ion beam etching giving etch conditions and etch rates; Ref. (Matsushita, K., 1990b)

Review: laser-assisted etching of InP; with summary table of etchants, etch conditions, and etch rates; Ref. (Matsushita, K., 1990d)

Review: plasma etching of InP; with table of typical etchants, etch conditions and etch rates; Ref. (Matsushita, K., 1990a)

Review: reactive ion etching and ion-beam etching of InP; with summary table of etchants, etch conditions, and etch rates; Ref. (Matsushita, K., 1990d)

Reactive ion etch; Cl₂; Ref. (Barker, R.A., 1982); (Bosch, M.A., 1981)
Reactive ion etch; Cl\textsubscript{2}, Cl\textsubscript{2}/O\textsubscript{2} (4:1); InP photolithography; Ref. (Coldren, L.A., 1981b)

Reactive ion etch; Cl\textsubscript{2}/Ar/O\textsubscript{2}; Application: followed by HCl etch for vertical sidewall laser mirror; Ref. (Coldren, L.A., 1982a,b, 1983)

Reactive ion etch; CH\textsubscript{4}/H\textsubscript{2}; InP etch kinetics; Ref. (Hayes, T.R., 1989a,b)

Reactive ion dry etch in Cl\textsubscript{2}/O\textsubscript{2} which leaves the pattern with an initial 75° wall angle; followed by HCl wet etch to form 90° facets; Ref. (Hemenway, B.R., 1983)

Reactive ion etch; CCl\textsubscript{2}F\textsubscript{2}/Ar/O\textsubscript{2}; Ref. (Hu, E.L., 1980)

Reactive ion etch; CH\textsubscript{4}/H\textsubscript{2}; InP anisotropic etching; Ref. (McNabb, J.W., 1991)

Reactive ion etch; Cl\textsubscript{2}, CCl\textsubscript{2}F\textsubscript{2}; GaAs and InP; Ref. (Pang, S.W., 1991)

Reactive ion etch; SiCl\textsubscript{4}, SiCl\textsubscript{4}/Ar; InP and GaAs (1 0 0); Ref. (Stern, M.B., 1983)

Reactive ion etch; C\textsubscript{2}H\textsubscript{6}/H\textsubscript{2}; Study: InP SiO\textsubscript{2} masked 240 nm period grating etch; shows profiles; Ref. (Sugimoto, Y., 1992a)

Reactive ion etch; CHF\textsubscript{3}/H\textsubscript{2}; Study: InP grating etch; Ref. (Tennant, D.M., 1992)

Reactive ion etch; CCl\textsubscript{2}F\textsubscript{2}/Ar/O\textsubscript{2}; InP and GaAs; Ref. (Turley, S.E.H., 1982)

Reactive ion etch study; Cl\textsubscript{2}/Ar/CH\textsubscript{4}/H\textsubscript{2}; InP photolithography sidewall damage; Ref. (van Roijen, R., 1992)

Reactive ion etch; Cl, CCl\textsubscript{2}F\textsubscript{2}, CHF\textsubscript{3}; InP and GaAs (1 0 0) for grating fabrication; Ref. (Yuba, Y., 1983b)

Reactive ion etch; CH\textsubscript{4} + H\textsubscript{2}; Application: InP mesa etch with SiN\textsubscript{x} mask; Ref. (Nordell, N., 1992b)

Reactive ion etch; CCl\textsubscript{4}/O\textsubscript{2}; Application: InP laser gratings; Ref. (Hirata, K., 1984)

Reactive ion beam etch; Cl\textsubscript{2}; InP; photoluminescence study of surface damage; Ref. (Tadokoro, T., 1990)

Reactive ion etch; Br\textsubscript{2} + N\textsubscript{2}; Br\textsubscript{2} + Ar; Application: etched facet laser of InP; Ref. (Takimoto, K., 1989)

Reactive ion beam etch; Cl\textsubscript{2}; GaAs and InP; Ref. (Tadokoro, T., 1988, 1989)

Reactive ion etch; ClCH\textsubscript{3} with H\textsubscript{2}, He, O\textsubscript{2}, Ne or Ar; GaAs and InP; GaAs and InP etch selectivity depend on gas combinations; Ref. (Law, V.J., 1992)

Reactive ion etching; Ar, He, CH\textsubscript{4}/H\textsubscript{2}, CH\textsubscript{4}/Ar, CH\textsubscript{4}/He, CH\textsubscript{4}/H/Ar; InP structural and electrical modifications studied by Raman spectroscopy; Ref. (Maslar, J.E., 1993)
Reactive ion etching; CH$_4$/H$_2$; InP; deep etching with photoresist and SiO$_2$ masks; near vertical sidewalls and flat bottoms; Ref. (Niggebrugge, U., 1985)

Reactive ion etch; CH$_4$/H$_2$/CO$_2$; Application: InP waveguide and mirror facet etch; Ref. (Schilling, M., 1994)

Reactive ion etch; SiCl$_2$/Cl$_2$ at 240°C; Application: InP/InGaAsP waveguides and mirrors; Ref. (Schneider, J., 1994)

Reactive ion etch; Ni- and W-masked pattern structures on InP using SiCl$_4$; damage characterization; Ref. (Manin-Ferlazzo, L., 1999)

Reactive ion etch; O$_2$/CH$_4$/H$_2$/Ar; InP, use of O$_2$ to prevent etch limiting polymer build-up in 10 µm deep laser mirror fabrication; Ref. (Schramm, J.E., 1994a)

Reactive ion etch; Cl$_2$/BCl$_3$/Ar and CCl$_2$F$_2$/BCl$_3$/Ar for III–V compounds; Ref. (Juang, Y.Z., 1994)

Reactive ion etch; CH$_4$/H$_2$; InP and InGaAsP selective from InAlAs; fluorine free to use with SiO$_2$ masks; Ref. (Arnot, H.E.G., 1993b)

Reactive ion etch; Cl$_2$/HBr/BCl$_3$/Ar; InP via holes; Ref. (Hur, K.Y., 1994a)

Reactive ion etch; Cl$_2$/HBr/BCl$_3$/Ar; Application: using lift-off carbon masks for etching deep features on InP; Ref. (Hur, K.Y., 1994b)

Reactive ion etch; C$_2$H$_6$; Application: InP grating photolithography; Ref. (Matsuda, M., 1991)

Reactive ion etch, first step pattern etch in InP using CH$_4$/H$_2$. (for MOVPE regrowth); Ref. (Bertone, D., 1999)

Reactive ion etch of InP-based materials with CH$_4$/H$_2$; damage study; Ref. (Böttner, Th., 1996)

Reactive ion etch of Si$_3$N$_4$ masked InP mesas, followed by wet etch for controlled undercutting of mask in preparation for MOVPE regrowth; Ref. (Fang, R.Y., 1997)

Reactive ion etch; CH$_4$/H$_2$; InP; study of etch mechanism; Ref. (Feurprier, Y., 1997)

Plasma etching of InP in CH$_4$–H$_2$ mixtures; study of etch mechanism; Ref. (Feurprier, Y., 1998a)

Reactive ion etch; CH$_4$/H$_2$; of InP; study of surface damage with X-ray photoelectron spectroscopy; Ref. (Feurprier, Y., 1998b)

Reactive ion etch; CF$_6$, SF$_6$; selective removal of tungsten from III–V semiconductors using a titanium etch mask; Ref. (Fullowan, T.R., 1992b)

Reactive ion etch of InP in CH$_4$/H$_2$; reaction modeling; Ref. (Houlet, L., 1999)
Reactive ion etch of InP using CH$_4$/H$_2$/Ar; damage study; Ref. (Hu, E.L., 1996b)

Reactive ion beam etch; N$_2$/O$_2$ of InP; characterization of surface damage; Ref. (Iber, H., 1997)

Reactive ion etch of InP using CH$_4$/H$_2$; uniformity study; Ref. (Janiak, K., 1996)

Reactive ion etch; CHF$_3$/O$_2$; removal of SiN$_x$ mask from InP; Ref. (Kollakowski, St., 1998)

Reactive ion etch of InP using CH$_4$/H$_2$; investigation of oxide residues. HF, dilute; removal of oxide residues from RIE etched InP prior to regrowth; Ref. (Lee, B.-T., 1996)

Reactive ion etch of InP mesas using CH$_4$/H$_2$; characterization of mesa sidewall deposits; Ref. (Lee, B.-T., 1999)

Reactive ion etch; CH$_4$/H$_2$/Ar; Application: mesa etch on InP for MOCVD regrowth; Ref. (Nordell, N., 1992a)

Reactive ion etch; CH$_4$/H$_2$; Application: mesa etch on InP prior to MOCVD regrowth; Ref. (Nordell, N., 1991)

Reactive beam etching of InP using Br$_2$ + N$_2$; fabrication of 250 nm period diffraction grating; Ref. (Oku, S., 1997)

Reactive ion etching; CH$_4$/H$_2$/O$_2$/Ar; InP-based materials; 10 μm vertical etch profiles; Ref. (Schramm, J.E., 1997)

Reactive ion etch; CH$_4$/H$_2$; Application: InP laser diode mesa formation; followed by oxygen plasma treatment to remove RIE etch polymer by-products. H$_2$SO$_4$; treatment to remove RIE etch polymer by-products; Ref. (Yamamoto, N., 1998)

Reactive ion etch of InP using H$_2$/CH$_4$; surface study using focused Ga + ion beam — SIMS; Ref. (Yu, S., 1999)

Reactive ion etching; CH$_4$/H$_2$ and C$_2$H$_6$/H$_2$; electrical measurement study of InP surface damage; Ref. (Yamamoto, N., 1997a)

Reactive ion etching; C$_2$H$_6$/H$_2$ of InP; electrical drift from etch-induced deep donor defects; Ref. (Yamamoto, N., 1997b)

Reactive ion etch in Cl$_2$ of InP, GaAs, ZnSe and ZnTe; conditions for smooth etching and assessment of surface damage; Ref. (Yoshikawa, T., 1996)

Reactive ion etching; Cl$_2$; InP; Ref. (Van Roijen, R., 1992)

RIE Ar ion damage study; comparison of GaAs and InP; Ref. (Yu, D.G., 1997a)
Reactive ion etch; CH₄/H₂/Ar of InP; improved interfaces of regrown material due to hydrogen interaction with defects; Ref. (Yu, D.G., 1996)

Plasma etch; CF₄; InP surface damage study by photoreflectance; Ref. (He, L., 1991)

Plasma etch; CCl₄, CHCl₃, CF₂Cl₂, BCl₃; Ref. (Donnelly, V.M., 1983)

Plasma etch; PCl₃/Ar, CCl₂F₂/Ar, CH₄/H₂/Ar; AlInP selective etch from GaAs; Ref. (Lothian, J.R., 1992c)

Plasma etch; HBr/H₂, HBr/CH₄, HBr/Ar, GaAs, GaSb, AlGaAs, InP, InSb, InGaAs, InAlAs; gives data on etch rates and photolithographic etch profiles; Ref. (Pearton, S.J., 1992a)

Plasma etch; CCl₃F/O₂; Ref. (Burton, R.H., 1982, 1983)

Plasma etching; CH₄/H₂; GaAs and InP etch characteristics dependence on temperature; gives favorable surface roughness compared with Cl-based etchants; Ref. (Carter, A.J., 1989)

ECR plasma etch; CH₄/H₂/Ar/Cl₂; InP via holes; Ref. (Khara, R., 1994)

ECR plasma; Study: SiO₂ mask etch on GaAs and InP; SF₆ gives superior SiO₂ sidewall smoothness than CF₄; Ref. (Ren, F., 1992b)

ECR plasma; Cl₂, BCl₃; Study: comparison on GaAs and InP; shows etch rate dependences on microwave power, RF power, sample placement, and temperature; Ref. (Pang, S.W., 1992b)

ECR plasma etch; CH₄ + H₂ + Ar; InP; addition of PCl₃ eliminates surface degradation; Ref. (Pearton, S.J., 1991b)

ECR etch; CH₄/H₂; InP and GaAs; comparison of multipolar and magnetic mirror ECR sources; Ref. (Pearton, S.J., 1994b)

Plasma damage; H₂ and Ar; on InGaAs and InP; Ref. (Pearton, S.J., 1992c)

ECR plasma etch; HI/H₂, CH₄/H₂ and C₂H₂/H₂; InP submicron gratings; Ref. (Pearton, S.J., 1992d)

Dry etch ion damage in InP; diffusion of defects; modeling of diffusion; Ref. (Yu, D.G., 1997b)

ECR etch; CH₄/Ar/H₂; InP nanometer size, Ag-masked features; Ref. (Wiedensohler, A., 1992)

ECR etch; Cl₂/CH₄/H₂; InP at 150°C for laser mesa fabrication; Ref. (Constantine, C., 1992)

ECR etch; HBr/H₂/AECR etch, HBr/H₂/Ar and HI/H₂/Ar, InP, GaAs, AlGaAs; effect of substrate temperature; Ref. (Chakrabarti, U.K., 1994)

ECR hydrogen plasma surface oxide removal from InP; Ref. (Holstra, P.G., 1995)
ECR etch of deep via holes in InP using Cl2/Ar; etch rate comparison for InP, GaAs, InGaAs, GaAlAs, AlInAs, SiO2, Ti and Ni; Ref. (Ko, K.K., 1995b)

ECR plasma etch; ICl/Ar and IBr/Ar; InP, InGaAs, InSb, GaAs, GaSb, AlGaAs; study of etch rates and morphologies; Ref. (Lee, J.W., 1997c)

ECR plasma etch; CH3Cl/Ar/H2 of InP; smooth, residue-free surfaces above 120°C; Ref. (Nozawa, H., 1998)

ECR etch; CCl2F2, BCl3, Cl2; study of GaAs and InP etch characteristics and comparison with RIE; Ref. (Pang, S.W., 1992a)

ECR etch of InP and GaAs using Cl2, BCl3 and CH4–H2 plasmas; Ref. (Pearton, S.J., 1994f)

ECR etch; Ar/Cl2 of InP via holes; dependence on wafer temperature; Ref. (Sabin, E.W., 1998)

ECR plasma etch; Ar, Ar/Cl2, Ar/Cl2/H2 and Ar/Cl2/H2/CH4; Study of etch dependence on temperature for InP, GaP, and GaAs; Ref. (Shul, R.J., 1996b)

ECR etch; Ar plasma; InP; study of plasma temperature effects; Ref. (Thomas III, S., 1996a)

ECR etch; Cl2/Ar of InP, GaAs and InGaAs; atomic force microscopy study of surface roughening; Ref. (Thomas III, S., 1995b)

ECR Cl2/Ar etch process for distributed Bragg mirrors in laser structures on InP and GaAs, using Ni mask; Ref. (Thomas III, S., 1996b)

ECR plasma etch; CH4/H2/Ar; InP etch process with rate in excess of 120 nm/min

RIE using CH4/H2/O2; InP etch process with rate in excess of 135 nm/min; Ref. (Whelan, C.S., 1997)

ECR plasma etch; Cl2/Ar; InP etch profile dependence on Cl2 concentration; Ref. (Ying, F., 1997)

Plasma etch; C2F3Cl3:O2; InP etch study; best results with C2F3Cl3:O2 (7:3); Ref. (Novakova, E.M., 1985)

Plasma etch; C2F3Cl3; InP etch study; rate dependence on pressure and temperature; Ref. (Novikova, E.M., 1986)

Plasma etch; C2F3Cl3:O2; InP etch study; best results with C2F3Cl3:O2 (7:3); Ref. (Novikova, E.M., 1986)

Plasma etch; hydrogen etching of GaAs, GaSb, InP and their oxides. InP etching preferentially removes phosphorus and leaves In to accumulate on the surface; Ref. (Chang, R.P.H., 1982)
Plasma etch; CCl₄; InP and GaAs; time dependent etch rates indicate inhibition of etching above 250°C by a chlorocarbon deposit; Ref. (Gottscho, R.A., 1982)

Plasma etch; Cl₂; InP and GaAs; non-volatile reaction by-product InCl₃ limits low temperature etching; Ref. (Donnelly, V.M., 1982)

Plasma etch; CCl₄; HCl; InP and GaAs; Ref. (Smolinsky, G., 1983)

Plasma etch; CH₄ + H₂ + Ar; InP; sidewall roughness is related to roughness of mask edge; Ref. (Chakrabarti, U.K., 1991)

Plasma etch; CH₄ + H₂; InP with SiO₂ and Si₃N₄ dielectric masks and with Al and Ti/Au metal masks; Ref. (Lothian, J.R., 1992d)

Plasma etch; BCl₃:Cl₂; GaAs, AlGaAs, InP; etch rate is temperature dependent; Ref. (Contolini, R.J., 1988)

Plasma etch; Ar; InP; study of induced defects; Ref. (Luo, J.K., 1992)

Inductively coupled plasma etch using CH₄/H₂/O₂ of InGaAs/InP HBTs; conditions for InGaAs selectivity of 30; Ref. (Etrillard, J., 1999a)

Inductively coupled plasma etch of GaAs and InP for HBTs using SiCl₄; Ref. (Etrillard, J., 1999b)

Study on InP of etch damage dependence on ion energy using CH₄/H₂/O₂; comparing inductively-coupled plasma etch to reactive ion etch; Ref. (Etrillard, J., 1996)

inductively coupled plasma etch; CH₄/H₂ of InP; study of pattern etching and etch damage; Ref. (Etrillard, J., 1997)

ICP and ECR etching of InP submicron pillars using SiCl₄/Ar; Ref. (Hatate, H., 1998)

Inductively couple plasma etch (ICP); Ar; of GaAs and InP; etch damage comparison to ECR etch; Ref. (Lee, J.W., 1997a)

Inductively coupled plasma (ICP) etch of InP using HBr/BCl₃/CH₄/H₂/Ar for Gunn diode mesa fabrication; Ref. (Liu, J.Q., 1988)

ICP etch of InP using SiCl₄/Ar; Ref. (Matsutani, A., 1998)

Inductively coupled plasma etch of InP using Cl₂/Xe; vertical, smooth patterns; Ref. (Matsutani, A., 1999)

Inductively coupled plasma etching of GaAs, GaP, InP in Cl₂/Ar, Cl₂/N₂, BCl₃/Ar, and BCl₃/N₂; comparison to ECR etch rates; Ref. (Shul, R.J., 1997b)

Plasma; H₂; InP, GaAs, InGaAs surface cleaning; Ref. (Tu, C.W., 1983)
H₂ plasma; high vacuum removal of surface contaminants from InP; Ref. (Tu, C.W., 1982)

InP surface cleaning in H₂ and H₂/CH₄/Ar plasmas; removes surface carbon and oxygen but depletes some surface phosphorus; Ref. (Parmeter, J.E., 1996)

Hydrogen remote plasma cleaning of InP surface, in situ in MOCVD reactor at 270°C provides an oxide-free surface superior to wet etching; Ref. (Losurdo, M., 1998)

Plasma etch of patterns in SiO₂ mask on InP using CHF₃/O₂; Ref. (Poole, P.J., 1999)

Ar ion beam-assisted Cl₂ etching of InP; Ref. (McNevin, S.C., 1986a)

Ar ion beam-assisted Cl₂ dry etching of InP; temperatures above 150°C are required to remove reaction products; Ref. (DeMeo, N.L., 1985)

Ar ion beam-assisted Cl₂ in situ etch for MBE InP; patterned by damage from a direct-write focused Ga ion beam; Ref. (Temkin, H., 1989)

Ion beam-assisted, maskless etch with 35 keV Ga⁺ focused ion beam in Cl₂ gas atmosphere; InP and Si; Ref. (Ochiai, Y., 1987)

Cl₂ focused ion beam etch; maskless etching; Ref. (Ochiai, Y., 1983)

Br₂-assisted Ar ion beam etch; smooth, vertical sidewalls in GaAs and InP; Ref. (Rossler, J.M., 1998)

Ar ion etching; Cl₂-assisted; Application: InP substrate patterning by etch of a Ga ion beam direct-write damage pattern; Ref. (Harriot, L.R., 1989)

Ion beam; Ar, CCl₂F₂; GaAs, AlGaAs, InP; Application: stripe waveguide profiles; Ref. (Webb, A.P., 1984)

Ar ion etch; reactive ion etch using iodine; InP; Ref. (Doughty, G.F., 1985)

Ar ion beam etch; InP for grating fabrication; Ref. (Yuba, Y., 1983a)

Ar ion etching; Application: InP LED microlenses; Ref. (Wada, O., 1984)

Ar ion beam etching; Application: InP spherical lens formation; Ref. (Wada, O., 1981)

Ar ion thinning for TEM; Ref. (Ueda, O., 1980b)

Ion milling; iodine, Ar, Xe; InP; Ref. (Chew, N.G., 1984)

Ar/O₂; CF₄, C₂F₆ and Ar ion milling of InGaAs, InP, GaAs, Si and Ge; gives etch rate comparison of reactive and non-reactive ion beam etching; reports different etching rates between photoresist and semiconductor; Ref. (Chen, W.X., 1986)
Ar ion sputter etching of InP; surface study; Ref. (Lau, W.M., 1987)

Ion beam etch; Ar + O₂; InP; Ref. (Webb, A.P., 1986)

Ion beam milling; Ar + O₂; InP; Ref. (Katzchner, W., 1984)

Ar ion sputter etch of InP; LN₂ cooled sample to improve surface morphology; Ref. (Bouadma, N., 1986)

Ion beam etching; CO; use of hafnium mask for GaAs and InP patterning; Ref. (Kempj, B., 1993)

Ar ion etch of InP; study of surface atomic bond lengths; Ref. (Mangat, P.S., 1993)

RIBE of InP-based materials with CH₄/H₂/Ar; etch is non-corrosive; Ref. (Boury, P., 1996)

RIBE of InP using CH₄/H₂/N₂; etch study; Ref. (Peyre, J.L., 1996)

RIBE of InP using trimethylamine/Ar; damage study; Ref. (Carlström, C.F., 1999)

Reactive ion beam etch and chemically-assisted ion beam etch using N₂/CH₄/H₂ and Ar/CH₄/H₂ of InP. CAIBE produces less polymer by-product; Ref. (Carlström, C.F., 1998)

RIBE/ECR etch; CH₄/H₂/N₂; InP, Raman study of etch damage; Ref. (Sendra, J.R., 1996a)

Chemically-assisted ion beam etch; Cl₂/BCl₃/IBr in a cryo-pumped vacuum system; GaAs and InP; Ref. (Daleiden, J., 1995)

CAIBE for InP optoelectronic devices using Cl₂, CH₃I and IBr₃; Ref. (Eisele, K.M., 1996)

CAIBE etch of InP using Cl₂/Ar; roughness from InCl₃ clusters; Ref. (Lamontagne, B., 1999)

CAIBE etch of undercut stripe in InP using Cl₂/Ar with tilted sample; Ref. (Poole, P.J., 1999)

CAIBE: comparison of Cl₂/Ar and HCl/Ar for etching InP; Ref. (Youtsey, C., 1995)

Cl₂-assisted Ar ion beam etch of InGaAsP/InP; optimum parameters for vertical sidewalls; at 250°C to accommodate low indium chloride volatility; Ref. (Youtsey, C., 1996)

CAIBE with Ar ion beam in Cl₂ ambient; InP patterning; comparison of mask materials: Cr/SiO₂, Ni, Ti, and hard baked photoresist; Ref. (Youtsey, C., 1994)

Cl-assisted RIE of InP; damage study; Ref. (Hu, E.L., 1996b)

Etch damage using low energy ions on semiconductors; Ref. (Hu, E., 1996a)

Focused Ga + ion beam patterning of InP; followed by HF (ultrasonic bath at 80°C) selective etch of the Ga implanted area to form a grating; Ref. (König, H., 1999)
ECR plasma oxidation; InP surface passivation; Ref. (Hu, Y.Z., 1993)

Plasma anodic oxidation; InP; Ref. (Fujuki, T., 1983)

Plasma oxidation; O₂, HNO₃; InP; Ref. (Michel, C., 1983)

**InGaAs**

Reactive ion etch; CF₄/O₂; InGaAs, study of surface treatment on photoluminescence behavior; Ref. (Juang, C., 1992)

Reactive ion etch; CH₄/H₂/Ar; Application: InGaAs FET gate etch; Ref. (Lecrossnier, D., 1987)

Reactive ion etch; CH₄ + H₂; Application: InGaAs/InP MQW rib waveguide; Ref. (Roberts, D.A., 1988)

Reactive ion etch; CH₄/H₂; CH₄/He; CH₄/Ar; Application: InP, InGaAs, InAlAs; InP etch rate = 800 Å/m; InGaAs etch rate = 400 Å/m; Ref. (Adesida, I., 1988)

Reactive ion etch; C₂H₆/H₂; InP, GaAs, InGaAs; excellent vertical walls and smooth surface are obtained at etching rate from 20 to 60 nm/min; this etchant gives high resolution and anisotropy with 2000 Å SiO₂ mask; Ref. (Matsui, T., 1988)

Reactive ion etching; CH₄:H₂; CH₃:Br; HBr; InGaAs selective etch from InAlAs; Ref. (Adesida, I., 1993)

Reactive ion etch surface damage assessment; InAlAs/InGaAs HEMTs; Ref. (Schramm, J.E., 1994b)

Reactive ion etch; CH₄/H₂/CO₂; Application: InGaAs(P)/InP mesa etch and laser mirror etch; Ref. (Ojha, S.M., 1994)

Reactive ion etch; CH₄/H₂, SiO₂ mask erosion and sidewall residues; InGaAsP/InP; Ref. (Lee, B.-T., 1993)

Reactive ion etch; assessment of damage in InAlAs/InGaAs heterostructures; Ref. (Agarwala, S., 1994)

Reactive ion etch; CH₄/H₂; Application: InGaAs/InP strip-loaded waveguides; sensitivity of optical loses to etch conditions; Ref. (Thirstrup, C., 1993)

Reactive ion etch; CH₄/H₂/Ar; InGaAs selective etch from InAlAs; Ref. (Schramm, J.E., 1993)

Reactive ion etch; HBr; InGaAs selective etch from InAlAs; selectivity of 160; Ref. (Agarwala, S., 1993a,b,c,d)

Reactive ion etch; CH₄/H₂; Application: InGaAs selective etch from InAlAs stop layer; Ref. (Lauterbach, Ch., 1991)
RIE; CH₄/H₂; Application: InGaAs/InP photodiode fabrication; Ref. (Park, C.-Y., 1995)

Reactive ion etch; CH₄/H₂; transistor gate recess etch; selective etch of InAlAs from InGaAs; Ref. (Cheung, R., 1996)

Reactive ion etch; CH₄/H₂ for gate recess in InGaAs/InAlAs HEMTs; AFM surface study; Ref. (Duran, H.C., 1995)

Reactive ion etch using CH₄ (8.3%) of InGaAs/InAlAs/InP for gate recess in HEMTs; Ref. (Duran, H.C., 1999)

Reactive ion etching; HBr for gate recess in InGaAs/InAlAs FETs; surface analysis; Ref. (Fay, P., 1994)

Reactive ion etch; CHF₃ + BCl₃; rate dependence on ternary composition for InAlAs and InGaAs; Ref. (Kao, H.-C., 1998)

Reactive ion etch of InAlAs/InGaAs using mixtures CHF₃ + BCl₃ and CF₄/BCl₃; selective removal of InGaAs from AlGaAs; Ref. (Lai, L.S., 1998)

Reactive ion etch; CH₄/H₂/Ar of InP/InGaAlAs/InGaAs heterostructure detectors; Ref. (Lemm, Ch., 1997)

Reactive ion etch; SiCl₄/SiF₄/HBr; selective etch of InGaAs and InP from InAlAs; pattern etch with masks of Si₃N₄ or NiCr; Ref. (Murad, S.K., 1995a)

Reactive ion etch; CH₄/H₂ of InGaAs; optimization; Ref. (Zavieh, L., 1998)

Reactive ion etch; CH₄/H₂/Ar of InP/InGaAlAs/InGaAs heterostructure detectors; Ref. (Kollakowski, St., 1998)

Reactive ion etch; CH₄/H₂/Ar; damage in AlGaAs/InGaAs MODFET structures; Ref. (Pereira, R., 1992)

Study of surface damage to InGaAs during Ar plasma exposure; suppression of damage in phosphine plasma; Ref. (Sugino, T., 1998)

ECR plasma etch; Cl₂; InGaAs study of etch rates and surface damage; Ref. (Thomas, S., 1994)

ECR etch; CH₄/H₂/Ar with PCl₃ added; InP and InGaAs; Ref. (Pearton, S.J., 1991d)

ECR plasma etch; Cl₂/Ar; InGaAs and GaAs etch; Ref. (Lee, W.-S., 1992)

ECR plasma etch; Cl₂/He; Application: InGaAs/AlGaAs HBT structures; Ref. (Miyakuni, S., 1992)

ECR plasma etch; Cl₂/N₂; Application: quantum box patterning in InGaAs/AlGaAs using Ni mask; Ref. (Ko, K.K., 1992)
ECR etch; Cl₂/CH₄/H₂; InGaAsP/InP; small dimension mesas and via holes; Ref. (Pearton, S.J., 1994a)

ECR plasma etch; CH₄/H₂/Ar; InGaAsP anisotropic dry etch; etch rates are independent of p- and n-doping levels; Ref. (Pearton, S.J., 1994d)

ECR etch; Cl₂/He; InGaAs/AlGaAs for HBTS; Ref. (Miyakuni, S., 1994)

ECR plasma etch; CH₄/H₂/Ar; Application to self-aligned InAlAs/InGaAs HBT; Ref. (Fullowan, T.R., 1992a)

ECR plasma etch of InGaAs/InP; comparison of CH₄/H₂/Ar and BCL₃/N₂; Ref. (Kopf, R.F., 1998)

ECR etch; Cl₂/Ar for etched mirrors in waveguides of In₀.₂₀Ga₀.₈₀As/GaAs; Ref. (Ko, K.K., 1995a)

ECR etching of InGaAs/InP using BCl₃ + N₂; end point monitoring using optical emission spectroscopy; Ref. (Kopf, R.F., 2000)

Cl₂ ICP plasma passivation of GaAs and InGaAs surface damage with Cl₂; Ref. (Berg, E.W., 1999)

Plasma damage; H₂ and Ar; on InGaAs and InP; Ref. (Pearton, S.J., 1992c)

Plasma etch; HBr/H₂, HBr/CH₄, HBr/Ar, GaAs, GaSb, AlGaAs, InP, InSb, InGaAs, InAlAs; gives data on etch rates and photolithographic etch profiles; Ref. (Pearton, S.J., 1992a)

Plasma; H₂; InP, GaAs, InGaAs surface cleaning; Ref. (Tu, C.W., 1983)

Plasma etch; CH₄/H₂ (1:5); Application: In₀.₅₃Ga₀.₄₇As/InP quantum well mesas; Ref. (Tai, K., 1988)

Ion beam etch; Ar/O₂, CF₄, C₂F₆ and Ar ion milling of InGaAs, InP, GaAs, Si and Ge; gives etch rate comparison of reactive and non-reactive ion beam etching; reports different etching rates between photoresist and semiconductor; Ref. (Chen, W.X., 1986)

Ion milling etch; Ar + O₂; InGaAs/InP quantum well structure profiling by photoluminescence at different depths; Ref. (Germann, R., 1988)

Ar ion-assisted Cl₂ selective etching of InP and InGaAs; Ref. (Temkin, H., 1988)

Ion beam etch; Ar + O₂; InGaAs/InP; induced damage is assessed from photoluminescence of a single quantum well; Ref. (Germann, R., 1989b)

Ar sputtering; In₀.₅₃Ga₀.₄₇As and In₀.₅₂Al₀.₅₃As; damage study

RIE; HBr; In₀.₅₃Ga₀.₄₇As and In₀.₅₂Al₀.₅₃As; damage study; Ref. (Maslar, J.E., 1995)

Chemically-assisted ion beam etch; Ar/Cl₂; Application: InGaAsP/InP laser facets; Ref. (Dzioba, S., 1993)
Chemically-assisted Ar ion beam etch with Cl$_2$; InP/InGaAs quantum dots prior to InP MOCVD regrowth; Ref. (Panepucci, 1996)

CAIBE; Cl$_2$ and BCl$_3$ with Ar ion beam; Application: laser mirrors in In$_{0.35}$Ga$_{0.65}$As/GaAs; Ref. (Sah, R.E., 1995)

CAIBE; mirror fabrication in InGaAs/GaAs/AlGaAs lasers; Cl$_2$/BCl$_3$/Ar at 60°C

CAIBE; mirror fabrication in InGaAs/InP lasers; IBr$_3$/Ar at 5°C; Ref. (Sah, R.E., 1996)

CAIBE; Cl$_2$/Ar; Application: patterned hole etch in InGaAs/InGaAsP Qws; Ref. (Scherer, A., 1998)

HBr photochemical dry etch; selectively removes InGaAs from InAlAs

H$_2$S:N$_2$ (1:9) photochemical gas sulfidization of In$_{0.52}$Al$_{0.48}$As; Ref. (Habibi, S., 1995b)

**InGaAsP**

Reactive ion etching; Cl$_2$/O$_2$; Application: InGaAsP/InP grooves and laser facets with vertical sidewalls and no undercutting; Ref. (Coldren, L.A., 1980)

Reactive ion etching; Cl$_2$/O$_2$; Application: InGaAsP/InP grooves and laser facets; Ref. (Coldren, L.A., 1981a)

Reactive ion etch; CH$_4$/H$_2$; Application: InP and InGaAsP grating with titanium layer mask; Ref. (Cremer, C., 1989)

Reactive ion etch; N$_2$, N$_2$/O$_2$; InP and InGaAsP etch profiles; Ref. (Katzchner, W., 1980)

Reactive ion etch; CCl$_4$/O$_2$; Application: InGaAsP/InP BH laser facet; Ref. (Mikami, O., 1983)

Reactive ion etch; chemically assisted; Application: InGaAsP/InP photodiode facet etch; Ref. (Williams, P.J., 1986)

Reactive ion etch; Cl$_2$ + O$_2$; Application: InGaAsP/InP deep groove etch for laser fabrication; Ti mask; Ref. (Coldren, L.A., 1984)

Reactive ion etch; C$_2$H$_6$ + H$_2$; Application: InGaAsP/InP lasers; InGaAsP etch rate < InP etch rate; vertical etched edges; Ref. (Matsui, T., 1989)

Reactive ion etch; CH$_4$ + Ar + H$_2$; InP, GaAs, InGaAs, AlGaAs and InGaAsP; Si$_3$N$_4$ mask is used; Ar reduces deposited hydrocarbon polymers and improves surface morphology; Ref. (Henry, L., 1987)

Reactive ion etch; Cl$_2$; Application: InGaAsP/InP buried crescent laser; photoresist mask; etched width is smaller than with wet chemical etch; Ref. (Kasukawa, A., 1987)
Angled reactive ion etch; Cl$_2$:Ar; InGaAsP/InP; Application: heterostructure laser diode; TiO$_2$ mask; Ref. (Saito, H., 1986a)

Reactive ion etch; Cl$_2$ + Ar; InP; Application: InGaAsP/InP etched mirror laser; Ref. (Saito, H., 1989a)

Reactive ion etch; Cl$_2$:Ar; Application: InGaAsP/InP for 1.3 µm laser; TiO$_2$ mask; Ref. (Saito, H., 1989b)

Angled reactive ion etch; Cl$_2$ + Ar; Application: InGaAsP/InP 1.3 µm laser diode; Ref. (Saito, H., 1986b)

Reactive ion etch; Cl$_2$ + Ar; Application: 1.3 µm InGaAsP/InP laser array with microcoated reflector; Ref. (Saito, H., 1989c)

Reactive ion etch; CH$_4$/H$_2$; Application InGaAsP/InP heterostructures; Ref. (Schmid, H., 1989)

Reactive ion etch; Ar‡Cl$_2$; Application: InGaAsP/InP formation of vertical wall ridge structures

Br$_2$/methanol (0.2%); 30 s etch prior to MOVPE regrowth of InP; Ref. (Catana, A., 1993)

Reactive ion etch; Cl$_2$ + CH$_4$ + H$_2$ + Ar; Application: mirror facet etch for InGaAsP/InP lasers; Ref. (van Gurp, G.J., 1989)

Reactive ion etch; CH$_4$/H$_2$; InP and InGaAsP selective etch from InAlAs; Ref. (Arnot, H.E.G., 1993a)

Reactive ion etch; CH$_4$/H$_2$; InGaAsP/InP patterning through SiO$_2$ mask; mask erosion and Si surface contamination; Ref. (Lee, B.-T., 1993)

Reactive ion etch of InGaAsP/InP lasers using CH$_4$/H$_2$

HBr:H$_2$O$_2$:H$_2$O removal of RIE damage before MOCVD regrowth; Ref. (Ahn, J.-H., 1996)

Reactive ion etch using CH$_4$/H$_2$ on InP/InGaAsP for 1/4 narrow grooves; alternating with O$_2$ ashing to remove polymer buildup; Ref. (Madhan Raj, M., 1999a)

Reactive ion etch of deep grooves for multiple mirrors in InGaAsP MQW lasers using CH$_4$/H$_2$ and O$_2$ ashing to remove polymer buildup; Ref. (Madhan Raj, M., 1999b)

Reactive ion etch of InGaAsP/InP using CH$_4$/H$_2$; SiO$_2$-masked grooves formed by alternating with O$_2$ ashing to remove polymer buildup (followed by wet etch damage removal prior to MOVPE regrowth); Ref. (Nunoya, N., 1999)

Reactive ion etch of SiO$_2$ mask pattern using CF$_4$; Ref. (Nunoya, N., 1999)

Reactive ion etch using CH$_4$/H$_2$/O$_2$ on InP/InGaAsP device structures; use of photoresist, SiN, Ti, NiCr masks for mirrors and deep trenches; Ref. (Qian, Y.H., 1999)
Reactive ion etch using SF$_6$ for Ti mask patterning and mask removal from InP/InGaAsP. (Qian, Y.H., 1999)

Reactive ion etch using CH$_4$/H$_2$ for InGaAs/InGaAsP ridge waveguide laser fabrication; damage profile; Ref. (Qui, B.C., 1997)

Reactive ion etch; CH$_4$/H$_2$; of InGaAsP/InGaAs lasers; low etch damage with low etch power and post etch anneal; Ref. (Qui, B.C., 1998)

Reactive ion etch; C$_2$H$_6$/H$_2$/O$_2$ mesa etch for InGaAsP/InP; suppressed side etching for laser diode mesa fabrication; Ref. (Sugimoto, H., 1993)

RIE multichamber to provide sequential etch steps without crosscontamination; InGaAsP laser arrays

RIE pattern etch with SiN$_x$ mask; CH$_4$/H$_2$/Ar; InGaAsP laser arrays; Ref. (Rothman, M.A., 1992)

Reactive ion etch; CH$_4$/H$_2$/Ar; depth monitoring of quantum well thicknesses of ~5 nm in InGaAsP/InP; Ref. (Stano, A., 1996)

Reactive ion etch; CH$_4$/H$_2$/Ar; facet formation in InGaAsP/InP lasers; Ref. (Whaley, R.D., 1998)

ECR etch of InGaAsP/InP in Cl$_2$/H$_2$; surface damage study; Ref. (Tamura, M., 1997)

ECR plasma etch; BCl$_3$/Ar; InGaAsP; In enriched surfaces for $T < 130^\circ$C; Ref. (Pearton, S.J., 1993b)

ECR etch; Cl$_2$/CH$_4$/H$_2$/Ar; InP/InGaAsP mesa etch at ~150$^\circ$C; fast without mask narrowing; Ref. (Ren, F., 1993)

ECR etch; CH$_4$/H$_2$/Ar; InGaAsP; Application: quantum well etch dimensions; Ref. (Ren, F., 1995b)

Inductively coupled plasma etch of nanostructures in GaAs and via holes in InP using a Ni mask with pure Cl$_2$ at 0.1 mTorr; Ref. (Berg, E.W., 1999)

Ar ion beam-assisted etch; Cl$_2$; Application: InGaAsP/InP laser mesa etch; Ref. (Yap, D., 1988a,b)

Chemically-assisted ion beam etch; Cl$_2$/Ar; Application: InGaAsP/InP laser facets; Ref. (Dzioba, S., 1993)

CAIBE of InP/GaInAsP in N$_2$/H$_2$/CH$_4$; damage study; Ref. (Anand, S., 1998)

Chemically-assisted ion beam etching; BCl$_3$/Ar of InGaAsP/InP and AlInGaAsP/InP; control of the sidewall slope by tilting the sample; Ref. (Daleiden, J., 1998)

Ar ion etch; InGaAsP/InP cross-section interface layer delineation; Ref. (Zargar’yants, M.N., 1983)
Ar ion sputter etch; Application: InP/InGaAsP BH Laser cavity etch

Br₂/methanol (0.5%); 2–3 s etch to remove ion damage; Ref. (Bouadma, N., 1987)

Ion beam etch with subsequent annealing in H₂ for 1 min at 200°C improves etched surface; Application: InGaAsP/InP distributed feedback laser diode; Ref. (Matsuoka, T., 1984)

GaAs

Review: ion-assisted etching of GaAs; RIE, RIBE, IBAE, and RBIBE techniques; with tables of etchants, etch conditions, and etch rates; Ref. (Ashby, C.I.H., 1990b)

Review: wet and dry chemical etching of GaAs; classifies wet etchants as non-electrolyte (those with rates which are diffusion limited or chemical reaction limited) and electrolyte (those based on anodic oxidation followed by dissolution of products); gives tables of wet and dry etchants; Ref. (Ashby, C.I.H., 1990f)

Review: ion-beam milling and sputter etching of GaAs; with table of etchants, etch conditions, and etch rates; Ref. (Ashby, C.I.H., 1990c)

Review: laser-assisted etching of GaAs; with table of etchant, etch conditions, and etch rates; Ref. (Ashby, C.I.H., 1990d)

Review: plasma etching of GaAs; with table of etchants, etch conditions, and etch rates; Ref. (Ashby, C.I.H., 1990e)

Reactive ion etch; CCl₂F₂; Application: GaAs selective etch from Al₀.₃Ga₀.₇As stop etch layer; selectivity > 4000; gas residence time dependent; Ref. (Cameron, N.J., 1991)

Reactive ion etch; CCl₂F₂/Ar; Ref. (Chaplart, J., 1983)

Reactive ion etch; SiCl₄:SiF₄ (1:9); GaAs selective etch from AlGaAs; Ref. (Tong, N., 1992b)

Reactive ion etch; Cl₂, CCl₂F₂; Ref. (Pang, S.W., 1991)

Reactive ion etch of via holes in GaAs using CCl₂F₂/O₂; Ref. (Astell-Burt, 1988)

Reactive ion etch; SiCl₄, SiCl₄/Ar; Ref. (Stern, M.B., 1983)

Reactive ion etch; CCl₂F₂/Ar/O₂; Ref. (Hu, E.L., 1980)

Reactive ion etching; Cl₂/BCl₃/Ar and BCl₃/Ar; Application: GaAs free standing airbridge contacts; Ref. (Hur, K.Y., 1992)

Reactive ion etch; CCl₄₋₋Fₓ/Ar; GaAs; Ref. (Klinger, R.E., 1981, 1983)

Reactive ion etch; Cl, CCl₂F₂, CHF₃; for grating fabrication; Ref. (Yuba, Y., 1983b)
Reactive ion etch; CCl\textsubscript{2}F\textsubscript{2}/Ar/O\textsubscript{2}; Ref. (Turley, S.E.H., 1982)

Reactive ion beam etch; Cl\textsubscript{2}; GaAs and InP; Ref. (Tadokoro, T., 1988, 1989)

Reactive ion etch; SiCl\textsubscript{4}; GaAs and Al\textsubscript{0.3}Ga\textsubscript{0.7}As-induced damage study; Ref. (Cheung, R., 1992)

Reactive ion etch; CH\textsubscript{4} + H\textsubscript{2}; GaAs n-type; electrical damage due to hydrogen passivation of donors; Ref. (Collot, P., 1990)

Reactive ion etch; ClCH\textsubscript{3} with H\textsubscript{2}, He, O\textsubscript{2}, Ne or Ar; GaAs and InP; GaAs and InP etch selectivity depend on gas combinations; Ref. (Law, V.J., 1992)

Reactive ion etch and resonance-radio frequency (ECR) plasma etching of GaAs; comparison of surface damage; Ref. (Cheung, R., 1989)

Reactive ion etch; SiCl\textsubscript{4}, BCl\textsubscript{3}, BCl\textsubscript{3}/Cl\textsubscript{2}, Cl\textsubscript{2}; GaAs etch damage study; Ref. (Shul, R.J., 1994)

Reactive ion etch; SiCl\textsubscript{4}/CH\textsubscript{4}/Ar; AlInGaP and GaAs; Ref. (Chang, C.V.J.M., 1994)

Reactive ion etch; SiCl\textsubscript{4}/SiF\textsubscript{4}; Application: GaAs selective from AlGaAs for gate recess in MODFET fabrication

HF buffered: RIE SiO\textsubscript{x} residue removal; Ref. (Ballegeer, D.G., 1993)

Reactive ion etch; Cl\textsubscript{2}/BCl\textsubscript{3}/Ar; Application: GaAs photoresist patterned via holes; Ref. (Nordheden, K.J., 1993)

Reactive ion etch; SiCl\textsubscript{4}; GaAs with AlGaAs stop layer; GaAs: etch rate ratio is >10,000:1; Ref. (Murad, S.K., 1993)

Reactive ion etch; comparison of Cl\textsubscript{2}/BCl\textsubscript{3}/Ar and CCl\textsubscript{2}F\textsubscript{2}/BCl\textsubscript{3}/Ar for III–V compounds

NH\textsubscript{4}OH:H\textsubscript{2}O\textsubscript{2}:H\textsubscript{2}O (1:1:50); GaAs substrate cleaning prior to RIE; Ref. (Juang, Y.Z., 1994)

Reactive ion etch; CCl\textsubscript{2}F\textsubscript{2}; Application: via hole formation in GaAs; Ref. (Hilton, K.P., 1985)

Reactive ion etch; CCl\textsubscript{2}F\textsubscript{2}; Application; via holes in GaAs; Ref. (Hipwood, L.G., 1985)

Reactive ion etch; CCl\textsubscript{3}F\textsubscript{2}, SiCl\textsubscript{4}, BCl\textsubscript{3}, CF\textsubscript{4} and mixtures with Ar; GaAs via hole fabrication characteristics; Ref. (Geissberger, A.E., 1985)

Reactive ion etch of via holes in GaAs using Cl\textsubscript{2}/SiCl\textsubscript{4}; Ref. (Salimian, S., 1987)

Reactive ion etch; CCl\textsubscript{2}F\textsubscript{2}; Application: GaAs selective etch with AlGaAs etch stop; GaAs: selectivity > 4000:1; Ref. (Cameron, N.I., 1993)

Reactive ion etching, SiCl\textsubscript{4} + Cl\textsubscript{2}; Application: via holes in GaAs; Ref. (Cooper, C.B., 1987a)
Reactive ion etch surface damage (a) and Ar ion beam damage (b) assessment from cathodo- and photo-luminescence of buried quantum wells as damaged surface is incrementally thinned by oxidation/stripping steps; Ref. (Green, D.L., 1993a,b)

Reactive ion etch; Application: CCl₂F₂; GaAs mesa etch; Ref. (Ren, F., 1994)

Reactive ion etch; SiCl₄/He/Ar; nanoscale columns in GaAs using gold islands as masks; Ref. (Ahopelto, J., 1995)

Reactive ion etch; Cl₂ and SiCl₄; GaAs; study of characteristics for etching via holes; Ref. (Camacho, A., 1994)

Reactive ion Etch; SiCl₄; GaAs, smooth surfaces with H₂ plasma pretreatment to remove oxides; Ref. (Choquette, K.D., 1995)

Reactive ion etch; SiCl₄ + CF₄ + O₂ + He; GaAs selective etch from Al₀.₁₁Ga₀.₈₉As; Ref. (Smith, L.E., 1993)

Reactive ion etch of via holes in GaAs using Cl₂/BCl₃/Ar; model of etch rate dependence on via depth; Ref. (Abraham-Schauner, B., 1999)

Reactive ion etch; CH₄/H₂ of p-InGaP and p-GaAs; etch rate study; Ref. (Chan, R.H., 1996)

RIE etch damage study of n-GaAs in CH₄/H₂ and H₂ plasmas; Ref. (de Wolf, I., 1992)

CHF₃ and NH₃ additives for reactive ion etching of GaAs using CCl₂F₂ and SiCl₄; Ref. (Din, K.-S., 1992a)

Reactive ion etch; CCl₂F₂; GaAs pattern etching of deep features comparing metal, Si₃N₄ and photoresist masks; Ref. (Din, K.-S., 1992b)

Reactive ion etch and ECR etch; BCl₃/Cl₂/CH₄/H₂/Ar of GaN and GaAs; radially uniform etching; Ref. (Franz, G., 1999)

Application of reactive-ion-beam etching to recessed-gate GaAs metal–semiconductor field-effect transistors; Ref. (Imai, Y., 1987)

Reactive ion etch; Cl₂/BCl₃/Ar slot via holes in GaAs; Ref. (Nordheden, K.J., 1999)

RIE (Cl₂/BCl₃/SiCl₄) and ECR (Cl₂/BCl₃) high rate plasma etch of via holes in GaAs; Ref. (Shul, R.J., 1997a)
Reactive ion beam etch process; Cl\textsubscript{2}; GaAs process for fabricating antireflection surface structure; Ref. (Wendt, J.R., 1996)

Plasma etch; HBr/H\textsubscript{2}, HBr/CH\textsubscript{4}, HBr/Ar; GaAs, GaSb, AlGaAs, InP, InSb, InGaAs, InAlAs; gives data on etch rates and photolithographic etch profiles; Ref. (Pearton, S.J., 1992a)

Plasma etch; CCl\textsubscript{4}, CHCl\textsubscript{3}, CF\textsubscript{2}Cl\textsubscript{2}, BCl\textsubscript{3}; InP and GaAs review; Ref. (Donnelly, V.M., 1983)

Plasma; H\textsubscript{2}; InP, GaAs, InGaAs surface cleaning; Ref. (Tu, C.W., 1983)

H\textsubscript{2} plasma damage study; GaAs; X-ray photoelectron spectroscopy analysis; Ref. (Debiemme-Chouvy, C., 1993)

Reactive ion etch; CH\textsubscript{4}/H\textsubscript{2} and SiCl\textsubscript{4}
Ar and Ne ion beam etching
ECR plasma etching in CCl\textsubscript{2}F\textsubscript{2}/He; GaAs surface conductance measurement assessment of etch damage; Ref. (Foad, M.A., 1993)

Reactive ion etch; CF\textsubscript{4}–O\textsubscript{2}; GaAs pattern etch with TaSi\textsubscript{x} contact mask for self-aligned MESFETs; Ref. (Chen, C.P., 1992)

ECR plasma; Study: SiO\textsubscript{2} mask etch on GaAs and InP; SF\textsubscript{6} gives superior SiO\textsubscript{2} sidewall smoothness than CF\textsubscript{4}; Ref. (Ren, F., 1992b)

ECR plasma; O\textsubscript{2} oxidation of GaAs; Cl\textsubscript{2} etch; Study: in situ mask formation with electron beam patterning; Ref. (Takado, N., 1992)

ECR plasma etch; Application: mask patterning for AlGaAs/GaAs HBTs; O\textsubscript{2} discharge for polydimethylglutarimide mask etch; SF\textsubscript{6} discharge for SiN mask; Ref. (Lothian, J., 1992e)

ECR plasma; Cl\textsubscript{2}, BCl\textsubscript{3}; Study: comparison on GaAs and InP; shows etch rate dependences on microwave power, RF power, sample placement, and temperature; Ref. (Pang, S.W., 1992b)

ECR plasma etch; SiCl\textsubscript{4}; Study: etch rates, etch profiles and uniformity; Ref. (Choquette, K.D., 1992)

ECR plasma; CH\textsubscript{3}I, C\textsubscript{2}H\textsubscript{5}I, and C\textsubscript{3}H\textsubscript{7}I with Ar and H\textsubscript{2}; Study: etch rates, surface morphology, damage, etch anisotropy for InP, InAs, InSb, GaAs, AlGaAs, GaSb, InAlAs, InGaAs, and InAlP; Ref. (Chakrabarti, U.K., 1992)

Resonance-radio frequency (ECR) plasma and RIE etching of GaAs; comparison of surface damage; Ref. (Cheung, R., 1989)

ECR plasma etch; CH\textsubscript{4} + H\textsubscript{2} + Ar; GaAs; Ref. (Law, V.J., 1991a,b)

ECR plasma etch; PCl\textsubscript{3} + Ar; Application: In\textsubscript{0.2}Ga\textsubscript{0.8}As–GaAs QW ridge waveguide lasers; Ref. (Pearton, S.J., 1991c)
ECR plasma etch; BCl$_3$/Ar; GaAs; Ref. (Yang, L.W., 1994)

ECR etch; CH$_4$/H$_2$; InP and GaAs; comparison of multipolar and magnetic mirror ECR sources; Ref. (Pearton, S.J., 1994b)

ECR H$_2$ plasma etch followed by Cl$_2$ thermochemical vapor etch; GaAs surface cleaning for MBE; Ref. (Hong, M., 1993)

ECR etch; Cl$_2$; Oxide mask with e-beam patterning; GaAs; Ref. (Kohmoto, S., 1992)

ECR etch; HBr/H$_2$/Ar and HI/H$_2$/Ar; InP, GaAs, AlGaAs; effect of substrate temperature; Ref. (Chakrabarti, U.K., 1994)

ECR etch; BCl$_3$/Ar; GaAs and AlGaAs mesa etch; Ref. (Pearton, S.J., 1993d)

ECR plasma etch; CCl$_2$F$_2$, BCl$_3$/SF$_6$, SiCl$_4$/SF$_6$; GaAs selective etch from AlGaAs or InGaAs; These require removal of residual etch stop surface components: HF$_3$ or InCl$_3$ or InF$_3$; Ref. (Pearton, S.J., 1993c)

ECR plasma etch; H$_2$; alternative dry etch for removal of residues; Ref. (Pearton, S.J., 1993c)

ECR plasma etch, electron-beam assisted; Cl$_2$ + Ar; GaAs etch rate is 10× greater with e-beam

ECR plasma etch, electron-beam assisted; SF$_6$ + Ar; GaAs selective etch from AlGaAs

ECR plasma etch; CH$_4$/H$_2$ + Ar; Application: InGaAsP tapered stripes using anisotropy dependence on bias voltage; Al$_2$O$_3$ or Ti masks; Ref. (Zengerle, R., 1993)

ECR plasma etch; CCl$_2$F$_2$/He; Application: GaAs quantum dot fabrication with metal mask

ECR plasma etch; CF$_4$; Application: silicon nitride layer etch

ECR plasma; O$_2$; Application: photoresist removal from GaAs; Ref. (Rishton, S.A., 1993)

ECR plasma etching Cl$_2$ surface reaction followed by Ar to desorb non-volatile GaCl$_3$; GaAs, InGaAs, AlGaAs and InP; Ref. (Ko, K.K., 1993)

ECR plasma etch; H$_2$; GaAs and AlGaAs surface oxide removal for MBE growth; Ref. (Choquette, K.D., 1993a,b)

ECR plasma cleaning of C-doped GaAs in situ for MBE; Ref. (Watanabe, N., 1993c)

ECR etch; trench etching in GaAs; scaling of etch rates to pattern aspect ratio; Ref. (Bailey III, A.D., 1995b)

ECR etch; study at low temperature; Cl$_2$/Ar, BCl$_3$/Ar for GaAs, AlGaAs, GaSb; CH$_4$/H$_2$/Ar for InP; Ref. (Pearton, S.J., 1995a)

ECR etch; BCl$_3$/Ar or Cl$_2$/Ar; GaAs, AlGaAs and GaSb, etch behavior at temperatures from +25 to −30°C; low temperature minimizes photoresist undercutting; Ref. (Pearton, S.J., 1994c)
ECR and RIE etch of refractory metal contacts on GaAs; induced damage; Ref. (Shul, R.J., 1995b)

ECR etch; Cl2/Ar, BCl3/Ar, Cl2/BCl3/Ar, and SiCl4/Ar; GaAs, study of damage to p–n junction diodes; Ref. (Shul, R.J., 1995c)

ECR etch surface damage study; GaAs; Ref. (Ko, K.K., 1994)

ECR plasma; Ar/Cl2; Study and modeling of trench profile dependence in GaAs and Si on etch temperature; Ref. (Bailey III, A.D., 1995a)

ECR etch damage, time dependence; GaAs; Ref. (Berg, E.W., 1999)

ECR plasma etch; Cl2/Ar; GaAs; surface damage study; Ref. (Eddy, C.R., 1997)

ECR plasma etching; CH4/H2/Ar for compound semiconductor; study of gas species versus process conditions; Ref. (Eddy Jr., C.R., 1999)

ECR plasma etch; CH4/H2/Ar; comparison of masking materials (SiNx, W, photoresist) for pattern etching of GaAs; Ref. (Lee, J.W., 1996a)

Electron cyclotron resonance ion stream etching of GaAs with SF6–CF4–SiF4–O2 for WSiN-gate FETs; Ref. (Jin, Y., 1997)

ECR plasma etch; ICl/Ar and IBr/Ar; InP, InGaAs, InSb, GaAs, GaSb, AlGaAs; study of etch rates and morphologies; Ref. (Lee, J.W., 1997c)

ECR plasma etch; IBr/Ar; room temperature processing of GaAs, AlGaAs, GaSb, InP, InGaAs, InSb. Requires hard mask (photoresist degrades). Chemistry is H2-free, thus avoiding p-dopant passivation and polymer deposition; Ref. (Lee, J.W., 1997d)

ECR plasma etch; ICl/Ar; etch study on GaAs, GaSb, InP, and InSb; Ref. (Lee, J.W., 1997e)

ECR-RIBE etch; Cl2; GaAs; optimization of etch conditions; Ref. (Nishioka, K., 1997)

ECR etch with hydrogen; GaAs; in situ surface cleaning for MBE regrowth of GaAs; Ref. (Niwa, T., 1997)

ECR etch; CF4/O2/Ar; Application: patterning SiNx films on GaAs; Ref. (Olson, R.J., 1996)

ECR etch; CCl2F2, BCl3, Cl2; study of GaAs and InP etch characteristics and comparison with RIE; Ref. (Pang, S.W., 1992a)

ECR etch of InP and GaAs using Cl2, BCl3 and CH4–H2 plasmas; Ref. (Pearton, S.J., 1994f)

ECR etch damage of GaAs p–n junctions in O2 and H2 discharges; Ref. (Pearton, S.J., 1992f)

ECR etch of GaAs using Cl2/CH4; Ref. (Penner, B., 1999)
ECR plasma; hydrogen; surface cleaning of GaAs for MBE regrowth; Ref. (Takanashi, Y., 1998)

Inductively coupled plasma etch of nanostructures in GaAs and via holes in InP using a Ni mask with pure Cl₂ at 0.1 mTorr; Ref. (Berg, E.W., 1999)

Inductively couple plasma etch of GaAs using NH₃; damage of Schottky diode; Ref. (Meyer, L.C., 1999)

RIE inductively coupled plasma etch of GaAs, GaP, AlGaAs, GaSb in Cl₂–Ar mixtures; Ref. (Hahn, Y.B., 1999b)

Inductively couple plasma etch (ICP); Ar; of GaAs and InP; etch damage comparison to ECR etch; Ref. (Lee, J.W., 1997)

inductively coupled Ar plasma; GaAs; FET device degradation study

ECR Ar plasma; GaAs; FET device degradation study; Ref. (Ren, F., 1997a)

Inductively coupled plasma etching of GaAs, GaP, InP in Cl₂/Ar, Cl₂/N₂, BCl₃/Ar, and BCl₃/N₂; comparison to ECR etch rates; Ref. (Shul, R.J., 1997b)

Capacitance coupled plasma; BCl₃/Cl₂ of GaAs; rate enhancement by adding Lewis acid gas (BCl₃); Ref. (Franz, G., 1998)

Magnetron RIE plasma etch; CH₄/H₂/Ar; GaAs surface damage study; H₂ passivation; Ref. (McLane, G.F., 1994a,b)

Magnetron ion etch; SiCl₄/Cl₂ of GaAs; via hole sidewall passivation by etch residues; Ref. (Takano, H., 1996)

Magnetron reactive ion etching of GaAs in CCl₂F₂ and SiCl₄; lower bias voltages than conventional RIE result in less damage; Ref. (McLane, G., 1992)

Magnetron ion etching of via holes in GaAs using SiCl₄; Ref. (Mitra, A., 1998)

High density plasma etching of GaAs in Cl₂/Ar; study of surface chemistry and damage; Ref. (Leonhardt, D., 1998)

RF plasma etch; C₃H₈ + H₂; GaAs; greater etch rates than with CH₄ + H₂; Ref. (Law, V.J., 1990a)

RF plasma etch; CH₄ + H₂; GaAs; etch rate dependence on temperature and CH₄ concentration; Ref. (Law, V.J., 1990b)

Plasma etch; PCl₃ + Ar; GaAs with Au mask; dependence on bias; Ref. (Lothian, J.R., 1992d)

Plasma etch; hydrogen etching of GaAs, GaSb, InP and their oxides. InP etching preferentially removes phosphorus and leaves In to accumulate on the surface; Ref. (Chang, R.P.H., 1982)
Plasma etch; CCl\textsubscript{4}; InP and GaAs; time dependent etch rates indicate inhibition of etching above 250°C by a chlorocarbon deposit; Ref. (Gottscho, R.A., 1982)

Plasma etch; Cl\textsubscript{2}; InP and GaAs; non-volatile reaction by-product InCl\textsubscript{3} limits low temperature etching; Ref. (Donnelly, V.M., 1982)

Plasma etch; CCl\textsubscript{4}; HCl; InP and GaAs; Ref. (Smolinsky, G., 1983)

Plasma etching characteristics:

- HF, C\textsubscript{2}F\textsubscript{6}, CF\textsubscript{3}Cl, CHF\textsubscript{3}, C\textsubscript{2}Cl\textsubscript{4}, CBrCl\textsubscript{2}, CHCl\textsubscript{3}, PH\textsubscript{3}, H\textsubscript{2}, H\textsubscript{2}O; these do not etch GaAs or its oxide
- CCl\textsubscript{4}, CCl\textsubscript{2}F\textsubscript{2}, PCl\textsubscript{3}, HCl etch both GaAs and its oxide
- Cl\textsubscript{2}, COCl\textsubscript{2} etch GaAs but not its oxide
- Cl\textsubscript{2} etches GaP and GaSb but not their oxides
- HCl etches GaP and GaSb and their oxides but not InP; Ref. (Smolinsky, G., 1981)

Plasma etched via holes in GaAs with 6% Cl\textsubscript{2} + 94% BCl\textsubscript{3}; Ref. (D'Asaro, L.A., 1980)

300 kHz pulse plasma etching of GaAs using a mixture of ClCH\textsubscript{3} and H\textsubscript{2}; Ref. (Law, V.J., 1993)

Plasma etch damage modeling; GaAs; Ref. (Rahman, M., 1992)

Plasma surface oxidation; GaAs; FTIR study of surface chemical reactions; Ref. (Aydl, E.S., 1993)

Plasma passivation of GaAs; NH\textsubscript{3} and H\textsubscript{2}; in situ monitoring of surface reactions with attenuated-total-reflection Fourier-transform-spectroscopy (ATR FTIR); Ref. (Aydl, E.S., 1995)

Ar ion sputtering; etch rate = 650 Å/s; etch profiles; Ref. (Gloersen, P.G., 1975)

Glancing-angle Ar ion beam, low damage sputtering to clean GaAs surfaces for MBE growth; Ref. (Labanda, J.G.C., 1995)

Ion beam; Ar, CCl\textsubscript{2}F\textsubscript{2}; GaAs, AlGaAs, InP; Application: stripe waveguide profiles; Ref. (Webb, A.P., 1984)

Ar ion milling and plasma etch; cathodoluminescence study of surface damage; best surface combines ion milling with 1 min wet etch; Ref. (Papadopoulo, A.C., 1990)

Ar and Xe ion sputtering of GaAs (1 1 0); STM study of damage; Ref. (Wang, X.-S., 1995)

In situ Ar ion milling to remove oxide from GaAs prior to Ge/Ni/Au–Ge/Mo contact deposition to improve Ohmic contact; Ref. (Ren, F., 1992c)

Ar ion etch damage of GaAs; study of Schottky diodes and DLTS; Ref. (Chen, C.-H., 1997) van Hassel, J.G., 1995)
Ar ion surface cleaning of GaAs; damage effects on Schottky diodes

Ar/O₂; CF₄, C₂F₆ and Ar ion milling of InGaAs, InP, GaAs, Si and Ge; gives etch rate comparison of reactive and non-reactive ion beam etching; reports different etching rates between photoresist and semiconductor; Ref. (Chen, W.X., 1986)

Ar ion beam etch; GaAs damage effects on surface depletion; Ref. (Li, F., 1993)

Ar ion beam etch; GaAs surface cleaning for low resistance contacts; Ref. (Starkeev, G., 1993)

Ion beam etching; CO; use of hafnium mask for GaAs and InP patterning; Ref. (Kempj, B., 1993)

In situ Ar sputter etching of GaAs for MBE; Ref. (Millunchick, J.M., 1995)

Neutral charge fast atom etching of GaAs; Ref. (Shimokawa, F., 1989)

Ion beam etch, chemically assisted; Cl₂; GaAs vertical facets; Ref. (Hagberg, M., 1994)

Chemically-assisted ion beam etch; Cl₂/BCl₃/IBr in a cryo-pumped vacuum system; GaAs and InP; Ref. (Daleiden, J., 1995)

Focused ion beam etch; Ga + ion beam assisted Cl₂ etching of GaAs for in situ patterning and MBE overgrowth; Ref. (Kalburge, A., 1997)

Cl₂ assisted Ar ion etching; Application: GaAs/AlGaAs laser facets; Ref. (Behfar-Rad, A., 1989)

CAIBE; I₂/Ar⁺; GaAs and GaSb; Ref. (Bharadwaj, L.M., 1991)

Electron-beam assisted dry etch, ECR plasma; Cl₂ + Ar; GaAs/AlGaAs; GaAs selective etch from AlGaAs using SF₆; no optical or electrical damage compared with ion beam etching; Ref. (Watanabe, H., 1993a,b)

H₂ atomic beam cleaning of GaAs in situ for MBE; Ref. (Rouleau, C.M., 1993)

Surface cleaning of GaAs in hydrogen radicals for MBE epilayer regrowth; Ref. (Burke, T.M., 1997)

In vacuo maskless GaAs etching using ion or laser-induced reaction of adsorbed vapors of SO₂Cl₂ and 1,2-dichloroethane; Ref. (Marshall, D., 1994)

AlGaAs/GaAs

Reactive ion etch; SiF₆/SiCl₄; AlGaAs/GaAs with use of etch stop layers of AlGaAs and InGaAs; Ref. (Cooper, C.B., 1987b); (Tong, N., 1992b)

Reactive ion etch; CCl₄/He; Application: AlGaAs selective etch from GaAs with selectivity > 1000; Ref. (Hida, H., 1989)
Reactive ion etch; SiCl$_4$ + SiF$_4$; Application: GaAs selective etch from AlGaAs for MODFET processing; Ref. (Ketterson, A.A., 1989)

Reactive ion etch; CH$_4$ + H$_2$; Application: GaAs selective etch from AlGaAs; Ref. (Law, V.J., 1989)

Reactive ion etch; BCl$_3$ + He; AlGaAs/GaAs; very small etch rate dependence on Al content; Ref. (Franz, G., 1993)

Reactive ion etch; CCl$_2$F$_2$ + He; GaAs selective etch from Ga$_{0.7}$Al$_{0.3}$As; gives etch rate selectivity dependence on gas pressures and concentrations; Ref. (Hikosaka, K., 1981)

Reactive ion etch; C$_2$F$_6$ and SiCl$_4$; damage assessment in GaAs/AlGaAs

H$_2$SO$_4$:H$_2$O$_2$:H$_2$O (1:8:600); GaAs RIE damage removal; Ref. (Ooi, B.S., 1994)

Reactive ion etch; CH$_4$/H$_2$; AlGaAs/InGaAs/GaAs structure surface damage study. Superior smooth surfaces and etch rate controllability compared to chlorinated gases; Ref. (van Es, C.M., 1993)

Reactive ion beam etch, in situ optical monitoring; AlGaAs/GaAs; Ref. (Vawter, G.A., 1994)

Reactive ion etch; SiCl$_4$/SiF$_4$; selective removal of GaAs from AlGaAs; damage effects on MODFETs; Ref. (Balleger, D.G., 1992)

Cl$_2$ reactive ion beam etching of Al$_{0.4}$Ga$_{0.6}$As to form trench grating for distributed Bragg reflectors; Ref. (Zubrycki, W.J., 1999)

Reactive ion etch damage; mechanism modeling; results with GaAs/AlGaAs; Ref. (Chen, C.-H., 1995)

Reactive ion etch; BCl$_3$/(Ar, He); study of AlGaAs etching; Ref. (Franz, G., 1996)

Reactive ion etch; BCl$_3$; selective removal of GaAs from AlGaAs or InGaAs; Ref. (Kazior, T.E., 1992)

Reactive ion etching; BCl$_3$/CCl$_3$F$_2$/He; GaAs and Al$_{0.76}$Ga$_{0.24}$As at equal rates; for vertical sidewall etch; Ref. (Mukherjee, S.D., 1987)

Reactive ion etch; SiCl$_4$/SiF$_4$; addition of O$_2$ increases selectivity of etching GaAs from AlGaAs; Ref. (Murad, S.K., 1996a)

Reactive ion etch; SiCl$_4$/SiF$_4$; for damage free GaAs/AlGaAs MESFETs and HEMTs; Ref. (Murad, S.K., 1995b)

Reactive ion etch of GaAs and AlGaAs in SiCl$_4$; conditions for selective and non-selective behavior; Ref. (Murad, S.K., 1994)

Reactive ion etch damage; CH$_4$/H$_2$; in Al$_{0.25}$Ga$_{0.75}$As; traps; Ref. (Pereira, R.G., 1996a)
Reactive ion etch damage; CH₄/H₂ of Al₀.₂₅Ga₀.₇₅As; effect on transport properties; Ref. (Pereira, R.G., 1996b)

Reactive ion etch; CCl₂F₂; study of the role of AlF₃ as etch stop in selective removal of GaAs from AlGaAs; Ref. (Seaward, K.L., 1988)

RIE etch; CF₆, SF₆; Application: mesa etch on AlGaAs/GaAs prior to MOCVD regrowth; Ref. (Ogura, M., 1995) RIE etch; CH₄/H₂; Al₀.₄₈In₀.₅₂As etch optimization; Ref. (Carpi, E.L., 1995)

Plasma etch; BCl₃:Cl₂; GaAs, AlGaAs, InP; etch rate is temperature dependent; Ref. (Contolini, R.J., 1988)

ECR plasma etch; Cl₂/NF₃/Ar; GaAs selective etch from AlGaAs; Ref. (Lee, W.-S., 1992)

ECR plasma etch; CH₄ + H₂; AlGaAs; Ref. (Pearton, S.J., 1991a)

ECR plasma; CCl₂F₂; Application: GaAs selective etch from AlGaAs; selectivity > 200; Ref. (Ren, F., 1992a)

ECR etch; BCl₃/Ar; GaAs and AlGaAs mesa etch; Ref. (Pearton, S.J., 1993d)

ECR plasma etch; H₂; AlGaAs substrate in situ cleaning for GaAs MBE growth; Ref. (Kondo, N., 1993)

ECR etch; non-selective for GaAs AlGaAs; BCl₃/Cl₂/N₂/Ar; where BCl₃ reduces oxidation effects for AlGaAs and N₂ protects from sidewall polymer deposition when using photoresist masks; Ref. (Constantine, C., 1995)

ECR ion etch; Cl₂/Ar of GaAs/AlGaAs quantum wire transistors; passivation of damage with Cl₂ plasma; Ref. (Ko, K.K., 1996)

ECR etch; CF₆/CHF₃ of AlGaAs; annealing of damage; Ref. (Mitani, K., 1996)

ECR etch; CH₄/H₂/Ar of GaAs and AlGaAs; study of surface damage with spectroscopic ellipsometry; Ref. (Snyder, P.G., 1995)

ECR etch; Ar; AlGaAs; surface damage study; p-type more susceptible to damage than n-type; Ref. (Stradtmann, R.R., 1996)

ECR plasma etch; Cl₂/Ar, Cl₂/N₂, Cl₂/H₂ of GaAs, and GaP; Ref. (Lee, J.W., 1996b)

ECR etch; Cl₂/Ar; Application: mesa etch on AlGaAs/GaAs prior to MOCVD regrowth; Ref. (Ogura, M., 1995)

ECR etch; CCl₂F₂/O₂, CH₄/H₂/Ar processing of GaAs/AlGaAs HEMTs; Ref. (Pearton, S.J., 1992e)
Inductively coupled plasma etch; BCl$_3$/Cl$_2$/Ar of GaAs/AlGaAs; high rate, low damage. Study of etch dependence on gas composition; Ref. (Agarwala, S., 1998)

Inductively coupled plasma etch; BCl$_3$/Cl$_2$; rate/profile study of GaAs/AlGaAs; Ref. (Agarwal, S., 1999)

Inductively coupled plasma etch; BCl$_3$/Cl$_2$; etched mirrors for ridge lasers; Ref. (Horst, S.C., 1997)

Inductively coupled plasma etch; Cl$_2$; grating etch in AlGaAs/InGaAs QW structures; Ref. (Berg, E.W., 1998)

ICP etch using Ar, damage of AlGaAs; Ref. (Lee, J.W., 1997b)

Radical-beam ion-beam etch (separate control of Cl$^-$ and H$^+$ radicals and physical Ar$^+$ ions); Study; AlGaAs dry etching characteristics; etch rates; surface morphologies; Ref. (Skidmore, J.A., 1992)

Ion beam; Ar, CCl$_2$F$_2$; GaAs, AlGaAs, InP; Application: stripe waveguide profiles; Ref. (Webb, A.P., 1984)

Ion beam etch of AlGaAs using nitrogen; etch damage profiles; Ref. (Otte, K., 1999)

Ar ion milling; energy dependence and damage depth distribution; GaAs/AlGaAs; uses degradation of a single quantum well to assess damage depth; Ref. (Germann, R., 1989a)

Ar ion etch damage study; GaAs and InP; enhanced defect diffusion with illumination energies above bandgap; Ref. (Chen, C.-H., 1996)

Cl$_2$ assisted Ar ion beam etching; Application: vertical sidewall laser mirrors in AlGaAs/AlGaInP; Ref. (Unger, P., 1993)

Cl$_2$ assisted Ar ion etch; AlGaAs/GaAs sidewall facets using SiO$_2$ mask

Reactive ion etch; CF$_4$; transfer of photoresist pattern to SiO$_2$ mask; Ref. (Liang, J.J., 1994)

Cl$_2$ chemically assisted Ar ion beam etching of GaAs to form 3D interlinked mesh structures; Ref. (Cheng, C.C., 1996)

Cl$_2$ reactive ion beam etch; AlGaAs/GaAs in situ etch prior to AlGaAs regrowth by MBE; Ref. (Kohmoto, S., 1996)

CAIBE; Ar/Cl$_3$ of AlGaAs/GaAs in ultrahigh vacuum to eliminate aluminum oxide problems; Ref. (Hryniewicz, J.V., 1997)

CAIBE damage of AlGaAs/GaAs using BCl$_3$/Cl$_2$; post-etch damage removal by Cl$_2$ flow at 120°C without plasma; Ref. (Daleiden, J., 1999)
Chemically assisted ion beam etch (CAIBE); Cl₂/Ar of AlGaAs/GaAs laser mirrors; Ref. (Tihanyi, P., 1987)

Ion-beam etching; Cl₂ assisted; AlGaAs; H⁺ enhances etch rate and roughness; Ref. (Skidmore, J.A., 1993)

H₂ plasma oxide removal; AlGaAs cleaning for MBE overgrowth; Ref. (Choquette, K.D., 1993c)

**AlInGaP**

Reactive ion etch; SiCl₄/CH₄/Ar; AlInGaP and GaAs; Ref. (Chang, C.V.J.M., 1994)

RIE using BCl₃/Ar from GaAs, GaInP, AlGaInP, and AlInP; selective removal of GaAs from InGaP; selective removal of InGaP from AlInP; Ref. (Juang, Y.Z., 1998)

ECR etch; CCl₂F₂/Ar; AlGaInP/GaInP low damage; Ref. (Hommel, J., 1994)

ECR etch; ICl and IBr; comparison for etching InGaAlP; Ref. (Hong, J., 1996a)

ECR etch; CH₄/H₂/Ar; Application: InGaP mesa etch

ECR etch; BCl₃/Ar; Application: GaAs and AlGaAs mesa etch

(NH₄)₂Sₓ; Application: surface passivation of InGaP; Ref. (Pearton, S.J., 1993d)

Inductively coupled plasma (ICP) etch of InGaAlP using BCl₃ and BBr₃ with or without Ar; AlInP acts as etch stop for InGaP and AlGaP Ref. (Hong, J., 1998a)

**InAs**

Ar + low energy ion milling of InAs; damage study using Raman scattering; Ref. (Anzer, T.A., 2000)

**GaSb**

Reactive ion etch; SiCl₄; GaSb and GaAlSb etch study for selective and non-selective etch conditions; Ref. (Ou, S.S., 1996)

ECR etch; BCl₃/Ar or Cl₂/Ar; GaAs, AlGaAs and GaSb, etch behavior at temperatures from +25 to –30°C; low temperature minimizes photoresist undercutting; Ref. (Pearton, S.J., 1994c)

ECR etch; CH₄/H₂/Ar of GaSb and InSb; Ref. (Mileham, J.R., 1997)

ECR etch; CH₄/H₂/N₂; InSb damage study using Resonant Raman scattering; Ref. (Sendra, J.R., 1996b)

ICP etching of GaSb and AlGaAsSb using BCl₃/Ar and Cl₂/Ar; Ref. (Zhang, L., 1999)

CAIBE; Ar + I₂; GaAs and GaSb; Ref. (Bharadwaj, L.M., 1991)
**InGaP**

Reactive ion etch; CH$_4$/H$_2$ of p-InGaP and p-GaAs; etch rate study; Ref. (Chan, R.H., 1996)

Reactive ion etch; BCl$_3$/Ar of GaInP/InGaAs/GaInP; surface damage in HEMTs; Ref. (Kuo, C.-W., 1998a)

Reactive ion etch; BCl$_3$ + Ar (6:4); selective etch of GaAs from InGaP for gate recess of FETs; Ref. (Kuo, C.-W., 1998b)

Reactive ion etch; BCl$_3$ of InGaP; study of etch characteristics; Ref. (McLane, G.F., 1997)

ECR plasma etc.; CH$_4$/H$_2$/Cl$_2$/Ar; InGaP; Application InGaP/GaAs HBTs; Ref. (Yang, L.W., 1994)

ECR etch; CH$_4$/H$_2$/Ar; InGaP; Ref. (Pearton, S.J., 1993d,e, 1994c)

ECR plasma etch; Cl$_2$/Ar, BCl$_3$/Ar, BCl$_3$/N$_2$, ICl/Ar, and IBr/Ar; study of etch rates for InGaP and AlGaP; Ref. (Hong, J., 1997)

ECR etch; Cl$_2$/Ar; high etch rate conditions for InGaP and AlInP; Ref. (Hong, J., 1996b)

ECR plasma etch; BCl$_3$/Ar; of InGaP, AlInP and AlGaP; comparison to RIE; Ref. (Hong, J., 1996c)

ECR plasma etch of AlGaAs and InGaP in Ar and SF$_6$; study of surface damage; Ref. (Lee, J.W., 1997f)

ECR high power plasma etch; CH$_4$/H$_2$/Ar; of InGaP, AlInP, and AlGaP; Ref. (Lee, J.W., 1996c)

ECR etch of GaAs/InGaP quantum wires using CH$_4$/H$_2$/Ar; annealing of damage; Ref. (Maximov, I., 1999a)

ECR etch; BCl$_3$/N$_2$ of InGaP/GaAs structures and InP; Ref. (Ren, F., 1996)

ECR etch; BCl$_3$/N$_2$; etch study of InP, InAlP, and InGaP; Ref. (Ren, F., 1996b)

Plasma etch of InGaP and GaAs in PCl$_3$/Ar, CCl$_2$F$_2$/Ar, CH$_4$/H$_2$/Ar; Conditions for selective etch of GaAs from InGaP are determined; Ref. (Lothian, J.R., 1992b)

Plasma etch; PCl$_3$/Ar and CCl$_2$F$_2$/Ar; InGaP selective etch from GaAs; Ref. (Lothian, J.R., 1992a)

Inductively coupled plasma etching in Cl$_2$ and BCl$_3$ of InGaP, InAlP and AlGaP; study of etch behavior; Ref. (Hong, J., 1998b)

ICP etch study of InGaP, AlInP and AlGaP using CH$_4$/H$_2$/Ar and Cl$_2$/Ar; Ref. (Hong, J., 1998c)
**InN, AlN, GaN**

Reactive ion etch; SiCl₄:Ar (1:1) and SiCl₄:SiF₄ (1:1); GaN; Ref. (Adesida, I., 1993b)

Reactive ion etch; SiCl₄; SiCl₄:Ar (1:1); SiCl₄:SiF₄ (1:1); GaN; patterns masked with NiCr; profiles; Ref. (Adesida, I., 1993c)

Reactive ion etching of GaN and AlGaN using Cl₂/CH₄/Ar; Ref. (Basak, D., 1999)

Reactive ion etch; BCl₃/N₂ of GaN; nitrogen decreases etch rate of sapphire substrates; Ref. (Fedison, J.B., 1997)

Reactive ion etch and ECR etch; BCl₃/Cl₂/CH₄/H₂/Ar of GaN and GaAs; radially uniform etching; Ref. (Franz, G., 1999)

Reactive ion etching; BCl₃ of GaN etch study; Ref. (Lin, M.E., 1994)

RIE etch; CHF₃/Ar and C₂ClF₅/Ar; GaN; Ref. (Lee, H., 1995a)

RIE plasma etch of patterned GaN; CHF₃/Ar, C₂ClF₅/Ar, C₂ClF₅/Ar/O₂, SiCl₄, CHCl₃; sputtered iron nitride (Fe–8% N) mask is resistant to Cl-based ion etch and easily removed; Ref. (Lee, H., 1998)

RIE plasma etch; SiCl₄, Ar of n-GaN; damage effects on Ohmic contacts; Ref. (Ping, A.T., 1998)

Reactive ion etching of GaN films; CHF₃/Ar and C₂ClF₅/Ar; study; Ref. (Lee, H., 1996)

Reactive ion etching of AlGaN/GaN using Cl₂; Application to FET gate recessing; Ref. (Chen, H.-C., 1999)

Reactive ion etch of GaN patterns using SF₆ and Ar; damage study; Ref. (Cheung, R., 1999)

ECR plasma etch; CH₄/H₂/Ar and Cl₂/H₂; InN, AlN and GaN dry etching characteristics; Ref. (Pearston, S.J., 1993a)

ECR plasma etch; CH₄/H₂; Cl₂/H₂; CCl₂F₂/Ar; InN, presence of H₂ or F₂ is necessary for equi-rate removal of group III and nitrogen etch products; Ref. (Abernathy, C.R., 1994)

ECR etch; BCl₃/Ar; GaN; Application: quantum well etch dimensions; Ref. (Ren, F., 1995b)

ECR plasma etch of InN and GaN using ICl; Ref. (Lee, J.W., 1996d)

ECR etch of patterns in GaN; CH₄/H₂/Ar; Ref. (Pearston, S.J., 1994e)

ECR etch; Cl₂/H₂/CH₄/Ar at 170°C; GaN, InN, AlN; Ref. (Shul, R.J., 1995a)

ECR etch; Cl₂/H₂/Ar/CH₄; etch study on AlN, InN, InGaN, InAlN; Ref. (Shul, R.J., 1996a)
ECR and RIE with Cl₂/Ar and CH₄/H₂/Ar; rates for GaN, AlN, InN, and InGaN; Ref. (Vartuli, C.B., 1996a)

ECR etch; Cl₂/Ar and BCl₃/Ar; AlGaN etch behavior; Ref. (Vartuli, C.B., 1997a)

ECR etch study; IBr/Ar of GaN, InN, InAlN, AlN, and InGaN; Ref. (Vartuli, C.B., 1997b)

ECR, high density plasma etch; CH₄/H₂, Cl₂H₂, HBr/H₂, HI/H₂ of GaN, InN and AlN; Ref. (Vartuli, C.B., 1996b)

ECR etch; ICl/Ar of GaN, InN, InAlN, AlN, and InGaN; Ref. (Vartuli, C.B., 1996c)

ICP etch; CH₄/H₂/Ar and CH₄/H₂/N₂; GaN, AlN, InN, InGaN, and InAlN; Ref. (Vartuli, C.B., 1997c)

ECR plasma etch of GaN, InN, and InGaN in ICl/Ar and IBr/Ar; selective etch of GaN from InN, AlN, or InAlN; Ref. (Vartuli, C.B., 1997d)

ECR plasma etching of GaN, AlN, InN, InGaN, and InAlN in Cl₂/Ar, CH₄/H₂/Ar, ICl/Ar, and IBr/Ar. Study of etchant selectivity. Cl-based etches maximize selectivity; Ref. (Vartulli, C.B., 1996e)

ECR etch; Cl₂/CH₄/H₂/Ar; GaN and AlN; comparison with RIE; Ref. (Pearton, S.J., 1996a)

ECR and RIE etch damage from Ar plasmas on InN, InGaN, and InAlN; Ref. (Pearton, S.J., 1995b)

ECR etch; BCl₃, BCl₃/Ar, BCl₃/N₂; InAlN surface damage; Ref. (Ren, F., 1996c)

ECR plasma etch; BCl₃, BCl₃/Ar, BCl₃/N₂; of an InAlN and GaN FET structure. Surface N loss produces poor rectifying gate contacts for metals deposited on etched surfaces; Ref. (Ren, F., 1997b)

ECR and ICP etch of SiO₂ patterned GaN; SF₆/Ar and CF₄/O₂; Ref. (Ren, F., 1998)

Inductively coupled plasma etch of GaN, InN and AlN with BI₃, BBr₃, ICl and Ibr; Ref. (Cho, H., 1999a)

Inductively coupled plasma etch, selective removal of InN and InGaN from GaN using BI₃ and BBr₃; Ref. (Cho, H., 1999b)

ICP of GaN, InN, AlN, InAlN and InGaN in Cl₂ and CH₄/H₂ plasmas; Ref. (Cho, H., 1998a)

Inductively coupled plasma etch; Cl₂/Ar, Cl₂/N₂, Cl₂/H₂ of InN, InGaN, GaN, InAlN and AlN; dependences on Cl₂ percent and pressure; Ref. (Cho, H., 1998b)

Inductively coupled plasma etching; Cl₂/Xe, Cl₂/Ar, and Cl₂/He of InN, GaN, and AlN; study of etch characteristics; Ref. (Hahn, Y.B., 1999a)

Inductively coupled plasma etch; Cl₂/H₂; GaN etch characteristics; effect of surface stoichiometry on Ohmic contact; Ref. (Kim, H.-S. 1997)
Inductively coupled plasma etch of GaN using Cl₂/BCl₃; Ref. (Kim, H.S., 1999)

Inductively coupled plasma etch; Cl₂/Ar and Cl₂/BCl₃ of GaN; Ref. (Lee, Y.H., 1998)

Inductively coupled plasma etch of GaN using Cl₂/Ar and Cl₂/N₂ gases; Ref. (Sheu, J.K., 1999)

Inductively coupled plasma etching of GaN using Cl₂/Ar; damage in Schottky diodes; Ref. (Zhang, A.P., 2000)

ICP etch of GaN in Cl₂/H₂/Ar; Ref. (Shul, R.J., 1996c)

ICP of GaN, AlN, InN in Cl₂/Ar, XCl₂/N₂, Cl₂/H₂, Cl₂/SF₆, BCl₃/Ar, BCl₃/H₂, BCl₃/N₂, and BCl₃/SF₆ plasmas; Ref. (Shul, R.J., 1998)

CAIBE of GaN and GaAs using Cl₂–Ar; vertical, smooth sidewalls for laser facets; Ref. (Khan, F.A., 1999)

Magnetron ion etch; BCl₃, SF₆/BCl₃, H₂/BCl₃, Ar/BCl₃; of InGaN and InAlN (reactive ion etch with magnetic field to confine plasma electrons close to the surface); Ref. (McLane, G.F., 1996)

Chemically assisted ion beam etch; Ar/Cl₂ of AlGaN; Ref. (Ping, A.T., 1997)

CAIBE of GaN; Ar ion beam with HCl gas; lower etch rates than with Cl₂; Ref. (Adesida, I., 1995)

CAIBE of GaN with Cl₂ in Ar beam; etch profile dependence on tilt angle; Ref. (Lee, W.J., 1999)

CAIBE of GaN and GaAs using Cl₂–Ar; vertical, smooth sidewalls for laser facets; Ref. (Eberhard, F., 1999)

Chemically assisted ion beam etching (CAIBE); Cl₂ in Ar; Application: mirror facet etch in InGaN/AlGaN laser diodes; Ref. (Kneissl, M., 1998)

CAIBE etching of GaN; with HCl and H₂/Cl₂; Ref. (Ping, A.T., 1996)

Ga focused ion beam micromilling of GaN; rates up to 0.6 μm³/nA s; rates two to five times lower for substrates (sapphire, SiC and Si); Ref. (Steck, A.J., 1999)

Ga + ion micromachining of laser gratings in GaN; Ref. (Chyr, I., 1999)

Ion beam etch of GaN using CO₂; Ref. (Topf, M., 1999)

H₂ thermal cleaning of sapphire substrate, in situ MOVPE; 1070°C; Ref. (Kim, J.-H., 1999)

Si

Review of plasma etching and reactive ion etching principles; Si; Ref. (Coburn, J.W., 1982)

Low energy Ar + ion sputter etching of Si; Ref. (Reader, P.D., 1975)
Safety

Plasma etch environmental concerns; Ref. (Flamm, D.L., 1993)

Dry etch environmental hazard; CF$_2$Cl$_2$, CF$_4$, etc.; Ref. (Mocella, M.T., 1991)

3.3. Dry etch — material selective

InP from InAlAs

Reactive ion etch; CH$_4$/H$_2$; InP and InGaAsP selective from InAlAs; fluorine free to use with SiO$_2$ masks; Ref. (Arnot, H.E.G., 1993b)

InGaAs(P) from InP

Inductively coupled plasma etch using CH$_4$/H$_2$/O$_2$ of InGaAs/InP HBTs; conditions for InGaAs selectivity of 30; Ref. (Etrillard, J., 1999a)

ECR etch; CH$_4$/H$_2$/Ar; InP/InGaAsP; bias control of selectivity Ref. (Pearson, S.J., 1991e)

InGaAs from InAlAs

Reactive ion etching; CH$_4$:H$_2$; CH$_3$:Br; HBr; InGaAs selective etch from InAlAs; Ref. (Adesida, I., 1993)

Reactive ion etch; CH$_4$/H$_2$; Application: InGaAs selective etch from InAlAs stop layer; Ref. (Lauterbach, Ch., 1991)

Reactive ion etch; SiCl$_4$/SiF$_4$/HBr; selective etch of InGaAs and InP from InAlAs; pattern etch with masks of Si$_3$N$_4$ or NiCr; Ref. (Murad, S.K., 1995a)

Reactive ion etch; SiCl$_4$/SiF$_4$/HBr; selective etch of InGaAs and InP from InAlAs; pattern etch with masks of Si$_3$N$_4$ or NiCr; Ref. (Murad, S.K., 1995a)

Photochemical etch in HBr gas; selective etch of InGaAs from InAlAs; selectivity of ~100 results from non-volatile oxide formation on InAlAs; Ref. (Habibi, S., 1995a,b)

Reactive ion etch; SiCl$_4$/SiF$_4$; addition of O$_2$ increases selectivity of etching GaAs from AlGaAs; Ref. (Murad, S.K., 1996a)

Photochemical dry etch; CH$_3$Br with a low pressure mercury lamp; InGaAs selective etch from InAlAs; selectivity of 25; Ref. (Kuroda, S., 1992)

Photochemical etch in HBr gas; selective etch of InGaAs from InAlAs; selectivity of ~100 results from non-volatile oxide formation on InAlAs; Ref. (Habibi, S., 1995a)

HBr photochemical dry etch; selectively removes InGaAs from InAlAs; Ref. (Habibi, S., 1995b)

HBr gas; photochemical etch using a 172 nm excimer lamp, selective removal of InGaAs from InAlAs; Ref. (Tanaka, J., 1996)
Cl₂ photochemical etching using ArF excimer laser; selective removal of InAlAs from InGaAs; Ref. (Takazawa, H., 1998)

**InAlAs from InGaAs**

Reactive ion etch; CH₄/H₂; transistor gate recess etch; selective etch of InAlAs from InGaAs; Ref. (Cheung, R., 1996)

**GaAs from AlGaAs**

Reactive ion etch; CCl₂F₂: Application: GaAs selective etch from Al₀.₃Ga₀.₇As stop etch layer; selectivity > 4000; gas residence time dependent; Ref. (Cameron, N.J., 1991)

Reactive ion etch; SiCl₄:SiF₄ (1:9); GaAs selective etch from AlGaAs; Ref. (Tong, N., 1992b)

Reactive ion etch; ClCH₃ with H₂, He, O₂, Ne or Ar; GaAs and InP; GaAs and InP etch selectivity depend on gas combinations; Ref. (Law, V.J., 1992)

Reactive ion etch; SiCl₄/SiF₄; Application: GaAs selective etch from AlGaAs for gate recess in MODFET fabrication

HF buffered: RIE SiOₓ residue removal; Ref. (Ballegeer, D.G., 1993)

Reactive ion etch; SiCl₄ + CF₄ + O₂ + He; GaAs selective etch from Al₀.₁₁Ga₀.₈₉As; Ref. (Smith, L.E., 1993)

ECR plasma etch; CCl₂F₂, BCl₃/SF₆, SiCl₄/SF₆; GaAs selective etch from AlGaAs or InGaAs; These require removal of residual etch stop surface components: HF₃ or InCl₃ or InF₃; Ref. (Pearton, S.J., 1993c)

Electron-beam assisted dry etch, ECR plasma; Cl₂ + Ar; GaAs/AlGaAs; GaAs selective etch from AlGaAs using SF₆: no optical or electrical damage compared with ion beam etching; Ref. (Watanabe, H., 1993a,b)

Reactive ion etch; SiCl₄ + SiF₄; Application: GaAs selective etch from AlGaAs for MODFET processing; Ref. (Ketterson, A.A., 1989)

Reactive ion etch; CH₄ + H₂; Application: GaAs selective etch from AlGaAs; Ref. (Law, V.J., 1989)

Reactive ion etch; CCl₂F₂ + He; GaAs selective etch from Ga₀.₅Al₀.₅As; gives etch rate selectivity dependence on gas pressures and concentrations; Ref. (Hikosaka, K., 1981)

Reactive ion etch; SiCl₄/SiF₄; selective removal of GaAs from AlGaAs; damage effects on MODFETs; Ref. (Ballegeer, D.G., 1992)

Reactive ion etch; BCl₃; selective removal of GaAs from AlGaAs or InGaAs; Ref. (Kazior, T.E., 1992)
Reactive ion etch; CCl$_2$F$_2$; study of the role of AlF$_3$ as etch stop in selective removal of GaAs from AlGaAs; Ref. (Seaward, K.L., 1988)

ECR plasma etch; Cl$_2$/NF$_3$/Ar; GaAs selective etch from AlGaAs; Ref. (Lee, W.-S., 1992)

ECR plasma; CCl$_2$F$_2$; Application: GaAs selective etch from AlGaAs; selectivity > 200; Ref. (Ren, F., 1992a)

Reactive ion etch; SiCl$_4$/SiF$_4$ (1:9); GaAs selective etch from AlGaAs; Ref. (Tong, N., 1992b)

Reactive ion etch; CCl$_2$F$_2$; Application: GaAs selective etch from Al$_{0.3}$Ga$_{0.7}$As stop etch layer; selectivity > 4000; gas residence time dependent; Ref. (Cameron, N.J., 1991)

ECR plasma etch; Cl$_2$/NF$_3$/Ar; GaAs selective etch from AlGaAs; Ref. (Lee, W.-S., 1992)

ECR plasma; CCl$_2$F$_2$; Application: GaAs selective etch from AlGaAs; selectivity > 200; Ref. (Ren, F., 1992a)

AsBr$_3$ thermochemical in situ etching for molecular beam epitaxy; temperature dependent etch rate selectivity for InAs from GaAs and GaAs from AlGaAs; vee-groove pattern dependence on material and temperature; Ref. (Schuler, H., 2000)

**GaAs from InGaAs**

Reactive ion etch; SiF$_6$/SiCl$_4$; AlGaAs/GaAs with use of etch stop layers of AlGaAs and InGaAs; Ref. (Cooper, C.B., 1987b)

ECR etch; Cl$_2$; GaAs selective removal from InGaAs; indium chloride by-products stop etching of InGaAs at room temperature; Ref. (Reed, J.D., 1995)

**GaAs from InGaP**

RIE using BCl$_3$/Ar from GaAs, GaInP, AlGaInP, and AlInP; selective removal of GaAs from InGaP; selective removal of InGaP from AlInP; Ref. (Juang, Y.Z., 1998)

Reactive ion etch; BCl$_3$ + Ar (6:4); selective etch of GaAs from InGaP for gate recess of FETs; Ref. (Kuo, C.W., 1998b)

Plasma etch of InGaP and GaAs in PCl$_3$/Ar, CCl$_2$F$_2$/Ar, CH$_4$/H$_2$/Ar; Conditions for selective etch of GaAs from InGaP are determined; Ref. (Lothian, J.R., 1992b)

**AlGaAs from GaAs**

Reactive ion etch; CCl$_4$/He; Application: AlGaAs selective etch from GaAs with selectivity > 1000; Ref. (Hida, H., 1989)
**InGaP from GaAs**

Plasma etch; PCl$_3$/Ar and CCl$_2$F$_2$/Ar; InGaP selective etch from GaAs; Ref. (Lothian, J.R., 1992a)

Reactive ion etch; ClICH$_3$ with H$_2$, He, O$_2$, Ne or Ar; GaAs and InP; GaAs and InP etch selectivity depend on gas combinations; Ref. (Law, V.J., 1992)

**InAlP from GaAs**

Plasma etch; PCl$_3$/Ar, CCl$_2$F$_2$/Ar, CH$_4$/H$_2$/Ar; AllnP selective etch from GaAs; Ref. (Lothian, J.R., 1992c)

**AlGaP from GaAs**

Plasma etch; PCl$_3$/Ar, CCl$_2$F$_2$/Ar, CH$_4$/H$_2$/Ar; AllnP selective etch from GaAs; Ref. (Lothian, J.R., 1992c)

**GaSb from AlGaSb**

Reactive ion etch; SiCl$_4$; GaSb and GaAlSb etch study for selective and non-selective etch conditions; Ref. (Ou, S.S., 1996)

**GaN from InN, AlN**

ECR plasma etch of GaN, InN, and InGaN in ICl/Ar and IBr/Ar; selective etch of GaN from InN, AlN, or InAlN; Ref. (Vartuli, C.B., 1997d)

ECR plasma etching of GaN, AlN, InN, InGaN, and InAlN in Cl$_2$/Ar, CH$_4$/H$_2$/Ar, ICl/Ar, and IBr/Ar. Study of etchant selectivity. Cl-based etches maximize selectivity; Ref. (Vartulli, C.B., 1996)

**InN from GaN**

Inductively coupled plasma etch, selective removal of InN and InGaN from GaN using BI$_3$ and Bbr$_3$; Ref. (Cho, H., 1999b)

**W from InP**

Reactive ion etch; CF$_6$, SF$_6$; selective removal of tungsten from III–V semiconductors using a titanium etch mask; Ref. (Fullowan, T.R., 1992b)

**SiN$_x$ from InP**

Reactive ion etch; CHF$_3$/O$_2$; removal of SiN$_x$ mask from InP; Ref. (Kollakowski, St., 1998)

ECR plasma etch; Application: mask patterning for AlGaAs/GaAs HBTs; O$_2$ discharge for polydimethylglutarimide mask etch; SF$_6$ discharge for SiN mask; Ref. (Lothian, J., 1992e)
**Ti from InP**

Reactive ion etch using SF$_6$ for Ti mask patterning and mask removal from InP/InGaAsP. (Qian, Y.H., 1999)

3.4. *Dry etch — passivation*

**InP**

ECR plasma oxidation study of InP; Ref. (Hu, Y.Z., 1994)

ECR plasma oxidation; InP surface passivation
HF:H$_2$O, dilute; InP oxide removal; Ref. (Hu, Y.Z., 1993)

**GaAs**

Nitridization of GaAs in plasmas of N$_2$ + O$_2$ with pretreatment in O$_2$ + Ar plasma; Ref. (Hara, A., 1998)

Sulfur passivation of GaAs surface using a sulfur glow discharge plasma; Ref. (Hou, X., 1996)

Sulfur passivation of GaAs from H$_2$S; study of reaction behavior; Ref. (Jönsson, J., 1993)

Oxidation of GaAs in steam environment at 500–520°C; thickness versus time; patterns using SiO$_2$ mask; Ref. (Oh, T.-H., 1996)

Sulfidization of GaAs (1 1 0) by gas phase polysulfide treatment; study of surface stabilization by S; Ref. (So, B.K.L., 1996)

H$_2$S + polysulfide gas exposure (N$_2$ through a liquid bubbler of pH-adjusted polysulfide solution) sulfidation of GaAs and InP; study of surface roughness and oxygen content; Ref. (Choy, W.H., 1999)

Si$_3$N$_4$ surface passivation of GaAs by plasma nitridation of a Si layer; Ref. (Diatezua, D.M., 1998)

Sulfidization of GaAs; thermal and photoinduced dissociation of H$_2$S; Ref. (Nooney, M.G., 1995)

H$_2$S gas sulfidization of GaAs; Ref. (Shun, J., 1991)

H$_2$O, thermal oxidation of AlInAs; Ref. (Petit, P., 1997)

ECR nitridization of GaAs using N$_2$ plasma; formation of As–N bonds for SiN$_x$ deposition; Ref. (Landheer, D., 2000)

3.5. *Dry etch — thermochemical*

**InP**

Thermochemical vapor etch; HCl + H$_2$ + PH$_3$; etch through SiO$_2$ masks for OMVPE; Ref. (Caneau, C., 1991)
Thermochemical vapor etch; HCl + H₂ + PH₃; InP in situ etch for OMVPE; Ref. (Pak, K., 1986)

Thermochemical vapor etch; PCl₃ + H₂; Application InP VPE growth; Ref. (Chevrier, J., 1981)

Thermochemical vapor etch; ethylene dibromide + H₂ + PH₃; InP (1 0 0) in situ etch for OMVPE; Ref. (Clawson, A.R., 1984, 1985)

Thermochemical vapor etch; HI/H₂/Ar, CH₄/H₂/Ar; GaAs, InP, InAs, InSb, InGaAs, InAlAs, InAlP; Ref. (Pearton, S.J., 1992b)

Thermal etching (degradation) in H₂; thermal etch in H₂ of LPE reactor; Ref. (Lum, W.Y., 1979)

Thermal degradation, InP surface morphology after 600°C anneal, and degradation inhibition by 1 monolayer of MBE GaAs deposit; Ref. (Matsui, Y., 1987)

Thermochemical HCl vapor etch for InP; low pressure OMVPE substrate etch at 650°C; Ref. (Agnello, P.D., 1985)

Thermochemical vapor etch; ethylene dibromide (EDB); InP; low temperatures to avoid InP thermal degradation are achieved by use of a separate high temperature decomposition of the EDB; Ref. (Chang, H.L., 1985)

Low temperature thermochemical etching of InP, GaAs and InSb using remote plasma decomposition of ethylene dibromide; Ref. (Iyer, R., 1989)

Thermal etching and mass transport in InP vee-grooves during hydrogen heat treatment; (Tanahashi, T., 1983)

Thermochemical vapor etch; HCl; InP and GaAs in situ surface cleaning for MBE growth; Ref. (Contour, J.P., 1987)

Thermochemical vapor etch; Cl₂; GaAs and InP in situ vacuum technique for MBE substrate cleaning; Ref. (Furuhata, N., 1989)

Thermochemical vapor etch; HCl in VPE-hydride growth; InGaAs; Ref. (Quinlan, K.P., 1985)

Thermochemical vapor etch; Cl₂/H₂ for InP and GaAs; thermodynamic analysis of etching; Ref. (McNevin, S.C., 1986b)

Thermochemical vapor etch; PCl₃; InP in situ CBE etch; Ref. (Tsang, W.T., 1993)

Thermochemical etch; PCl₃; InP in situ CBE chamber etch at 550°C; Ref. (Chiu, T.H., 1994)

PCl₃ in situ MBE vapor etch; InP pattern etching for regrowth; Ref. (Tsang, W.T., 1995)

Thermal etching (degradation) of InP in H₂; PH₃ surface stabilization; Ref. (Clawson, A.R., 1979)
Thermochemical etch of InP using Cl; damage study; Ref. (Hu, E.L., 1996b)

Thermochemical vapor etch of InP structure in Cl₂ in a ECR system; optimum temperature of 280°C to minimize surface roughness; Ref. (Maximov, I., 1997)

Thermochemical vapor etch; CCl₄; InP in situ etch from MOVPE; Ref. (Kibbler, A.E., 1990)

In situ CBE digital etching of InP for selective epitaxy using trisdimethylaminophosphorus adsorption/desorption at 400°C; Ref. (Otsuka, N., 1999)

In situ CBE digital etching of InP for selective epitaxy using tert-butylphosphine (TBP) adsorption/desorption at 390°C; Ref. (Otsuka, N., 1998)

Thermochemical etch; Cl₂; InP/InGaAs pattern etching at ~300°C for fabricating quantum wires; Ref. (Panepucci, R., 1995)

Thermal degradation of InP; correlation of thermal pits to crystal defects; enhancement of dark defects in the crystal volume; Ref. (Sartorius, B., 1989)

**GaAs**

Thermochemical vapor etch; HCl + H₂ + AsH₃; Ref. (Bhat, R., 1975)

Thermochemical etch; AsH₃, HCl; GaAs in situ etch for OMVPE; Ref. (Bhat, R., 1978); (Guel, G., 1992)

Thermochemical vapor etch; HCl; InP and GaAs in situ surface cleaning for MBE growth; Ref. (Contour, J.P., 1987)

Thermochemical etch of AlGaAs/GaAs in HCl with H₂ at 710°C; Application: for OMVPE regrowth; Ref. (Shimoyama, K., 1991)

Thermochemical vapor etch; AsCl₃ + H₂; GaAs (1 0 0) and (1 1 1)B in cold wall reactor; Ref. (Bhat, R., 1977)

Thermochemical vapor etch; AsCl₃ + H₂; GaAs in situ etch for OMVPE; Ref. (El Jani, B., 1982a,b)

Thermochemical vapor etch; HCl + H₂ + H₂O; GaAs; Ref. (Michelitsch, M., 1964)

Thermochemical vapor etch; HI/H₂/Ar, CH₄/H₂/Ar; GaAs, InP, InAs, InSb, InGaAs, InAlAs, InAlP; Ref. (Pearton, S.J., 1992b)

Thermochemical vapor etch; Cl₂; GaAs under high vacuum conditions; temperature range: 100–700°C; surface and profile characteristics of SiO₂-masked patterns; Ref. (Furuhata, N., 1990)

Thermochemical vapor etch; ICl; GaAs etch rate study in 100–300°C temperature range; Ref. (Hahn, L., 1993)
Dimethylzinc; Application: thermochemical vapor etch of GaAs above 380°C in H₂ for OMVPE growth; Ref. (Akram, S., 1992)

Thermochemical vapor etch; Cl₂; GaAs and InP in situ vacuum technique for MBE substrate cleaning; Ref. (Furuhata, N., 1989)

Thermochemical vapor etch; Cl₂/H₂ for InP and GaAs; thermodynamic analysis of etching; Ref. (McNevin, S.C., 1986)

Low temperature thermochemical etching of InP, GaAs and InSb using remote plasma decomposition of ethylene dibromide; Ref. (Iyer, R., 1989)

Thermochemical etch; Cl₂; GaAs; identification of the reaction products over the temperature range 330–950 K; Ref. (Su, C., 1993)

Thermochemical vapor etch; AsCl₂ + H₂ in situ etch of GaAs prior to VPE growth; comparison of etched surface roughness with initial surface reflection; Ref. (Németh-Sallay, M., 1993)

Thermochemical etch; Cl₂; GaAs and AlGaAs in situ MBE; at 350°C; etched surfaces suitable for layer regrowth; Ref. (Lee, H.G., 1993)

Thermochemical vapor etch using AsCl₃/He; GaAs in situ substrate etch for CVD; Ref. (DiLorenzo, J.V., 1975)

Thermochemical Cl₂ etching of GaAs; pulsed laser heating to desorb etch products; photomask pattern etching of vias and recesses; Ref. (Foulon, F., 1992a, 1993)

Thermochemical vapor etch; CCl₄ in MOCVD reactor; GaAs and InAs etch rates from 500 to 650°C; InAs ≫ GaAs; Ref. (Stockman, S.A., 1994)

Atomic H oxide reduction on GaAs surfaces

(H₂SO₄:H₂O₂:H₂O (4:1:1) GaAs surface preclean prior to H oxide reduction); Ref. (Petit, E.J., 1994)

Thermochemical vapor etch; Cl₂; GaAs selective etch from InAs at 130°C in a MBE chamber; Ref. (Miya, S., 1993)

ECR H₂ plasma etch followed by Cl₂ thermochemical vapor etch; GaAs surface cleaning for MBE; Ref. (Hong, M., 1993)

Thermochemical vapor etch; Cl₂; GaAs under high vacuum conditions; temperature dependence and cross-section profiles; Ref. (Furuhata, N., 1990)

Thermochemical etch; AsCl₃; GaAs at 600°C; Ref. (Chiu, T.H., 1994)

Thermochemical laser assisted dry etch of GaAs in Cl₂; Ref. (Tucker, A.W., 1983)
Thermochemical laser-induced dry etch of GaAs in CCl₄; Ref. (Takai, M., 1983, 1984, 1985)

Thermochemical Cl₂ and Ar ion beam assisted Cl₂ in situ etching of GaAs surfaces for MBE GaAs regrowth; surface study; Ref. (Mui, D.S.L., 1993)

Thermochemical etch; HCl + AsH₃; GaAs/AlGaAs in situ etch at 750°C prior to MOVPE regrowth of GaAs; Ref. (Kizuki, H., 1993a)

Thermochemical vapor etch; HCl; in situ etch for GaAs MOCVD regrowth on AlGaAs; optimization of AsH₃ flow rate to minimize dislocation density in regrowth; Ref. (Kizuki, H., 1993b)

Thermochemical etch; Cl₂ in UHV; GaAs and InAs; use of InAs as mask on GaAs at 130°C; patterning by enhanced InAs etch rate from electron beam; Ref. (Miya, S., 1993)

Thermochemical etch; Cl₂; GaAs for MBE in situ surface cleaning; Ref. (Osaka, F., 1994)

Thermochemical vapor etch; Br₂; GaAs (1 1 0); etching and desorption of etching products above ~575 K; Ref. (Patrin, J.C., 1993a)

AsCl₃ in situ MBE vapor etch; GaAs surface cleaning; Ref. (Tsang, W.T., 1995)

Br thermochemical etch of GaAs; STM study of etch mechanism dependence on Br concentration at 700 K; Ref. (Brake, J., 1997)

Br etch mechanism study of GaAs by STM; Ref. (Cha, C.Y., 1997)

Monolayer etching of GaAs in Br₂ vapor; study of etch kinetics; Ref. (Cha, C.Y., 1996)

Thermochemical etch; Cl₂; in situ etch of InGaAs for regrowth of AlInAs by MBE; Ref. (Chavarkar, P., 1997)

Thermochemical etch of AlGaAs with HCl; in situ MOVPE; Ref. (Fujii, K., 1994)

Thermochemical vapor etch; CH₃I; GaAs in situ etch for OMVPE; Ref. (Wang, C., 1992)

Thermochemical etching of SiO₂-patterned GaAs using AsCl₃ in a CBE reactor; Ref. (Guyaux, J.L., 1999)

Thermochemical nitridization of GaAs in NH₃; synchrotron photoemission spectroscopy study; Ref. (Huh, C., 1998)

Thermochemical etch; HCl in situ GaAs etch for MBE AlGaAs overgrowth; Ref. (Kadoya, Y., 1998)

HCl gas thermochemical etch; In situ etch of GaAs/AlGaAs for MOVPE regrowth of GaAs; two steps: 350°C for 60 min surface cleaning (etch rate 2 Å/min) then 750°C GaAs etch (800 Å/min); Ref. (Kizuki, H., 1997)
Thermochemical etch; tris-dimethylaminoarsenic in situ etch of GaAs for MBE regrowth of AlGaAs; Ref. (Li, N.Y., 1997)

Thermochemical vapor etch; CCl₄; GaAs in situ pregrowth etch for OMVPE; Ref. (Rebey, A., 1998)

Thermochemical vapor etch; VCl₄; GaAs in situ pregrowth etch for OMVPE; Ref. (Rebey, A., 1998)

Thermochemical and photochemical etching; GaAs in HCl and Cl₂; study of etching mechanisms; Ref. (Senga, T., 1996)

Thermochemical etching of GaAs/AlGaAs structure using laser-induced etch in CCl₂F₂ and C₂H₂F₄; Ref. (Park, S.-K., 2000)

Thermochemical etch mechanism study of Cl₂ on GaAs (0 0 1) surfaces; Ref. (Simpson, W.C., 1996)

Thermochemical etch; Cl₂ of GaAs; study of temperature dependence of surface composition and reconstruction; Ref. (Tanaka, N., 1995)

Thermochemical etch; CBr₄; in situ MOCVD etch of GaAs and AlAs; Ref. (Tateno, K., 1997)

Thermochemical etch; AsBr₃; GaAs reaction mechanism study; rate is limited by formation/desorption of GaBr; Ref. (Zhang, J., 1997)

Bisdimethylaminochlorarsine; thermochemical vapor etch for gas source MBE GaAs surface cleaning; Ref. (Okamoto, N., 1998)

Scanning tunneling microscopy study of halogen atom interactions on GaAs (1 1 0) surfaces; shows dissociative adsorption and etching at steps and terraces depending on temperature fluence and flux; Ref. (Patrin, J.C., 1993b)

HNO₃ (without water) vapor etch; GaAs oxidation; Ref. (Michel, C., 1982)

Thermal oxidation of GaAs; effects of temperature and doping; studied with Raman scattering, AES, and ellipsometry; Ref. (Rim, A., 1993)

Thermal oxidation; AlGaAs/GaAs; N₂ saturated with H₂O; 70 min at 425°C; Ref. (Maranowski, S.A., 1993)

Vapor oxidation of AlGaAs at 425°C with H₂O in N₂; Ref. (Sugg, A.R., 1993)

AsBr₃ thermochemical in situ etching for molecular beam epitaxy; temperature dependent etch rate selectivity for InAs from GaAs and GaAs from AlGaAs; vee-groove pattern dependence on material and temperature; Ref. (Schuler, H., 2000)

**InAlAs**

Lateral oxidation of InAlAs and AlAsSb layers on InP by heating in water saturated N₂; study of properties; Ref. (Legay, P., 1997)
GaN
Thermal desorption of oxygen and carbon from AlN and GaN surfaces in UHV; Ref. (King, S.W., 1998)
Thermal desorption of GaN in vacuum; not effective for removing O and C; GaN decomposition occurs >800–900°C; Ref. (Smith, L.L., 1996)

Si
Thermochemical vapor etch; HCl H₂; silicon; Ref. (Ban, V.S., 1975)

3.6. Dry etch — photochemical

InP
Vapor etch; GaAs and InP by ultra-violet photodecomposition of methyl-halides; etch rate > 10⁴ times the dark reactions; Ref. (Ehrlich, D.J., 1980)
Vapor etch by ultra-violet photodecomposition of methyl-halides; Ref. (Ehrlich, D.J., 1980)
Laser-induced dry etch of InP using UV photolysis of CH₃I; direct write patterning contrast is enhanced by presence of surface oxide; Ref. (Durose, K., 1988)
Excimer laser-assisted etch; CH₃Br or CF₃Br at 193 or 248 nm wavelength; InP, Si, Al; Application: InP/InGaAs avalanche photodiodes; Ref. (Peyre, J.L., 1988)
Laser-induced thermochemical dry etch in Cl₂; GaAs, InP, InSb and GaP; Ref. (Takai, M., 1988)
Cl₂ exposure of InP surface with pattern projection, excimer laser desorption of InCl₃; Application: waveguide fabrication; Ref. (Matz, R., 1993)
Thermochemical vapor etch; Cl₂; InP; laser-induced etching; Ref. (Ding, L., 1988)
Laser assisted dry etching of InP using Cl₂ for diffraction patterned periodic structures; Ref. (Prasad, M., 1997)
Gas phase polysulfide in N₂ from a bubbler; analysis of S on the InP surface; Ref. (Kwok, R.W.M., 1995)

GaAs
Vapor etch; GaAs and InP by ultra-violet photodecomposition of methyl-halides; etch rate > 10⁴ times the dark reactions; Ref. (Ehrlich, D.J., 1980)
Vapor etch by ultra-violet photodecomposition of methyl-halides; Ref. (Ehrlich, D.J., 1980)
Electron-beam-induced Cl₂ etching of GaAs patterns; Ref. (Akita, K., 1989)

Electron-beam-induced Cl₂ etch; GaAs; oxidized surface is resistive to etching, whereas irradiated region etches easily for maskless patterning; Ref. (Sugimoto, Y., 1992b)

Electron-beam-induced HCl maskless pattern etching of GaAs; Ref. (Akita, K., 1991a)

Photoassisted dry etch; Cl₂/He (1:3); GaAs monolayer by monolayer etch by surface chlorination followed by laser desorption of surface chlorides; Ref. (Bourne, O.L., 1993)

UV photochemical etching of GaAs in CF₃Br or CH₃Br; Ref. (Brewe, P., 1984)

Photoassisted dry etch; Cl₂; GaAs; self-terminating chloronation reaction followed by laser photodesorption of surface chlorides; Ref. (Maki, P.A., 1989)

Focused Ga ion beam etching of GaAs in Cl₂; Auger surface study; Ref. (Toshihiko, K., 1993)

Laser enhanced Reactive ion etch; CCl₄ + H₂; GaAs; Ref. (Tsukada, N., 1984)

Laser-induced GaAs etching in CH₃Br; Ref. (Osgood Jr., R.M., 1983)

Laser-induced etching of GaAs in Cl₂ and O₃ gases; Ref. (Koren, G., 1988)

Laser-induced photoetching of Si in Cl₂ and NF₃ gases; Ref. (Horiike, Y., 1987)

Laser-induced thermochemical, maskless etch using CHClF₂ and C₂H₂F₄ on GaAs; Ref. (Kim, M.-S., 1997)

Laser-assisted Cl₂ etch; GaAs low temperature etch from physisorbed Cl₂; Ref. (Shih, M.C., 1992)

Laser-induced thermochemical dry etch in Cl₂; GaAs, InP, InSb and GaP; Ref. (Takai, M., 1988)

Photochemical dry etching of GaAs in plasma-decomposed HCl + He; Ref. (Ashby, C.I.H., 1984)

Photochemical dry etching of GaAs in HBr; Ref. (Brewer, P.D., 1985)

Photochemical removal of GaAs layers with surface adsorbed Cl₂; low temperature (140 K) enhances photo selectivity; Ref. (Shih, M.C., 1995)

Photochemical dry etch of GaAs in HBr; Ref. (Brewer, P.D., 1986)

Layer by layer etch of GaAs (1 1 0) by Cl₂ exposure followed by laser photodesorption; Ref. (Han, B.Y., 1998)

Photoetching (193 nm excimer laser) in low pressure Cl₂ at 140 K of GaAs, GaSb, InAs, InSb; Ref. (Lin, J.-L., 1995)
Layer by layer etching of GaAs by Cl₂ adsorption followed by UV laser photochemical stripping; Ref. (Meguro, T., 1997)

Thermochemical and photochemical etching; GaAs in HCl and Cl₂; study of etching mechanisms; Ref. (Senga, T., 1996)

Laser assisted Cl₂ etch of AlGaAs and GaAs. Laser desorbs non-volatile GaCl₃; Ref. (Takatani, S., 1995)

Thermochemical, laser-induced dry etch of GaAs in Cl₂; Ref. (Foulon, F., 1992b)

GaP

Laser-induced thermochemical dry etch in Cl₂; GaAs, InP, InSb and GaP; Ref. (Takai, M., 1988)

GaSb

Pulsed UV laser assisted oxidation and oxide desorption of GaSb; Ref. (Petit, E.J., 1991a)

Oxide desorption from GaSb using pulsed UV laser; Ref. (Petit, E.J., 1991b)

InSb

Laser-induced thermochemical dry etch in Cl₂; GaAs, InP, InSb and GaP; Ref. (Takai, M., 1988)

InGaAs

Photochemical dry etch; CH₃Br with a low pressure mercury lamp; InGaAs selective etch from InAlAs; selectivity of 25; Ref. (Kuroda, S., 1992)

Photochemical etch in HBr gas; selective etch of InGaAs from InAlAs; selectivity of ~100 results from non-volatile oxide formation on InAlAs; Ref. (Habibi, S., 1995a)

HBr photochemical dry etch; selectively removes InGaAs from InAlAs; Ref. (Habibi, S., 1995b)

HBr gas; photochemical etch using a 172 nm excimer lamp, selective removal of InGaAs from InAlAs; Ref. (Tanaka, J., 1996)

Cl₂ photochemical etching using ArF excimer laser; selective removal of InAlAs from InGaAs; Ref. (Takazawa, H., 1998)

GaN

Photoenhanced reactive ion etch of GaN and BN using BCl₃/Cl₂/Ar/N₂; Ref. (Tempez, A., 1999)

UV laser ablation etch; GaN patterns; Ref. (Zhang, J., 1998)
3.7. Dry etch — rate monitoring

ECR etch, rate monitoring with laser reflectance; GaAs, AlAs, AlGaAs in situ measurement; Ref. (Grober, L.H., 1994)

ECR etch; Cl₂/Ar; GaAs; in situ mass spectrometry monitoring of volatile by-products to assess etch efficiency; Ref. (Kahaian, D.J., 1995)

ECR etch, optical monitoring; Cl₂/Ar; InP and GaAs; Ref. (Thomas III, S., 1995a)

Reactive ion beam etch, in situ optical monitoring; AlGaAs/GaAs; Ref. (Vawter, G.A., 1994)

Dry etch optical emission spectroscopy monitoring of etch products to determine etch endpoint for removing InAlAs emitter layers without removing InGaAs base layers in HBT structures; development of modeling algorithm; Ref. (Hanish, C.K., 1997)

ECR etch in situ surface roughness measurement with a laser reflectometer; Ref. (Parker, M.A., 1996)

ECR etching of InGaAs/InP using BCl₃ + N₂; end point monitoring using optical emission spectroscopy; Ref. (Kopf, R.F., 2000)

Etch thickness monitoring by use of ECV profiling with spaced marker layers; Ref. (Somogyi, K., 1990)

Ion beam etch, in situ monitoring of secondary ion species; Ref. (Webb, A.P., 1986)

CAIBE etch, in situ monitoring of secondary ion species; Ref. (Webb, A.P., 1987)

4. Wet etchants by chemical composition

A–B etch (see AgNO₃:CrO₃:HF:H₂O)

Adipic acid:NH₄OH:H₂O₂

Adipic acid:NH₄OH:H₂O₂ (1 g adipic acid in 5 ml H₂O; NH₄OH to adjust pH over the range 5.3–7.0; H₂O₂ added in the range of volume ratios of 0.013–0.12); InGaAs removal from InAlAs; selectivity up to 250; Ref. (Higuchi, K., 1997)

Adipic acid; InGaAs selective etch from InAlAs and InAlAs selective etch from AlAs; Ref. (Broekaert, T.P.E., 1992b)

AgNO₃:CrO₃:HF:H₂O {A–B etch}
InP

\[ \text{H}_2\text{O}:\text{AgNO}_3:\text{CrO}_3:\text{HF} \ (10 \text{ ml}:40 \text{ mg}:5 \text{ g}:8 \text{ ml}) \ {\text{A–B etch}; \ InP \ (100) \ etch \ rate = 600 \ \text{Å/min at 20}^\circ\text{C}; \ Ref. (Clawson, A.R., 1978)} \]

\[ \text{H}_2\text{O}:\text{AgNO}_3:\text{CrO}_3:\text{HF} \ (2 \text{ ml}:8 \text{ mg}:1 \text{ g}:1 \text{ ml}) \ {\text{A–B etch}; Application: InP dislocation etch pit delineation; Ref. (Woodward, J., 1982)} \]

A–B etch; Application: InP dislocation delineation; 60°C for 20–30 min; Ref. (Takeda, Y., 1980)

A–B etch comparison with HF:HBr (5:1) and (10:1); InP dislocation etch pit delineation study; Ref. (Kotani, T., 1980)

A–B etch; InP dislocation etch pit delineation; Ref. (Huber, A., 1975)

\[ \text{CrO}_3:\text{AgNO}_3:\text{H}_2\text{O}:\text{HF} \ (1 \text{ g}:8 \text{ mg}:2 \text{ ml}:1 \text{ ml}) \ {\text{A–B etch}; \ InP, delineation of pits, ridges, and striations, 30–90 min at 60°C; Ref. (Brown, G.T., 1980)} \]

\[ \text{AgNO}_3:\text{CrO}_3:\text{HF}:\text{H}_2\text{O} \ (40 \text{ mg}:5 \text{ g}:8 \text{ ml}:10 \text{ ml}) \ {\text{A–B etch}; Application: InP layer delineation; Ref. (Rosztoczy, F.E., 1970)} \]

A–B etch; Layer interface and defect delineation in GaAs, InP, InGaAs, InGaP, GaP; for As-compounds several seconds at 20°C; for P-compounds many minutes at 50–75°C; Ref. (Olsen, G.H., 1974)

\[ \text{CrO}_3:\text{AgNO}_3:\text{H}_2\text{O}:\text{HF} \ (1 \text{ g}:8 \text{ mg}:2 \text{ ml}:1 \text{ ml}) \ {\text{A–B etch}; Application: InP defect delineation etch; 60 min at 60°C; Ref. (Hirano, R., 1993)} \]

InGaAs

A–B etch; InGaAs dislocation etch pit delineation, 3 min at 20°C; Ref. (Takeda, Y., 1978, 1980)

A–B etch:HF (1:3); Application: InGaAs dislocation etch pit delineation for 10 s at 60°C; HF slows the etch rate; Ref. (Susa, N., 1980a,c)

A–B etch; Application: InGaAs dislocation etch pit delineation; Ref. (Ahmad, K., 1979)

InGaAsP

A–B etch, modified: \[ \text{H}_2\text{O}:\text{AgNO}_3:\text{CrO}_3:\text{HF} \ (10 \text{ ml}:140 \text{ mg}:5 \text{ g}:8 \text{ ml}) \ {\text{A–B etch}; InGaAsP dislocation etch pit delineation; 30 min at 75°C; Ref. (Theil, F.A., 1979)} \]

\[ \text{H}_2\text{O}:\text{AgNO}_3:\text{CrO}_3:\text{HF} \ (10 \text{ ml}:40 \text{ mg}:5 \text{ g}:8 \text{ ml}) \ {\text{A–B etch}; InGaAsP LPE layer defect delineation; 25 min at 65°C; Ref. (Shirafuji, J., 1981)} \]

A–B etch; Application: InGaAsP/InP layer interface delineation a few seconds at 100°C; Ref. (Wright, P.D., 1977)
A–B etch: layer interface delineation; Ref. (Olsen, G.H., 1979)

A–B etch tried, but too fast attack; Alternative was KOH:K₃Fe(CN)₆:H₂O (8 g:0.5 g:100 ml); InGaAsP p–n junction delineation; Ref. (Lourenco, J.A., 1983)

H₂O:AgNO₃:CrO₃:HF (10 ml:40 mg:5 g:8 ml) {A–B etch}; Defect delineation etchant; Application to InP and InGaAsP: at 75°C for 30 min; Ref. (Mahajan, S., 1981)

**GaAs**

H₂O:AgNO₃:CrO₃:HF (2 ml:8 mg:1 g:1 ml) {A–B etch}; GaAs dislocation etch pit delineation; Ref. (Abrahams, M.S., 1965)

H₂O:AgNO₃:CrO₃:HF (2 ml:8 mg:1 g:1 ml) {A–B etch}; GaAs etch rate = 4 μm/min at 65°C; Ref. (Colliver, D.J., 1976)

H₂O:AgNO₃:CrO₃:HF {A–B etch}; Review of GaAs etching; Ref. (Mukherjee, S.D., 1985)

A–B etch; Layer interface and defect delineation in GaAs, InP, InGaAs, InGaP, GaP; for As-compounds several seconds at 20°C; for P-compounds many minutes at 50–75°C; Ref. (Olsen, G.H., 1974)

A–B etch; Application: GaAs epilayer p–n junction delineation; Ref. (Sin, Y.K., 1991)

A–B etch to reveal growth striations in LEC GaAs; Ref. (Miyazawa, S., 1982)

A–B etch; GaAs dislocation etch pit delineation; Ref. (Stirland, D.J., 1978)

A–B etch; GaAs (1 0 0) 5 min at room temperature for defect etch pit delineation; Ref. (Stirland, D.J., 1986)

A–B etch; GaAs dislocation etch pit delineation study; Ref. (Stirland, D.J., 1977)

A–B etch; GaAs etch pit defect delineation; 3 min at room temperature; etch rate ~3 μm/min; Ref. (Nordquist, P.E.R., 1993)

A–B etch; GaAs defect delineation; 10 μm etch depth; correlation of MBE layer defects to substrate etch pits; Ref. (Takagishi, S., 1993)

A–B etch; GaAs striation delineation etch
  A–B:H₂O (1:5); GaAs striation delineation etch; Ref. (Pandelisev, K.A., 1990)

**AlGaAs/GaAs**

H₂O:AgNO₃:CrO₃:HF(10 ml:40 mg:5 g:8 ml) {A–B etch}; GaAs/AlGaAs layer cross-section interface delineation; {1 1 1} facets along ⟨0 1 1⟩; {2 2 1} facets along ⟨0 1 1⟩; Ref. (Demeester, P., 1988)
GaP

A–B etch; with A = 40 ml H₂O:40 g CrO₃, and B = 40 ml H₂O:0.3 g AgNO₃; A:B (3:1); GaP 15 min at boiling; etch pits show 1:1 correlation with H₃PO₄:H₂O₂ photoetch; Ref. (Gottschalch, V., 1979)

H₂O:AgNO₃:CrO₃:HF (10 ml:40 mg:5 g:8 ml) {A–B etch}; GaP defect delineation; 50 min at 75°C; Ref. (Iizuka, T., 1971)

A–B etch; Layer interface and defect delineation in GaAs, InP, InGaAs, InGaP, GaP; for As-compounds several seconds at 20°C; for P-compounds many minutes at 50–75°C; Ref. (Olsen, G.H., 1974)

H₂O:AgNO₃:CrO₃:HF (10 ml:40 mg:5 g:8 ml); 15–60 min at 75°C; {A–B etch}; The higher temperatures and changes in compositions are necessary to retard precipitates which accumulate on the etched surface; Ref. (Saul, R.H., 1968)

GaAsP

A–B etch; Application: GaAsP dislocation etch pit delineation; Ref. (Stringfellow, G.B., 1969)

AgNO₃:HF:HNO₃:H₂O {RC etch}

InP

AgNO₃:HF:HNO₃:H₂O (40 mg:16 ml:24 ml:32 ml) {RC etch}; Application: InP (1 1 1)B dislocation delineation; etch time a few hours; Ref. (Lee, T.P., 1980); (Takeda, Y., 1978)

GaP

H₂O:AgNO₃:HNO₃:HF (8 ml:10 mg:6 ml:4 ml) {RC etch}; 1–3 min at 60°C; The higher temperatures and changes in compositions are necessary to retard precipitates which accumulate on the etched surface; Ref. (Saul, R.H., 1968); (Iizuka, T., 1971)

AgNO₃ (10 mg):HF (4 ml):HNO₃ (6 ml):H₂O (8 ml) (RC etchant); etch pit delineation in GaP; Ref. (Okada, H., 1999)

GaAs

AgNO₃:HF:HNO₃:H₂O (40 mg:16 ml:24 ml:32 ml) {RC etch}; GaAs (1 1 1) dislocation etch pit delineation. Added AgNO₃ reveals etch pits on both (1 1 1)A and (1 1 1)B; Ref. (Richards, J.L., 1960)

AgNO₃:HF:HNO₃:H₂O (40 mg:16 ml:24 ml:32 ml) {RC etch}; Application: GaAs dislocation propagation behavior study; Ref. (Yonenaga, I., 1993)

Ammonium tartarate (see (NH₄)₂C₄H₄O₆)
AZ400K (see photoresist developer)

**Bi(NO₃)₃:H₂O₂:HCl**

Bi(NO₃)₃:H₂O₂:HCl (0.38 g (Bi(NO₃)₂·5H₂O) in 15 ml H₂O₂ mixed with conc. HCl in the ratio 3:1); subsurface defect delineation on polished GaAs; Ref. (Sankaranarayanan, K., 1997)

**Br₂:dimethylformamide**

Br₂ in dimethylformamide (5%), etch rate = 1.9 μm/min; other etchants show no undercutting only in the ⟨110⟩A direction and are suitable for self-limiting vee-grooves. Only the anhydrous Br₂ etch shows no undercutting in the ⟨110⟩B direction; Ref. (Vozmilova, L.N., 1985)

**Br₂:ethanol**

Br₂/ethanol (20%), hot; GaP dislocation etch pit delineation; 30–60 s; Ref. (Val’kovskaya, M.I., 1967)

**Br₂:HBr:H₂O**

Br₂:HBr:H₂O (1:17:1000); Application: InP FET channel etch preparation for Schottky contact; Ref. (Chevrier, J., 1980)

Br₂:HBr:H₂O (1:17:300); InP surface treatment following H₂SO₄:H₂O₂:H₂O (4:1:1) for 2–4 min; etch rate = 0.8 μm/min; Ref. (Hyder, S.B., 1979)

Br₂:HBr:H₂O (1:17:300); etch rate = 0.8 μm/min for 2–4 min; Ref. (Saxena, R.R., 1980)

Br₂:HBr:H₂O (1:17:35); InP etch rate = 2 μm/min; Ref. (Colliver, D.J., 1976)

Br₂:HBr:H₂O (1:18:81); Ref. (Lubzens, D., 1977)

Saturated Br₂ water:HBr:H₂O (1:1:10); InGaAs best surface cleaning for InP OMVPE regrowth; etch rate = 80 Å/s; Ref. (Yablonovitch, E., 1992)

Saturated Br₂ water:HBr:H₂O; InGaAsP/InP laser surface grating etch; Ref. (Itaya, Y., 1984)

Saturated Br water:HBr:H₂O (1:10:40); InP/InGaAsP photolithography for submicron patterns; InP etch rate = 0.45 μm/min; gives dependence of etch rate and mask undercutting on H₂O + Br₂ concentrations; Ref. (Matsuoka, T., 1986)

Br₂:HBr:H₂O (1:17:35); XPS study of InP surface oxides following chemical treatment; Ref. (Hollinger, G., 1985)
Saturated bromine water (SBW): HBr:H₂O (1:10:40); Application: grating fabrication; dependence of etch depth on pattern spacing; Ref. (Nishida, T., 1993)

Saturated bromine water: HBr:H₂O; second step following RIE etch for patterns in InP; Ref. (Bertone, D., 1999)

HBr:Br₂:H₂O (5:0.1:100); Application: non-selective mesa etch for InGaP/GaAs; etch rate 0.6 μm/min for both materials; Ref. (Ginoudi, A., 1992)

Br₂:HBr:H₂O (1:17:35); 90 s InP wafer etch after Br₂/methanol chemical–mechanical polishing; Ref. (Guivarc’h, A., 1984)

SBW/HBr:HNO₃:H₂O (1:1:8); (SBW is prepared by putting 3 ml Br into 100 ml deionized water. SBW and HBr are mixed in proportions of 1–50 vol.%. Color of HBr changes to light yellow); non-selective etch of InGaAs/InP; rate = 15–20 Å/s at 4°C; etch of 500–1000 Å wide electron waveguide features with photoresist mask; Ref. (Maximov, I., 1999)

Br₂:alkaline

Br-containing alkali electrolytes; study of electrochemical mechanism; selectivity of InGaAs over InP; Ref. (Theuwis, A., 1999a)

Br₂:HBr:CH₃COOH (see HBr:CH₃COOH:Br₂)

Br₂:HCl:H₂O

Saturated Br₂ water:HCl:H₂O (10:1:20); gives etch rate dependence on acid concentration; Ref. (Saitoh, T., 1982)

Br₂:HCl:HNO₃ (see HCl:HNO₃:Br₂)

Br₂:HNO₃:HCl (see HCl:HNO₃:Br₂)

Br₂:HF:HNO₃:CH₃COOH (see HF:HNO₃:CH₃COOH:Br₂)

Br₂:HNO₃:HF:CH₃COOH (see HF:HNO₃:CH₃COOH:Br₂)

Br₂:H₃PO₄:H₂O

Saturated Br₂ water:H₂O:H₃PO₄ (2:15:5); InAlAs etch rate = 4000 Å/min for photolithography of second-order gratings; Ref. (Meneghini, G., 1989)

Saturated Br₂ water:H₃PO₄:H₂O (2:1:15); Application: InGaAsP and InP vee-groove grating etch; does not attack photoresists; Ref. (Prince, F.C., 1980)

Saturated Br₂ water:H₃PO₄:H₂O (4:15:2); Application: InGaAs submicron photolithography for quantum well dots; Ref. (Tan, I.-H., 1992)
\[ \text{H}_3\text{PO}_4:\text{H}_2\text{O} : \text{saturated bromine water} \ (1:15:2) ; \text{ undercut-mesa etch of InP for MOVPE regrowth following RIE etch} ; \text{ Ref. (Fang, R.Y., 1997)} \]

\[ \text{H}_3\text{PO}_4:\text{H}_2\text{O} : \text{saturated bromine water} \ (5:5:2) ; \text{ undercut-mesa etch of InP for MOVPE regrowth following RIE etch} ; \text{ Ref. (Fang, R.Y., 1997)} \]

\[ \text{H}_3\text{PO}_4:\text{H}_2\text{O} : \text{saturated bromine water} \ (10:10:1) ; \text{ undercut-mesa etch of InP for MOVPE regrowth following RIE etch} ; \text{ Ref. (Fang, R.Y., 1997)} \]

Saturated \( \text{Br}_2 \) water: \( \text{H}_3\text{PO}_4 : \text{H}_2\text{O} \) (2:1:15); \( \text{InP etch rate} \approx 56 \ \text{Å/s at 22°C}; \text{InGaAs etch rate} = 43 \ \text{Å/s}; \text{Ref. (Saitoh, T., 1982)} \)

**Br\(_2\):isopropanol**

\( \text{Br}_2: \text{isopropanol} \) (1.5 and 2.5%); \text{InP thinning etch for measuring diffusion profile}; \text{etch rates} = 0.5 \text{ and } 0.86 \ \mu\text{m/min at } -10^\circ \text{C}; \text{Ref. (Aytac, S., 1982)}

**Br\(_2\):KBr**

\( \text{Br}_2: \text{KBr solution} \); GaAs groove etch profile dependence on temperature; \text{Ref. (Kelly, J.J., 1988)}

\( \text{Br}_2: \text{KBr:H}_2\text{O} \) (1:10:89); \text{n-GaAs photoetchant for maskless laser-induced patterning}; \text{Ref. (Haynes, R.W., 1980)}

**Br\(_2\):methanol**

**InP**

\( \text{Br}_2: \text{methanol} \) (5%); \text{Application: InP substrate cleaning for VPE}; \text{Ref. (Kanbe, H., 1979)}

\( \text{Br}_2: \text{methanol} \) (3%); \text{InP (1 1 1)B etch rate} = 6 \ \mu\text{m/min}; \text{Ref. (Linh, N.T., 1975)}

\( \text{Br}_2: \text{methanol} \) (1.5%); \text{InP thinning etch}; \text{etch rate} = 0.5 \ \mu\text{m/min at } -10^\circ \text{C}; \text{Ref. (Aytac, S., 1982)}

\( \text{Br}_2: \text{methanol} \) (1%); \text{InP thinning etch}; \text{etch rate} = 2.7 \ \mu\text{m/min at } -10^\circ \text{C}; \text{Ref. (Aytac, S., 1982)}

\( \text{Br}_2: \text{methanol} \) (1%); \text{InP (1 0 0) etch rate} = 0.4 \ \mu\text{m/min}; \text{Ref. (Becker, R., 1973)}

\( \text{Br}_2: \text{methanol} \) (1 vol.%); \text{InP (1 0 0) etch rate} = 0.3 \ \mu\text{m/min}; \text{Ref. (Clawson, A.R., 1978)}

\( \text{Br}_2: \text{methanol} \) (1%); \text{Application: InP (1 1 1)B etch rate} = 2.5 \ \mu\text{m/min for LPE substrate preparation}; \text{Ref. (Linh, N.T., 1975)}

\( \text{Br}_2: \text{methanol} \) (1%); \text{Application: InP substrate cleaning for LPE}; \text{Ref. (Rezek, E.A., 1980); (Chen, P.C., 1981)}
Br₂/methanol (1 vol.%); InP, etch rate = 3000 Å/min; (0.5 vol.% etch rate = 2000 Å/min; Ref. (Tuck, B., 1973)

Br₂/methanol (1%); InP(1 1 1)B etch rate = 0.016 mg/cm²/s; InP (1 0 0) etch rate = 0.03 mg/cm²/s; Ref. (Tuck, B., 1973)

Br₂/methanol (1%); Application: InP substrate cleaning second step for VPE following H₂SO₄:H₂O₂:H₂O (5:1:1) {Caro’s etch} first step; Ref. (Towe, E.D., 1982); (Narayan, S.Y., 1981)

Br₂/methanol (1%); InP (1 0 0) reverse-mesa shaped {1 1 1}A surfaced groove along ⟨0 1 1⟩ and vee-groove {1 1 1}A surface along ⟨0 1 1⟩; Ref. (Westphalen, R., 1992)

Br₂/methanol (0.6%); 3 min, following first step
H₂SO₄:H₂O₂:H₂O (1:8:1); InP 1 min substrate cleaning; Ref. (Sakai, K., 1981)

Br₂/methanol (0.5%); InP etch rate = 2 μm/min; gives SiO₂ masked profiles; Ref. (Turley, S.E.H., 1982)

Br₂/methanol (0.5%); InP thinning etch; etch rate = 1.37 μm/min at −10°C; Ref. (Aytac, S., 1982)

Br₂/methanol (0.5 vol.%); InP (1 0 0) etch rate = 0.2 μm/min; Ref. (Clawson, A.R., 1978)

Br₂/methanol (0.3%); gives surface quality; attacks photoresists; Ref. (Adachi, S., 1981e)

Br₂/methanol (0.2%); 30 s etch prior to MOVPE regrowth of InP; Ref. (Catana, A., 1993)

Br₂/methanol (0.1–1%); etch procedures to obtain the best morphologies; Ref. (Saletes, A., 1988)

Br₂/methanol (0.1%); InP vee-groove etch, first step; exposes {1 1 1}A sidewalls but leaves surface defects. Third step of InP vee-groove etch; reduces the radius of the vee after H₂SO₄:H₂O₂:H₂O etch; Ref. (Kappelt, M., 1996)

Br₂/methanol (0.05%); Ellipsometry measurements to assess cleanest and smoothest etched surfaces; followed by H₂O rinse gives most abrupt surface; Ref. (Aspnes, D.E., 1981)

Br₂/methanol; InP polishing techniques for (1 0 0) substrates; Ref. (Chin, B.H., 1988)

Br₂/methanol; InP (1 0 0) polishing; dependence on Br concentration; Ref. (Chin, B.H., 1990)

Br₂/methanol; Application: InP substrate cleaning for LPE; Ref. (Nakajima, K., 1979); (Pearsall, T.P., 1977); (Sankaran, R., 1976); (Takeda, Y., 1978)

Br₂/methanol; Auger surface analysis; Ref. (Singh, S., 1982)

Br₂/methanol removal of surface polish damage, following first step H₂SO₄:H₂O₂:H₂O (1 0 0:0.92:5); InP surface cleaning; InP (1 0 0) etch rate = 0.02 μm/min; (1 1 1)B etch rate = 0.06 μm/min; gives etch rate dependence on H₂O₂ concentration; Ref. (Nishitani, Y., 1979)
Br₂/methanol etch; XPS surface study of InP residual Br dependence on methanol rinse time; Ref. (Kurth, E., 1988)

Br₂/methanol polishing etch (1% at RT for 1 min); one step in optimum InP surface cleaning; Ref. (Kurth, E., 1988)

Br₂/methanol etched InP; Study of oxide formation on Ref. (Wager, J.F., 1981)

Br₂/methanol (1%); InP surface cleaning for MBE regrowth gives high surface defect density; Ref. (Passenberg, W., 1997)

Br₂/methanol (3%); Application: via holes in InP FETs; rate ≈ 8 µm/min; Ref. (Trassaert, S., 1998)

Br₂/methanol (2%); vee-groove etching behavior with SiO₂ and photoresist masks; Ref. (Wang, J., 1998)

Br₂/methanol (1%); InP pattern etch for OMVPE; reentrant [1 0 0] direction profiles; Ref. (Zilko, J.L., 1991)

Br₂/methanol (2%); final polish of 40 µm InP mesas etched in HCl:H₃PO₄:lactic acid to reduce surface roughness; Ref. (Elías, P., 1999)

**InGaAs**

Br₂/methanol (1%); Application: InGaAs mesa etch; Ref. (Lee, T.P., 1981)

Br₂/methanol; Application: InGaAs mesa etch; Ref. (Leheney, R.F., 1981); (Kanbe, H., 1980); (Pearsall, T.P., 1978, 1980)

Br₂/methanol (1%); Application: InGaAs mesa photodiode etch, shows high dark current compared to peroxide etch; Ref. (Stocker, H.J., 1983)

Br₂/methanol (1 vol.%); InGaAs (1 0 0), MBE-grown, etch rate = 6 µm/min, InAlAs (1 0 0) etch rate = 8 µm/min. Gives InGaAs (1 0 0) etch rate dependence on orientation; shows etch profiles: for InGaAs only Br₂/methanol forms positive angle sidewalls on both (1 1 0) directions, giving good morphology and mesa shapes; same for InAlAs except also H₃PO₄:H₂O₂ (10:1) does not exhibit sidewall crystal habits; Ref. (Stano, A., 1987)

Br₂/methanol (0.5%) following first step H₂SO₄:H₂O₂:H₂O (3:1:1); InP substrate cleaning for MBE growth; Ref. (Bahl, S.R., 1991)

Br₂/methanol (1:2000); InGaAs, best surface cleaning for InP OMVPE regrowth; Ref. (Yablonovitch, E., 1992)

Br₂/methanol; InGaAs surface treatment followed by H₂O rinse and H₂O:NH₄OH (1:1) gives best contaminant-free interface; Ref. (Aspnes, D.E., 1982)
InGaAsP/InP

Br₂/methanol (1%); Application: InGaAsP surface cleaning for Schottky contacts; Ref. (Morgan, D.V., 1980); (Naitoh, M., 1982)

Br₂/methanol (1%); InGaAsP/InP; study of etch temperature on profile geometry and undercutting; Application: InGaAsP/InP double heterostructure laser; zero mask undercutting when etch at or below \(-58^\circ\text{C}\); Ref. (Huó, D.T., 1989e)

Br₂/methanol (0.5%); 2–3 s etch to remove ion damage; Ref. (Bouama, N., 1987)

Br₂/methanol (0.2%); Application: photolithography, InP vee-grooves; laser mirror etch with (1 1 1)A facets; very little mask undercutting; Ref. (Wright, P.D., 1980c)

Br₂/methanol (0.2%); InP/InGaAsP; with SiO \(_x\) masked patterns etch rate is enhanced by Br diffusion from masked areas; at low Br concentrations etch rate is diffusion limited and is independent of concentration, temperature and crystallographic orientation; Ref. (Brenner, T., 1994)

Br₂/methanol (0.1%); Application: InGaAsP stripe etch with SiO₂ mask for BH laser; Ref. (Itaya, Y., 1980)

Br₂/methanol (0.05%); Application: InGaAsP/GaAs etched mirror lasers; Ref. (Ishikawa, J., 1989)

Br₂/methanol; Application: InGaAsP thinning for X-ray lattice parameter profile; Ref. (Feng, M., 1980)

Br₂/methanol; Application: Photolithography: etch cross-section profiles; laser mirror etch; slight difference in etch rates between InGaAsP and InP; Ref. (Adachi, S., 1982b)

Br₂/methanol; InGaAsP and InP etch rates are similar for the concentration range from 0.1 to 4%; shows vee and dovetail groove cross-section etch profiles; Ref. (Adachi, S., 1982c)

Br₂/methanol; Application: InGaAsP/InP non-selective mesa etch; Ref. (Capasso, F., 1980); (Coldren, L.A., 1983); (Hurwitz, C.E., 1978); (Mito, I., 1982); (Armiento, C.A., 1979a); (Nelson, R.J., 1981); (Wright, P.D., 1980b); (Arai, S., 1981)

Br₂/methanol; Application: InGaAsP stripe etch for BH laser fabrication; Ref. (Hirao, M., 1980a,b); (Kano, H., 1979)

Br₂/methanol; shows groove etch profiles for vee-groove laser; Ref. (Imai, H., 1982)

Br₂/methanol; Application: InGaAsP/InP stripe and mesa etch for BH laser; Ref. (Nagai, H., 1980)

Br₂/methanol; Application: InP (1 0 0) vee- and dovetail-groove etch; Ref. (Nelson, R.J., 1980)

Br₂/methanol; Application: InGaAsP groove, stripe and channel etch; Ref. (Olsen, G.H., 1979, 1981)
Br$_2$/methanol; Application: InGaAsP/InP channel etch for BH laser fabrication; Ref. (Takahashi, S., 1980)

Br$_2$/methanol; Application: InGaAsP/InP laser mirror etch; Ref. (Wright, P.D., 1980a, 1982); (Adachi, S., 1981c,d)

Br$_2$/methanol; Application: InGaAsP/InP non-selective etch for photodiodes; Ref. (Takahashi, K., 1981)

Br$_2$/methanol; Application: InGaAsP/InP laser cantilever etch for microcleaving; Ref. (Szaplonczay, A., 1987)

Br$_2$/methanol (1%); InGaAsP/InP mesa etch; temperature dependence of etch rate; for $T < -58^\circ$C there is no undercutting of SiO$_2$ masks; Ref. (Hou, D.T.C., 1989)

**GaAs**

Br$_2$/methanol; review of GaAs etch characteristics; Ref. (Williams, R., 1990b)

Gives surface quality for Br$_2$/methanol (0.3%); (attacks photoresists); Ref. (Adachi, S., 1981e)

Br$_2$/methanol; GaAs chemi-mechanical polishing solution; Ref. (Dyment, J.C., 1971)

Br$_2$/methanol; GaAs polishing; Ref. (Sullivan, M.V., 1963)

Br$_2$/methanol; GaAs etching anisotropy is dependent on concentration; shows {1 1 1} plane terminated features for Br$_2$ <1%; shows {3 3 2} plane terminated features for Br$_2$ >1%; Application of negative bias increases etch rate and eliminates etch anisotropy; Ref. (Koszi, L.A., 1975)

Br$_2$/methanol; Application: GaAs mesa etch; destroys the Au mask layer; Ref. (Merz, J.L., 1976)

Br$_2$/methanol; attacks photoresists; Ref. (Otsubo, M., 1976)

Br$_2$/methanol (0.1–1%); etch procedures to obtain the best morphologies; Ref. (Saletes, A., 1988)

<table>
<thead>
<tr>
<th>Etch rate ($\mu$m/min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Br$_2$/methanol (1 wt.%);</td>
</tr>
<tr>
<td>GaAs (1 1 0)</td>
</tr>
<tr>
<td>GaAs (1 1 1)B</td>
</tr>
<tr>
<td>GaAs (1 1 1)A</td>
</tr>
<tr>
<td>GaAs (1 1 0)</td>
</tr>
</tbody>
</table>

Gives etch profile orientation dependence; Ref. (Tarui, Y., 1971)

Br$_2$/methanol; GaAs and InP XPS surface study giving binding energies and Ga/As and In/P surface compositions after etch; Ref. (Bertrand, P.A., 1981)
Br₂/CH₃OH (4%); masked pattern etch profiles on (0 0 1)GaAs; Ref. (Adachi, S., 1983)

Br₂/CH₃OH (1%); masked pattern etch profiles on (0 0 1)GaAs; Ref. (Adachi, S., 1983)

**GaSb**

Br₂/methanol (2%); GaSb(1 1 1)A etch pit defect delineation etch; Ref. (Doerschel, J., 1992)

Br₂/methanol (3%); GaSb etch pit delineation only on (1 1 1)A; Ref. (Costa, E., 1997)

Br₂/methanol (2%); GaSb mesa etch; room temperature 1 min; Ref. (Kodama, M., 1994)

Br₂/methanol (2%); GaSb; study and modeling of diffusion limited etching; Ref. (Tan, S.S., 1995)

**InAs**

InAs surface contaminant studies:
  Br₂/methanol (2%); InAs surface cleaning 5 min first step; followed by HF conc. InAs surface cleaning 5 min second step; followed by DI water rinse; leaves residual Br₂, F; demonstrates need for high purity water rinse to reduce ionic contaminants; Ref. (Brown, A., 1986)

Br₂/methanol (0.5%); InAs (1 1 1)B etch rate = 1 μm/min; Ref. (Sharma, B.L., 1966)

**GaP**

Br₂/methanol (5%); GaP etch rate at 20°C = 0.8 μm/min
  Br₂/methanol (1%); GaP etch rate at 20°C = 0.3 μm/min
  Br₂/methanol (0.5%); GaP etch rate at 20°C = 0.2 μm/min; Ref. (Kaminska, E., 1981)

Br₂/methanol; n- and p-type GaP; etch mechanism study; Ref. (Strubbe, K., 1993b)

Br₂/methanol; p-type GaP; etch mechanism study; Ref. (Strubbe, K., 1993a)

Br₂/methanol; GaAs and GaP polishing etchant; Ref. (Fuller, C.S., 1962)

**Safety**

Br/methanol; Safety
  1. Protect against skin contact; capable of severe burns
  2. Strong oxidizer; keep away from organic materials which can ignite; keep away from reducing agents (sodium, zinc, ammonium compounds) to avoid explosion
  3. Spilled Br₂ or Br₂/methanol can be neutralized with 5–10% sodium thiosulfate solution; Ref. (Walker, D.M., 1980)

**Br₂:methanol:CH₃COOH**

(Br₂:CH₃OH (1%):CH₃COOH (1:1); masked pattern etch profiles on (0 0 1)GaAs; Ref. (Adachi, S., 1983)
**Br$_2$: methanol:H$_3$PO$_4$**

(Br$_2$:CH$_3$OH (1%)):H$_3$PO$_4$ (1:1); masked pattern etch profiles on (0 0 1)GaAs; Ref. (Adachi, S., 1983)

Br$_2$/methanol (3 vol.%): H$_3$PO$_4$ (1:1); Application: InP mesa etch at 45°C; Ref. (Armiento, C.A., 1979b)

**Butane tetracarboxlic acid**

InGaAs selective etch from InAlAs and InAlAs selective etch from AlAs; Ref. (Broekaert, T.P.E., 1992b)

**$N$-$n$-butylpyridinium chloride**

0.3 M $N$-$n$-butylpyridinium chloride (CgH$_{14}$ClN):1 M NH$_3$F$_2$ (1:4); electrolyte for electrochemical $C$–$V$ profiling; does not destroy calomel electrodes (in BIORAD/Polaron proflers); useful on InP, GaAs, InGaAs, AlGaAs, AlGaP, GaP, InGaAsP, Si and Ge; Ref. (Faur, M., 1996)

**Butylthiobutane: HF:H$_2$O$_2$:H$_2$O** (see HF:H$_2$O$_2$:H$_2$O:butylthiobutane)

**Caro’s etch** (see H$_2$SO$_4$:H$_2$O$_2$:H$_2$O)

**Ce$^{4+}$:H$_2$SO$_4$**

Ce$^{4+}$:H$_2$SO$_4$ solution; InGaAsP selective etch from InP; Ref. (Kelly, J.J., 1988)

**Ce(SO$_4$)$_2$**

Ce(SO$_4$)$_2$; Ce(NO$_3$)$_3$; AlGaAs selective etch from GaAs; p-type AlGaAs selective from n-type; Ref. (Tijburg, R.P., 1976b)

Ce(SO$_4$)$_2$ (0.1 M): HNO$_3$:CH$_3$COOH (1:2:2); Growth striations on (1 1 0) in Te-doped GaSb; Ref. (Costa, E.M., 1997)

Ceric sulfate (saturated solution):HNO$_3$ (9:1); chromium etchant from semiconductor surface; etch rate $\sim$800 Å/min; Ref. (Glang, R., 1970)

Ceric sulfate (saturated solution):HNO$_3$ (9:1); chromium etchant from semiconductor surface; Ref. (Park, S., 1997)

**CH$_3$OH** (see methanol)

**CH$_3$CONHCH$_3$**

$N$-methyacetamide (CH$_3$CONHCH$_3$); electrolyte for anodization of GaAs; Ref. (Müller, H., 1975)
CH₃COOH:Br₂:HBr (see HBr:CH₃COOH:Br₂)
CH₃COOH:Br₂:HF:HNO₃ (see HF:HNO₃:CH₃COOH:Br₂)
CH₃COOH:HBr (see HBr:CH₃COOH)
CH₃COOH:HBr:Br₂ (see HBr:CH₃COOH:Br₂)
CH₃COOH:HBr:K₂Cr₂O₇ (see HBr:CH₃COOH:K₂Cr₂O₇)
CH₃COOH:HCl (see HCl:CH₃COOH)
CH₃COOH:HCl:HClO₄:HNO₃ (see HCl:HNO₃:CH₃COOH:HClO₄)
CH₃COOH:HCl:HNO₃ (see HCl:HNO₃:CH₃COOH)
CH₃COOH:HCl:H₃PO₄ (see HCl:H₃PO₄:CH₃COOH)
CH₃COOH:HCl:H₂O₂ (see HCl:CH₃COOH:H₂O₂ {KKI etch})
CH₃COOH:HClO₄:HCl:HNO₃ (see HCl:HNO₃:CH₃COOH:HClO₄)
CH₃COOH:HF:HNO₃ (see HF:HNO₃:CH₃COOH)
CH₃COOH:HF:H₂O₂ (see HF:CH₃COOH:H₂O₂)
CH₃COOH:HF:KMnO₄ (see HF:CH₃COOH:KMnO₄)
CH₃COOH:HNO₃ (see HNO₃:CH₃COOH)
CH₃COOH:H₂O₂
CH₃COOH:H₂O₂ (3:1); InP substrate cleaning; Auger analysis; Ref. (Singh, S., 1982)
CH₃COOH:H₂O₂:HCl (see HCl:CH₃COOH:H₂O₂ {KKI etch})
CH₃COOH:H₂O₂:HF (see HF:CH₃COOH:H₂O₂)
CH₃COOH:H₃PO₄ (see H₃PO₄:CH₃COOH)
CH₃COOH:K₂Cr₂O₇:HBr (see HBr:CH₃COOH:K₂Cr₂O₇)
CH₃COOH:KMnO₄:HF (see HF:CH₃COOH:KMnO₄)
CH₃CH₂OH (see ethanol)
CH₃CHOHCH₃ (see isopropanol)
**CH$_3$CSNH$_2$/NH$_4$OH**

CH$_3$CSNH$_2$/NH$_4$OH solution; GaAs surface passivation; Ref. (Lu, E.D., 1996)

CH$_3$CSNH$_2$/H$^+$ solution; GaAs surface passivation; Ref. (Lu, E.D., 1996)

**C$_4$H$_6$O$_6$:$H_2$O:$H_2$O$_2$**

C$_4$H$_6$O$_6$:H$_2$O:$H_2$O$_2$ (5:5:1); selective etch of InGaAs layer from InP; 8 min for 3000 Å; Ref. (Kallstenius, T., 1999a)

**C$_6$H$_4$O$_2$:C$_4$H$_6$O$_2$**

C$_6$H$_4$O$_2$:C$_4$H$_6$O$_2$ (quinone–hydroquinone) with NaOH or HCl to buffer the pH. GaAs selective etch from AlGaAs for pH = 10; AlGaAs selective etch from GaAs for pH = 1; Ref. (Tijburg, R.P., 1976b)

**Citric acid**

Citric acid (1 M); oxide removal agent from GaAs; Ref. (DeSalvo, G.C., 1996)

**Citric acid:$H_2$O$_2$**

**InGaAs**

Citric acid:$H_2$O$_2$ (10:1); Study: InAlAs selective etch from InP, selectivity >187; InGaAs selective etch from InP, selectivity >480. InGaAs selective from InAlAs, selectivity only 2.5. Shows etch profiles. InP etch rate at 20°C = 0.05 Å/s; InAlAs etch rate at 20°C = 10 Å/s; InGaAs etch rate at 20°C = 24 Å/s

Citric acid:$H_2$O$_2$ (1:1); InGaAs selective etch from InAlAs = 25. InGaAs etch rate at 20°C = 25 Å/s; InAlAs etch rate at 20°C = 1 Å/s; Ref. (Tong, M., 1992a)

Citric acid:$H_2$O$_2$ (5:1); Application InGaAs etch rate = 1000 Å/min; Ref. (O’Conner, P., 1982)

Organic acid solutions: OCA = oxalic acid:$H_2$O: citric acid (25 g:2 l:100 g), pH = 6.3

Etchant solutions (for InGaAs selective etch from InAlAs and InAlAs selective etch from AlAs): OCA:$H_2$O$_2$ (25:1):

<table>
<thead>
<tr>
<th>Compound</th>
<th>Etch Rate (nm/min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>In$<em>{0.53}$Ga$</em>{0.47}$As</td>
<td>75</td>
</tr>
<tr>
<td>In$<em>{0.52}$Al$</em>{0.48}$As</td>
<td>5</td>
</tr>
<tr>
<td>AlAs</td>
<td>0.20</td>
</tr>
</tbody>
</table>

Ref. (Broekaert, T.P.E., 1992a,b)

Citric acid:$H_2$O$_2$ (24:1); Application: InGaAs FET flat bottom gate recess etch; Ref. (Chai, Y.G., 1983)
Citric acid:H$_2$O$_2$ (24:1); Application: In$_{0.53}$Ga$_{0.47}$As FET gates; uses undercutting of photolithography mask to achieve submicron widths; Ref. (Chai, Y.G., 1985)

Citric acid:H$_2$O$_2$:H$_2$O (20:1:50); InGaAs selective etch from InP; 7 Å/s; Ref. (Miyamoto, Y., 1998)

Citric acid (50 wt.%):H$_2$O$_2$ (3:1); selective etch to define InGaAs mask pattern for HCl etching of InP; Ref. (Wang, J., 1998)

**InGaAs/InAlAs/InP**

Citric acid:H$_2$O$_2$ range (0.5:1)–(50:1); GaAs, InP, AlGaAs, InGaAs, InAlAs etch rates (selectivities are tabulated in the reference)

<table>
<thead>
<tr>
<th>Volume ratio of citric acid/H$_2$O$_2$</th>
<th>Etch rates of layers on InP substrate (Å/min)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>In$<em>{0.53}$Ga$</em>{0.47}$As</td>
</tr>
<tr>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>0.2</td>
<td>–</td>
</tr>
<tr>
<td>0.5</td>
<td>1235</td>
</tr>
<tr>
<td>1.0</td>
<td>1116</td>
</tr>
<tr>
<td>2.0</td>
<td>1438</td>
</tr>
<tr>
<td>5.0</td>
<td>1433</td>
</tr>
<tr>
<td>7.0</td>
<td>1421</td>
</tr>
<tr>
<td>10.0</td>
<td>1020</td>
</tr>
<tr>
<td>15.0</td>
<td>1013</td>
</tr>
<tr>
<td>20.0</td>
<td>665</td>
</tr>
<tr>
<td>50</td>
<td>303</td>
</tr>
<tr>
<td>100</td>
<td>–</td>
</tr>
<tr>
<td>$\infty$</td>
<td>0</td>
</tr>
</tbody>
</table>

Ref. (DeSalvo, G.C., 1992)

Citric acid:H$_2$O$_2$ (1:1); InGaAs selective etch from InAlAs; selectivity 25. InGaAs etch rate 22 Å/s; InAlAs etch rate 0.89 Å/s; Ref. (Tong, M., 1992c)

Citric acid:H$_2$O$_2$ (1:1); InGaAs selective etch from InAlAs; Ref. (Adesida, I., 1993a)

C$_6$H$_8$O$_7$(citric acid):H$_2$O$_2$:H$_2$O; 5 s wet etch following reactive ion etch of InP/InGaAlAs/InGaAs heterostructure detectors; removes about 150 Å InGaAs, 70 Å InAlGaAs and <20 Å InP; Ref. (Kollakowski, St., 1998)

Citric acid:H$_2$O:H$_2$O$_2$ (1:1:8); AlAs selective etch from InP as a sacrifice layer to lift-off InP epilayer from the substrate; Ref. (Bailey, S.G., 1993)

C$_6$H$_8$O$_7$(citric acid):H$_2$O$_2$:H$_2$O; 5 s wet etch following reactive ion etch of InP/InGaAlAs/InGaAs heterostructure detectors; removes about 150 Å InGaAs, 70 Å InAlGaAs and <20 Å InP; Ref. (Lemm, Ch., 1997)
InP

Citric acid:H$_2$O$_2$ (1:1); InP surface cleaning for MBE regrowth gives high surface defect density; Ref. (Passenberg, W., 1997)

GaAs

Citric acid:H$_2$O$_2$ (25:1); GaAs etch rate $= 20$ Å/s; does not attack photoresists; Ref. (Otsubo, M., 1976)

Citric acid:H$_2$O$_2$; GaAs etching; Ref. (Mukherjee, S.D., 1985)

Citric acid:H$_2$O$_2$:H$_2$O (50:x:50); $1 < x < 10$; GaAs etch rate study shows proportional dependence on H$_2$O$_2$ concentration; low etch rates are surface reaction limited and show flat bottomed profiles; high etch rates are H$_2$O$_2$-diffusion limited and show enhanced etching at mask edges; Ref. (Kohn, E., 1980)

Citric acid:H$_2$O$_2$ (3:1); GaAs selective etch from AlAs stop etch layer; Ref. (Grundbacher, R., 1993)

Citric acid:H$_2$O$_2$ (4:1); selective removal of GaAs from AlAs (and of low Al content AlGaAs from high Al content AlGaAs); shows dependence of etch rates (selectivity) on volume ratio; Ref. (Kim, J.-H., 1998)

Citric acid:NH$_4$OH:H$_2$O$_2$ (citric acid pH adjusted to 6.5 with NH$_4$OH; citric acid:H$_2$O$_2$ ratio $= 100$); selective etch of GaAs from Al$_{0.15}$Ga$_{0.85}$As and; shows etch rate dependence on concentration and pH; Ref. (Kitano, T., 1997)

Citric acid:H$_2$O$_2$:H$_2$O (3:15:150); GaAs gate recess etch for FETs. Electrochemical effects induced by electrical contact materials cause etch rate non-uniformities; Ref. (Metze, G.M., 1995)

Citric acid:H$_2$O$_2$:H$_2$O (1:1.4)–(6.2:1); selective removal of GaAs from AlGaAs; etch dependence on Al-composition and H$_2$O$_2$; Ref. (Moon, E.-A., 1998)

Citric acid:H$_2$O$_2$ (5:1); Application: selective removal of GaAs from AlGaAs etch stop layer for micromachining; undercutting etch rate is 0.09 μm/min; excellent uniformity and reproducibility; Ref. (Ribas, R.P., 1998)

Citric acid:H$_2$O$_2$ (100:1); study of oxidation/dissolution etch mechanism and selectivity of GaAs and AlGaAs; Ref. (Schneider, M., 1987)

Citric acid:H$_2$O$_2$ (25:1); InGaAs etch rate $= 1200$ Å/min

Citric acid:H$_2$O$_2$ (25:1); p-InGaAs etch rate $= 450$ Å/min

Citric acid:H$_2$O$_2$:H$_2$O (1:1:10); InGaAs etch rate $= 700$ Å/min; Ref. (Elder, D.I., 1983)
### InGaAs/AlGaAs/GaAs

Citric acid:H\textsubscript{2}O\textsubscript{2} range (0.5:1)–(50:1); GaAs, InP, AlGaAs, InGaAs, InAlAs etch rates (selectivities are tabulated in the reference)

<table>
<thead>
<tr>
<th>Volume ratio of citric acid/H\textsubscript{2}O\textsubscript{2}</th>
<th>Etch rates of layers on GaAs substrate (Å/min)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>GaAs</td>
</tr>
<tr>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>0.5</td>
<td>60</td>
</tr>
<tr>
<td>1.0</td>
<td>69</td>
</tr>
<tr>
<td>1.5</td>
<td>–</td>
</tr>
<tr>
<td>2.0</td>
<td>85</td>
</tr>
<tr>
<td>3.0</td>
<td>2169</td>
</tr>
<tr>
<td>4.0</td>
<td>2235</td>
</tr>
<tr>
<td>5.0</td>
<td>3140</td>
</tr>
<tr>
<td>6.0</td>
<td>–</td>
</tr>
<tr>
<td>7.0</td>
<td>2882</td>
</tr>
<tr>
<td>8.0</td>
<td>–</td>
</tr>
<tr>
<td>9.0</td>
<td>–</td>
</tr>
<tr>
<td>10.0</td>
<td>2513</td>
</tr>
<tr>
<td>15.0</td>
<td>1551</td>
</tr>
<tr>
<td>20.0</td>
<td>762</td>
</tr>
<tr>
<td>50</td>
<td>397</td>
</tr>
<tr>
<td>∞</td>
<td>0</td>
</tr>
</tbody>
</table>

Ref. (DeSalvo, G.C., 1992)

Citric acid:H\textsubscript{2}O\textsubscript{2} (10:1); GaAs selective etch from Al\textsubscript{0.3}Ga\textsubscript{0.7}As, selectivity = 90; GaAs etch rate = 0.21 μm/min at 18°C; Al\textsubscript{0.3}Ga\textsubscript{0.7}As etch rate = 0.022 μm/min at 18°C; Ref. (Juang, C., 1990)

Citric acid:H\textsubscript{2}O\textsubscript{2} (1:1); GaAs/AlGaAs/InGaAs blanket etch; AlGaAs etch rate is ∼1/3 that of GaAs and InGaAs; Ref. (Tan, I.-H., 1992)

Citric acid:H\textsubscript{2}O\textsubscript{2} (4:1); GaAs selective etch from Al\textsubscript{x}Ga\textsubscript{1-x}As:

<table>
<thead>
<tr>
<th>x</th>
<th>Etch rate ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.17</td>
<td>1.5</td>
</tr>
<tr>
<td>0.30</td>
<td>155</td>
</tr>
<tr>
<td>0.45</td>
<td>260</td>
</tr>
<tr>
<td>1.00</td>
<td>1450</td>
</tr>
</tbody>
</table>

Ref. (Tong, N., 1992b)

Citric acid:H\textsubscript{2}O (1 g of anhydrous citric acid:1 ml water); Application: InGaAs selective removal from GaAs; GaAs 40 Å/min; In\textsubscript{0.2}Ga\textsubscript{0.8}As 751 Å/min; Ref. (Reed, J.D., 1995)Citric acid:H\textsubscript{2}O\textsubscript{2} (4:1); selective etch of GaAs from Al\textsubscript{0.28}Ga\textsubscript{0.72}As; Ref. (Mao, B.-Y., 1994)
Citric acid:H₂O₂:H₂O (4:1:1); non-selective GaAs, AlGaAs etch rate ~4000 Å/min; Ref. (Mao, B.-Y., 1994)

Citric acid:H₂O₂:H₂O; Study of GaAs versus Al₀.₂₅Ga₀.₇₅As etch rate dependence on citric acid:H₂O₂ ratio and on H₂O concentration; Ref. (Mao, B.-Y., 1994)

Citric acid:H₂O₂ (10:1); selective, anisotropic etch for shaping cantilevers in 2 μm GaAs layers with InGaP etch stop layer; Ref. (Arslan, D., 1999)

Citric acid:H₂O₂ (m:1, with 1 < m < 9); GaAs substrate removal using AlAs or AlGaAs etch stop layers; problems with etch stop layer oxidation; Ref. (Carter-Coman, C., 1997)

Citric acid (1 wt.% anhydrous to 1 wt.% water):H₂O₂:H₂O (5:1:75); GaAs/non-selective etch; GaAs rate ~15.3 nm/min; AlGaAs rate = 17.6 nm/min; Ref. (Cho, S.-J., 1999)

Citric acid:H₂O₂ (2:1); Application: selective removal of GaAs from Al₀.₂₆Ga₀.₇₄As; selectivity of 70:1; Ref. (Dimroth, F., 1997)

Buffer:H₂O₂ (5:1); GaAs selective etch from AlGaAs or AlAs. Used for reproducible fabrication of integrated circuit GaAs FETs with etch stop layer of 25 Å Al₀.₃₅Ga₀.₆₅As or 8 Å AlAs. The buffered solution is insensitive to dilution or contamination. GaAs etch rate = 45 Å/s; Ref. (Brunemeier, B.E., 1993)

Citric acid:H₂O₂; Application: second step stairstep groove etchant for shaping grooves in AlAs/GaAs multilayer structures for quantum wire MOCVD growth; Ref. (Kicin, S., 1999)

ZnSe (Citric acid:H₂O₂)

Citric acid (100 g in 100 ml H₂O):H₂O₂ (30%) (3:1); surface cleaning of ZnSe (100 0) substrates; etch rate 400 Å/min; Ref. (Kobayashi, M., 1999)
Citric acid:HCl (see HCl: citric acid)

Citric acid:H₂O₂:H₃PO₄

Citric acid:H₂O₂:H₃PO₄:H₂O (55:5:1:220); mesa etch for AlInAs/InGaAs; 480 Å/min; Ref. (Berg, E.W., 1998)

Citric acid:H₂O₂:ethyleneglycol

Citric acid (3 g in 100 ml H₂O): ethyleneglycol (1:2), with pH adjusted to 6 using ammonia; electrolyte for anodizing Al₃Ga₁₋ₓAs; Ref. (Buda, M., 1998)

Citric acid:thiourea:isopropanol

Citric acid (1 mol l⁻¹):thiourea (1/3 mol l⁻¹):isopropanol; electrolyte for anodic passivation of GaSb; Ref. (Salesse, A., 1997)

Cl₂:H₂O

Saturated Cl₂ water; GaP etch rate temperature dependence is given; Ref. (Milch, A., 1976)

Cl₂:methanol

Cl₂/methanol; GaAs, InP, GaP, AlGaAs jet thinning of electron microscope specimens; Ref. (Bicknell, R.W., 1973)

Cl₂/methanol; GaP jet thinning for TEM samples; Ref. (Chase, B.D., 1972a); (Chase, B.D., 1972b)

Cl₂/methanol; Ref. (Fuller, C.S., 1962)

Cl₂/methanol (Cl₂-saturated solution): H₃PO₄ (1:1); GaP non-preferential chemical polish; Ref. (Oldham, W.G., 1965)

Cl₂/methanol; GaP jet thinning for TEM samples; Ref. (Chase, B.D., 1972)

CP-4 etch (see HF:HNO₃:CH₃COOH and HF:HNO₃:CH₃COOH:Br)

CrO₃:HCl:H₂O (see HCl: CrO₃:H₂O)

CrO₃:HF (see HF: CrO₃)

CrO₃:HF:H₂O:AgNO₃ (see AgNO₃: CrO₃: HF:H₂O {A-B etch})

CuCl:HCl (see HCl: CuCl)
CS$_2$

CS$_2$; rinse of ZnSe surface to remove residual Se; Ref. (Kobayashi, M., 1999)

Dash etch (see HF:HNO$_3$:CH$_3$COOH)

Dimethylformamide:Br$_2$ (see Br$_2$:dimethylformamide)

Dimethylformamide:HgCl$_2$ (see HgCl$_2$:dimethylformamide)

Dimethylsuсcinic acid

InGaAs selective etch from InAlAs and InAlAs selective etch from AlAs; Ref. (Broekaert, T.P.E., 1992b)

EDTA:NH$_4$OH

EDTA:NH$_4$OH (0.2 M ethylene diami ne tetraacetic acid disodium salt with ammonium hydroxide for pH control); electrolyte for photoelectrochemical etching of GaAs and GaSb; Ref. (Elliott, C.R., 1980)

p–n GaAs with 0.1 M EDTA/0.2 M NaOH electrolyte (gives good results); Ref. (Cabaniss, G.E., 1988)

EDTA electrolyte for C–V profiling of InP and GaAs materials; Ref. (Faur, M., 1994c)

EDTA:Te$_2$(SO$_4$)$_3$ (see Te$_2$(SO$_4$)$_3$:EDTA)

Ethanol:HCl (see HCl:ethanol)

Ethanol:Br$_2$ (see Br$_2$:ethanol)

Ethanol:HF (see HF:ethanol)

FeCl$_3$

FeCl$_3$ (21% diluted); laser scanned photochemical etch for vee-grooves in InP (1 0 0); Ref. (Moutonnet, D., 1988)

FeCl$_3$; n-InP photoetch with HeNe laser; Ref. (Svorcik, V., 1991)

FeCl$_3$:H$_2$O (40% w/v); Application: InP photoo etching of mesas; etch rate = 0.5 . under illumination, followed by clean-up etch of: Ref. (Lubzens, D., 1977)

FeCl$_3$:FeCl$_2$

FeCl$_3$:FeCl$_2$; AlGaAs selective etch from GaAs; Ref. (Tijburg, R.P., 1976b)
FeCl₃:HCl:H₂O (see HCl:FeCl₃:H₂O)

Fe₃(CN)₆:KOH (see KOH:Fe₃(CN)₆)

Fe₂(SO₄)₃:EDTA

Ferric sulfate (non-ahydrate):EDTA (disodium salt of ethylenediaminetetracetic acid):H₂O (5 g:3 g:100 ml); GaAs photoelectrochemical p–n junction delineation; Ref. (Greene, P.D., 1976)

FeNH₄(SO₄)₂:H₂O

FeNH₄(SO₄)₂:H₂O (1:12); n-InP photoetch with HeNe laser

FeSO₄(NH₄)₂SO₄:H₂O (1:6); n-InP photoetch with HeNe laser; Ref. (Svorcik, V., 1991)

Fumaric acid

InGaAs selective etch from InAlAs and InAlAs selective etch from AlAs; Ref. (Broekaert, T.P.E., 1992b)

Glycerine:HCl:HClO₄ (see HCl:HClO₄:glycerine)

HBF₄:H₂O:H₃PO₄ (see H₃PO₄:HBF₄:H₂O)

HBr

HBr; InP etch rate at 25°C ~6.5 μm/min; cross-section profiles; Ref. (Adachi, S., 1981b)

HBr; InP selective etch from InGaAsP; Ref. (Adachi, S., 1982c)

HBr; InP (1 0 0) etch rate = 4–8 μm/min, highly pitted surface; Ref. (Clawson, A.R., 1978)

HBr:H₂O (1:10); InP (1 0 0) etch rate = 167 Å/min; Ref. (Clawson, A.R., 1978)

HBr:H₂O (1:5); InP (1 0 0) etch rate = 250 Å/min; Ref. (Clawson, A.R., 1978)

HBr (9N); Application: InP photolithography grating at −15°C; (1 1 1)A facets; Ref. (Keavney, C.J., 1984)

HBr; etch rate = 1.5 μm/min; Etchant undercutting of SiO₂ masks on InP (1 0 0); Ref. (Vozmilova, L.N., 1985)

HBr (37%); InP vee-groove etch using titanium mask, first step to form sharp vees with minimal undercutting; 20 s at 20°C; Ref. (Bönsch, P., 1998)

HBr:Br₂:H₂O (see Br₂:HBr:H₂O)
HBr:CH$_3$COOH

HBr:CH$_3$COOH (1:1); InP etch rate at 25°C ~3.0 μm/min; cross-section profiles; Ref. (Adachi, S., 1981b)

HBr:CH$_3$COOH (1:1); InP selective etch from InGaAsP; profiles; Ref. (Adachi, S., 1982c)

HBr:CH$_3$COOH (1:1); Application: InGaAs/InP quantum dot patterning; at 5°C for 3 s; Ref. (Schmidt, A., 1992)

HBr:CH$_3$COOH (1:10); InP defect delineation; etch rate $\approx$1.7 μm/min; Ref. (Akita, K., 1979)

HBr:CH$_3$COOH; InP (100) orientation determination etch; Ref. (Nagai, H., 1980)

HBr:CH$_3$COOH (1:1); etch rate $\approx$0.9 μm/min; Etchant undercutting of SiO$_2$ masks on InP (100); Ref. (Vozmilova, L.N., 1985)

HBr:CH$_3$COOH (1:1) gives sawtooth grating on InP; Ref. (Westbrook, L.D., 1983)

HBr:CH$_3$COOH:Br$_2$

Electrochemical etch of InP in aqueous bromine solutions;

CH$_3$COOH:HBr:Br$_2$; mechanism of p-InP etch rate in dark and under illumination; Ref. (Notten, P.H.L., 1987)

HBr:CH$_3$COOH:K$_2$Cr$_2$O$_7$

HBr:CH$_3$COOH:K$_2$Cr$_2$O$_7$ (1:1:1); InP (100) etch rate = 3 μm/min non-stirring = 25 μm/min stirring; Ref. (Adachi, S., 1982a)

HBr:CH$_3$COOH:K$_2$Cr$_2$O$_7$ (1:1:1); InP and InGaAs mesa etch, equal rates for both; Ref. (Frei, M.R., 1991)

HBr:CH$_3$COOH:K$_2$Cr$_2$O$_7$ (1:2:1); InP (100) etch rate = 1.5 μm/min, non-stirring; etch pit free surfaces; etch pits form at lower K$_2$Cr$_2$O$_7$ concentrations; data is given on etch rate dependences on concentrations, surface quality, and photolithography etch profiles; nearly equal etch rates on InP and InGaAsP; Ref. (Adachi, S., 1982a)

K$_2$Cr$_2$O$_7$:HBr:CH$_3$COOH (3:1:1); Application: InGaAsP tilted laser facet etch; Ref. (Itaya, Y., 1984)

K$_2$Cr$_2$O$_7$:HBr:CH$_3$COOH (3:1:1); Application: InP (100) grating etch for BH laser; Ref. (Matsuoka, T., 1982)
HBr:CH₃COOH:K₂Cr₂O₇ (2:2:1); nearly equal etch rate ~2.5 μm/min for InGaAsP and InP

HBr:CH₃COOH:K₂Cr₂O₇ (1:1:1); Application: InGaAsP/InP laser; does not erode photoresist; provides very smooth and nearly vertical walls; Ref. (Adachi, S., 1982d)

K₂Cr₂O₇:HBr:CH₃COOH; Application: InGaAsP/InP laser cantilever etch for microcleaving; Ref. (Szaplonczay, A., 1987)

HBr:CH₃COOH:K₂Cr₂O₇; Application: InP and InGaAs etch with patterned Ti mask for quantum wires; Ref. (Schilling, O., 1993)

HBr:CH₃COOH:(1N K₂Cr₂O₇) (1:1:1); masked pattern etch profiles on (0 0 1)GaAs; Ref. (Adachi, S., 1983)

HBr:HCl

HBr:HCl (2:1) to (1:2); InGaAsP and InP etch rates vary with proportions; profiles; Ref. (Adachi, S., 1982c)

HBr:HCl:H₃PO₄ (see HCl:H₃PO₄:HBr)

HBr:HF

HF:HBr (5:1) and (10:1); InP dislocation etch pit delineation study; A–B etch comparison; Ref. (Kotani, T., 1980)

HF:HBr (5:1); InP dislocation etch pit delineation for 5 min at 20°C; Ref. (Susa, N., 1980a,c, 1981)

HF:HBr (1:10); Application: InP selective etch from InGaAsP; Ref. (Ueda, O., 1980a,b)

HF:HBr (1:10); InP defect delineation; etch rate = 0.9 μm/min; Ref. (Akita, K., 1979)

HBr:HF (1:15) at RT for 1–5 min; Defect delineation etchants; Application to InP and InGaAsP; Ref. (Mahajan, S., 1981)

HBr:HNO₃

HBr:HNO₃ (1:1); InP etch rate at 25°C ~11.0 μm/min; cross-section profiles; Ref. (Adachi, S., 1981b)

HBr:HNO₃ (1:1); InGaAsP and InP etch rates are similar; profiles; Ref. (Adachi, S., 1982c)

HBr:HNO₃ (3:1); InP dislocation delineation on (1 1 1) and (1 0 0); Ref. (Chu, S.N.G., 1982)

HBr:HNO₃ (3:1); Application: InP (1 1 1) dislocation etch pit delineation; for 7 s; Ref. (Fornari, R., 1989)
HBr:HNO₃ (3:1); InP dislocation delineation, superior reproducibility to H₃PO₄:HBr (2:1) (Huber etch); Ref. (Lourenço, J.A., 1984)

HBr:HNO₃:H₂O (1:1:5); InP etch rate at 25°C ~9.0 μm/min; cross-section profiles; Ref. (Adachi, S., 1981b)

HNO₃:HBr:H₂O (1:1:5); Application: InGaAsP/InP mesa etch for BH laser cavity; Ref. (Matsuoka, T., 1981)

HBr:HNO₃:H₂O (1:1:30); Application: InGaAsP selective etch from InP; Ref. (Koch, T.L., 1987)

HBr:HNO₃:H₂O; Application: InP mesa stripe using an InGaAsP interface layer to control the sidewall shape for reproducible height and width; Ref. (Huang, R.-T., 1990)

HBr:HNO₃:H₂O (1:1:4); Application: InP/InGaAs pattern etch with Au mask for quantum wires; etch rate 100–200 Å/min at 33°C; Ref. (Ils, P., 1993)

HNO₃:HBr (1:3); defect etch pit delineation; Ref. (Faur, M., 1993)

HBr:HNO₃ (1:1); masked pattern etch profiles on (0 0 1)GaAs; Ref. (Adachi, S., 1983)

HBr:HNO₃:H₂O (1:1:1); masked pattern etch profiles on (0 0 1)GaAs; Ref. (Adachi, S., 1983)

HNO₃:HBr:H₂O (1:1:10); undercut-mesa etch of InP for MOVPE regrowth following RIE etch; Ref. (Fang, R.Y., 1997)

HBr:H₂O₂

HBr:H₂O₂ (1:1); InP etch rate at 25°C ~23 μm/min; cross-section profiles; Ref. (Adachi, S., 1981b)

HBr:H₂O₂ (1:1); InGaAsP and InP etch rates are similar; profiles; Ref. (Adachi, S., 1982c)

HBr:H₂O₂:H₂O (1:1:10); InGaAsP/InP non-selective etch; Ref. (Wallin, J., 1992)

HBr:H₂O₂:H₂O; InP pattern etch for OMVPE regrowth; for normal and reentrant sidewall profiles; Ref. (Zilko, J.L., 1991)

HBr:H₂O₂:H₂O removal of RIE damage before MOCVD regrowth; Ref. (Ahn, J., 1996)

HBr:H₂O₂:Br₂ (see Br₂:HBr:H₂O₂)

HBr:H₂O:Br₂ (see Br₂:HBr:H₂O)

HBr:H₂O₂:H₂O:HCl

HBr:H₂O₂:H₂O:HCl (20:2:20:20); InP (1 0 0) photolithography vertical sidewalls; control of (1 1 1)A versus (1 1 1)B anisotropy; shows effects of changing HBr and HCl concentrations; Ref. (Huo, D.T.C., 1989b)
HBr:H₂O₂:HCl:H₂O (20:2:20:20); InP (1 1 1) and (1 0 0) dislocation etch pit delineation; etch pit shape and formation depend on H₂O₂ and water concentration; shelf time of this etchant is about 12 h; Ref. (Huo, D.T.C., 1989a)

**HBr:H₃PO₄** {Huber etch}

H₃PO₄:HBr (1:1); InP etch rate at 25°C ~2.0 μm/min; cross-section profiles; Ref. (Adachi, S., 1981b)

H₃PO₄:HBr (1:1); InP selective etch from InGaAsP; profiles; Ref. (Adachi, S., 1982c)

HBr:H₃PO₄ (1:2) {Huber etch}; InP defect delineation; etch rate = 0.25 μm/min; data is given on etch rates and etch pit delineation versus etchant composition; Ref. (Akita, K., 1979)

HBr:H₃PO₄ (1:2) {Huber etch}; InP, delineation of pits, ridges, and striations, 1–2 min at 20°C; Ref. (Brown, G.T., 1980)

H₃PO₄:HBr (2:1) {Huber etch}; application: InP dislocation etch pit delineation; 1–2 min at 20°C gives symmetrical etch pits; Ref. (Caridi, E.A., 1984)

H₃PO₄:HBr (2:1) {Huber etch}; InP dislocation etch pit delineation; comparison with A–B etch, HCl:HNO₃:H₂O (1:3:6), and HCl:HNO₃:Br₂ (10:20:0.25); Ref. (Huber, A., 1975)

H₃PO₄:HBr (2:1) {Huber etch}; Application: InP dislocation etch pit delineation; Ref. (Kimura, T., 1991); (Tamari, N., 1982a)

H₃PO₄:HBr (2:1) {Huber etch}; InP dislocation etch pit delineation for 150 s; Ref. (Westphalen, R., 1989)

HBr:H₃PO₄:H₂O (1:1:8); InGaAs etch at 0°C to define a lithography pattern for the purpose of using the thin InGaAs as an etch mask for underlying InP; eliminates mask undercutting; Ref. (Inamura, E., 1989)

HBr:H₃PO₄ (1:1), etch rate = 7.3 μm/min; Etchant undercutting of SiO₂ masks on InP (1 0 0); Ref. (Vozmilova, L.N., 1985)

H₃PO₄:HBr (2:1) {Huber etch} at RT for ~2 min; Defect delineation etchants; Application to InP and InGaAsP; Ref. (Mahajan, S., 1981)

H₃PO₄:HBr (2:1) {Huber etch}; defect delineation comparison with NaOH photochemical etch; Ref. (Yamamoto, A., 1981)

HBr:H₃PO₄ (1:2) {Huber etch}; Application; InP and InGaAsP epilayer etch pit defect delineation at RT; Ref. (Nakamura, M., 1993)

H₃PO₄:HBr (1:2) {Huber etch}; InP defect etch pit delineation; Ref. (Faur, M., 1993)
$\text{H}_3\text{PO}_4: \text{HBr}$ (2:1) (Huber etch); Application: InP defect delineation etch; 2 min at RT; Ref. (Hirano, R., 1993)

$\text{H}_3\text{PO}_4: \text{HBr}$ (2:1) {Huber etch}; InGaAsP dislocation etch pit delineation; 2 min at $25^\circ \text{C}$; Ref. (Theil, F.A., 1979)

$\text{HBr}: \text{H}_3\text{PO}_4: \text{H}_2\text{O}_2$

$\text{HBr}: \text{H}_3\text{PO}_4: \text{H}_2\text{O}_2: \text{H}_2\text{O}$; InP pattern etch for OMVPE regrowth; reentrant [0 1 0] direction profiles; Ref. (Zilko, J.L., 1991)

$\text{HBr}: \text{H}_3\text{PO}_4: \text{K}_2\text{Cr}_2\text{O}_7$

$\text{HBr}: \text{H}_3\text{PO}_4: \text{K}_2\text{Cr}_2\text{O}_7: \text{K}_2\text{Cr}_2\text{O}_7$ (2:2:1), dilute (1:1) with $\text{H}_2\text{O}$; Application: InP uniform thinning etch for incremental Hall measurements; etch rate $\sim 300 \text{ Å/s}$; Ref. (Whitney, P.S., 1988)

$\text{HBr}: \text{H}_3\text{PO}_4: \text{K}_2\text{Cr}_2\text{O}_7$ (2:2:1); InP and InGaAsP equal etch rate = 1.5 $\mu\text{m/minute}$; does not attack photoresist; Ref. (Adachi, S., 1982a)

$\text{HBr}: \text{H}_3\text{PO}_4: \text{K}_2\text{Cr}_2\text{O}_7$ (2:1:1); InP vee-groove etch for $\{1 1 0\}$ direction; attacks photoresist; undercuts; Ref. (Huo, D.T.C., 1990)

$\text{HBr}: \text{H}_3\text{PO}_4: \text{K}_2\text{Cr}_2\text{O}_7$ (1:1:1); masked pattern etch profiles on (0 0 1)GaAs; Ref. (Adachi, S., 1983)

$\text{HBr}$ (46%):$\text{H}_3\text{PO}_4$ (85%):$\text{K}_2\text{Cr}_2\text{O}_7$ (1N) (2:2:1); Application: etching of beveled surfaces on InGaAsP/InP structures to allow characterization of small angle cross-sections; etchant flow method to form the bevel; Ref. (Srnanek, R., 1997a)

$\text{HBr}$: $\text{H}_3\text{PO}_4: \text{K}_2\text{Cr}_2\text{O}_7$ (2:2:1); InP vee-groove (1 1 1)$A$ facet etch through $\text{SiO}_2$ mask at $23^\circ \text{C}$; Ref. (Wang, J., 1995, 1998)

$\text{HBr}: \text{K}_2\text{Cr}_2\text{O}_7$

$\text{HBr}: \text{K}_2\text{Cr}_2\text{O}_7$ (3:1); InP vee-groove sidewall smoothing (step 2) using titanium mask; Ref. (Bönsch, P., 1998)

$\text{HBr}: \text{K}_2\text{Cr}_2\text{O}_7: \text{H}_2\text{O}$ (BCA etch); InP etch dependence on solution composition; diffusion controlled polishing etch to kinetically controlled defect etch; Ref. (Weyher, J.L., 1994)

$\text{HBr}: \text{K}_2\text{Cr}_2\text{O}_7: \text{H}_3\text{PO}_4$ (see $\text{HBr}: \text{H}_3\text{PO}_4: \text{K}_2\text{Cr}_2\text{O}_7$)

$\text{HCl}$

$\text{InP}$

$\text{HCl}$; InP etch rate at $25^\circ \text{C}$ $\sim 12 \mu\text{m/minute}$; profiles; Ref. (Adachi, S., 1981b)
HCl (37%); InP (1 0 0) etch rate = 6.2 μm/min; Ref. (Becker, R., 1973)

HCl conc.; InP vertical wall groove etch (following reactive ion etch formation of the groove); Ref. (Coldren, L.A., 1982a,b, 1983)

HCl conc.; InP etch rate (1 1 1) B = 0.15 mg/cm²/s; etch rate (1 0 0) = 0.08 mg/cm²/s; Ref. (Tuck, B., 1973)

HCl conc.; InP etch rate =~ 12 μm/min at 25°C; gives SiO₂ masked profiles; Ref. (Turley, S.E.H., 1982)

HCl conc.; InP; SiO₂ masked etch profile study; Ref. (Westbrook, L.D., 1983)

HCl conc. is preferential vee-grooved etchant for InP (1 0 0) but shows damage on vee-groove walls due to high etch rate (7.33 μm/min at 22°C); Ref. (Edwards-Shea, L., 1985)

HCl conc.; GaAs and InP XPS surface study giving binding energies and Ga/As and In/P surface compositions after etch; Ref. (Bertrand, P.A., 1981)

HCl conc.; removal of Cr mask from GaAs; Ref. (Tihanyi, P., 1987)

HCl:H₂O; Shows data for InP etch rate dependence on dilution. InP electrochemical behavior shows HCl etching is purely chemical; Ref. (Notten, P.H.L., 1984)

HCl (10%); InP etch rate =~ 40 μm/min; oxide mask undercutting; Ref. (Schmitt, F., 1983)

HCl:H₂O (1:1); InP etch rate at 25°C ~0.07 μm/min; profiles; Ref. (Adachi, S., 1981b)

HCl:H₂O (1:1); InP surface morphology after 80 s etch, and etch inhibition with three monolayer MBE GaAs deposit; Ref. (Matsui, Y., 1987)

HCl:H₂O (2:1); InP (1 0 0) etch rate = 5 μm/min; acts as dislocation delineation etch with increased dilution; Ref. (Fiedler, F., 1982)

HCl:H₂O (4:1); Application: InP (1 0 0) orientation determination; ⟨1 1 0⟩ versus ⟨1 1 0⟩; Ref. (Suematsu, Y., 1982); (Kambyashi, T., 1980); (Stulz, L.W., 1983); (Iga, K., 1980c)

HCl:H₂O (5:1); InP substrate removal from InGaAs/InAlAs structure for transfer to glass substrate; Ref. (Arscott, S. 2000)

HCl:H₂O (1:10); InP substrate cleaning to introduce chloride ion absorbed layer for surface protection prior to LPE growth; Ref. (Nelson, A.W., 1982)

HCl:H₂O (1:20); Application: InP n-type photoelectrochemical etch with the sample biased to form a surface depletion layer; forms deep narrow grooves; Ref. (Bowers, J.E., 1985)

HCl:H₂O (1:20); electrolyte for photoelectrochemical etching of GaAs and InP; etch rates and profiles for via hole fabrication are given; Ref. (Khare, R., 1993a)
Electrochemical C–V profiling; InP carrier concentration with HCl electrolyte; Ref. (Ambridge, T., 1979b)

Electrochemical C–V profiling; InP with HCl electrolyte; Ref. (Cabaniss, G.E., 1988)

KCl electrolytes for photoetching of n-GaAs; Ref. (Haisty, R.W., 1961)

HCl; etch rate = 8.2 μm/min; Etchant undercutting of SiO₂ masks on InP (1 0 0) for the following; Ref. (Vozi milova, L.N., 1985)

HCl (1.2 M); electrolyte (pH = 0) for study of anodic dissolution of InP; Ref. (Erné, B.H., 1993)

HCl (1 M); electrolyte for photo-anodic etching and pulsed avalanche etching of InP (0 0 1); formation of pore arrays; Ref. (Hamamatsu, A., 1999)

HCl dilute (pH = 1.0); electrolyte for electrochemical etching of InP; study of reaction using voltammetry, XPS and STM; Ref. (Kaneshiro, C., 1998)

HCl:H₂O (5:1); InP rate ~15 μm/min

HCl:H₂O (1:1); InP rate <100 Å/min
HCl:H₂O (5:3); selective etchant to remove a sacrificial InP layer from between an InGaAs mask and an InGaAs etch stop layer to form micromachined cantilevers; Ref. (Mounaix, P., 1998)

HCl (1 M); photoelectrochemical etch study of InP; etch anisotropy dependence on etch conditions; Ref. (Soltz, D., 1996a)
HCl (1 M); monitoring of grating depth during photoelectrochemical etching on n-InP; Ref. (Soltz, D., 1996b)

HCl (1 M); InP surface etch and oxide removal prior to STM study in sulfuric acid solution; Ref. (Yao, H., 1998)

**InP/InGaAs**

HCl conc.; InP; Application: low angle groove etch to reduce optical reflection in solar cells; Ref. (Jenkins, P., 1991)

HCl:H₂O (3:1); Study: In₀.₅₂Al₀.₄₈As selective etch from In₀.₅₃Ga₀.₄₇As; etch rate = 108 Å/s; (InGaAs etch rate <200 Å/h); more dilute solutions will not etch InAlAs; (InGa)₀.₈Al₀.₂As exhibits no etch rate; (InGa)₀.₆₆Al₀.₃₄As etch rate = 18.3 Å/s; Ref. (Sauer, N.J., 1992)

HCl:H₂O (4:1); InP SiO₂ masked channel etch on InGaAs etch stop layer; Ref. (Sakai, K., 1981)

HCl:H₂O (3:1); InP selective etch from InGaAs; Ref. (Adesida, I., 1993a)
InP/InGaAsP

HCl; InP selective etch from InGaAsP; profiles; Ref. (Adachi, S., 1982c)

HCl conc.; InP (1 0 0) etch rate = 5.4 μm/min; InP selective etch from InGaAsP; Ref. (Ferrante, G.A., 1983)

HCl conc.; InP photolithography; gives HCl etch orientation dependence of sidewall profiles and InGaAsP mask undercutting following an initial reactive ion dry etch in Cl₂/O₂ which leaves the pattern with an initial 75° wall angle; Ref. (Hemenway, B.R., 1983)

HCl conc.; InP selective etch from InGaAsP; Review of III–V etching; Ref. (Kelly, J.J., 1988)

HCl conc.; InP selective etch from InGaAsP mask and stop layer; Ref. (Koch, T.L., 1987)

HCl conc.; InP selective etch from InGaAsP; Ref. (Liau, Z.L., 1982)

HCl:H₂O (1:1); InP selective etch from InGaAsP; profiles; Ref. (Adachi, S., 1982c)

HCl:H₂O (4:1); Application: InP selective substrate removal from InGaAs etch stop layer to allow backside SIMS measurements of metal contact diffusion profiles in InGaAs/InP structures; Ref. (Chen, W.L., 1992)

HCl:H₂O (4:1); Application: InP mesa etch for BH laser; Ref. (Kishino, K., 1980)

HCl:H₂O (4:1); Application: InP selective etch from InGaAsP; Ref. (Murotani, T., 1980); (Oe, K., 1980); (Utaka, K., 1980a,b); (Abe, Y., 1981); (Arai, S., 1981); (Chen, P.C., 1981)

HCl:H₂O (4:1); InP selective etch from InGaAsP at 4°C; Ref. (Wallin, J., 1992)

HCl:H₂O (1.5:1); InP selective etch from InGaAsP; Ref. (Chen, T.R., 1982)

HCl dilute; Application: InP selective etch from InGaAsP; Ref. (Ng, W., 1981); (Nelson, R.J., 1980)

HCl does not attack GaAs but reacts with InAs and InP; Ref. (Phatak, S.B., 1979)

HCl:H₂O (4:1); Application: InP selective etch from InGaAsP at 15°C for laser fabrication; Ref. (Chen, K.L., 1985)

HCl:H₂O (1:10); step 2 in damage removal from RIE etched InGaAsP/InP 1 min at RT; Ref. (Madhan Raj, M., 1999b)

HCl:H₂O (1:10); 1 min cleaning of RIE roughness on InP facets; Ref. (Madhan Raj, M., 1999a)

InAs

HCl conc.; InAs (0 0 1) orientation determination; Ref. (Faust, J.W., 1960)
HCl; photochemical; InAs and GaP etch characteristics under illumination; reaction kinetics dependence on semiconductor band structure; Ref. (Hsieh, H.F., 1993)

HCl (0.2 M); electrolyte for photoelectrochemical etch of InAs; Ref. (Harris, D., 1994)

**GaSb**

HCl:H\textsubscript{2}O\textsubscript{2}; GaSb etch pit defect delineation etch for all other orientations; Ref. (Doerschel, J., 1992)

HCl electrolyte; photochemical etching of n-GaSb; aerated solution to oxidize Sb; matte gray, faceted surface; Ref. (Propst, E.K., 1993)

HCl:H\textsubscript{2}O (1:1); p-GaSb surface cleaning first step, 30 s, followed by:

Buffered HF:H\textsubscript{2}O (1:1); p-GaSb surface cleaning, 30 s, for low resistance Au contacts; Ref. (Tadayon, B., 1995)

HCl:H\textsubscript{2}O (3:7); GaSb surface treatment to provide Sb surface termination prior to sulfidation; Ref. (Lin, C.L., 1998)

**GaP**

HCl; photochemical; InAs and GaP etch characteristics under illumination; reaction kinetics dependence on semiconductor band structure; Ref. (Hsieh, H.F., 1993)

**InGaP**

HCl:H\textsubscript{2}O (1:1); InGaP mesa etch; Ref. (Pearton, S.J., 1994c,e)

HCl:H\textsubscript{2}O (3:2); Application: selective etch of InGaP from GaAs; Ref. (Kobayashi, T., 1989)

HCl:H\textsubscript{2}O (1:1); Application: selective etch of InGaP from GaAs; Ref. (Lu, S.S., 1992)

HCl:H\textsubscript{2}O (1:1); Application: InGaP mesa etch; InGaP/GaAs surface recombination study; Ref. (Pearton, S.J., 1993d)

HCl:H\textsubscript{2}O (m:1, with 0.6 < m < 1.5); rate dependence for In\textsubscript{0.5}Ga\textsubscript{0.5}P, InGaAsP and GaAs; Ref. (Ito, H., 1995)

HCl; selective etch of InGaP from GaAs; Ref. (Brown, G.J., 1994)

**InAlP**

HCl:H\textsubscript{2}O (1:1); Application: selective removal of InAlP layer form GaAs; 20 s; Ref. (Holmes, A.L., 1995)
HCl:H₂O (1:10); Application: In₀.₅Al₀.₅P selective etch from GaAs; Ref. (Kuo, J.M., 1994)

**AlAs**

HCl dilute; AlAs etch stop layer removal from GaAs; Ref. (Grundbacher, R., 1993)

**GaAs**

HCl:H₂O (1:1); 2 min GaAs oxide removal; Ref. (Auret, F.D., 1992)

HCl:H₂O (1:1); Surface cleaning effects on GaAs light emission from Schottky contacts; assessment of etching on electronic surface behavior; Ref. (Adachi, H., 1981a)

HCl:H₂O (1:10) for 30 s, one step in Si substrate cleaning for GaAs MBE growth, followed by HF dip, DI water rinse and N₂ blow dry; Ref. (Christou, A., 1987)

HCl:H₂O (1:20); GaAs n-type selective photoetch from GaAs p-type, selectivity > 15,000. GaAs n-type selective etch from GaAs semi-insulating, selectivity ~30; Ref. (Khare, R., 1991)

HCl; GaAs oxide stripping etch; Ref. (Niehaus, W.C., 1976)

HCl:H₂O (1%); Photoetch of GaAs; Ref. (Mottet, S., 1983)

HCl:H₂O (1:10); GaAs native oxide removal, 3 min; Ref. (Watanabe, H., 1993b)

HCl:H₂O (1:20); electrolyte for photoelectrochemical etching of GaAs and InP; etch rates and profiles for via hole fabrication are given; Ref. (Khare, R., 1993a)

HCl (36%); GaAs 10–20 min etch shows monolayer flat surface; 10 s H₂O rinse dissolves oxides leaving an As-rich surface; Ref. (Song, Z., 1995)

HCl:H₂O; removal of sulfur contamination from GaAs following etch in H₂SO₄:H₂O₂:H₂O; Ref. (Butcher, K.S.A., 1996)

HCl:H₂O (1:1); oxide removal agent from GaAs; Ref. (DeSalvo, G.C., 1996)

HCl:H₂O (1:1) 2 min etch removal of oxide from GaAs; Ref. (Moran, P.D., 1999)

HCl (36%); GaAs treatment to remove surface oxide; study of dependence on HCl temperature and H₂O rinse; Ref. (Matsushita, K., 1998)

HCl:H₂O (1:1); GaAs deoxidation, 1 min; Ref. (Sik, H., 1996)

HCl:H₂O (1:1); Ni mask removal from InGaAs/AlGaAs structure; Ref. (Ko, K.K., 1992)

HCl; deoxidation of GaAs surface; photoluminescence degradation caused by surface oxide; Ref. (Suzuki, T., 1977)
HCl electrolyte for C–V profiling of InP and GaAs materials; Ref. (Faur, M., 1994c)

HCl conc.; GaAs (1 0 0) surface cleaning XPS study; leaves a nearly stoichiometric surface; Ref. (Olivier, J., 1990)

**AlInAs/InGaAs**

HCl:H₂O (3:1); selective removal of In₀.5₂Al₀.₄₈As from In₀.₅₃Ga₀.₄₇As for MEMS; Ref. (Seassal, C., 1996)

HCl:H₂O (1:10); GaAs native oxide removal at 25°C; Ref. (Watanabe, H., 1993a)

**AlGaAs/GaAs**

HCl; Application: Al₀.₅Ga₀.₅As selective etch from GaAs; Ref. (Dumke, W.P., 1972)

HCl (0.5 M); photoelectrochemical depth profile etch for AlGaAs/GaAs; Ref. (Wei, C., 1992)

HCl:H₂O (1:3); oxide removal from AlGaAs/GaAs; Ref. (Green, D.L., 1993b)

HCl:H₂O (1:20) electrolyte; photoelectrochemical dopant selective and bandgap selective etch; GaAs/AlGaAs structures; dependence on band structure; Ref. (Khare, R., 1993b)

HCl:H₂O (1:10); anodic oxide removal from AlₓGa₁₋ₓAs (to thin AlₓGa₁₋ₓAs by repeated discrete incremental steps); Ref. (Buda, M., 1998)

HCl, hot; selective removal of AlₓGa₁₋ₓAs from GaAs if x > 0.42; Ref. (Malag, A., 1993)

HCl:H₂O (1:1); selective removal of Al₀.₇Ga₀.₃As etch stop layer from GaAs layer
Alternate H₂O₂ 1 min soak followed by HCl:H₂O (1:1) 1 min soak (three cycles) of GaAs surface to reduce roughness after AlGaAs layer removal; Ref. (Zhang, C., 1999)

**AlGaP/GaAs**

HCl:H₂O (1:1) (25°C) compositional selectivity in AlₓGa₁₋ₓ)₀.₅In₀.₅P undoped:

<table>
<thead>
<tr>
<th>x</th>
<th>2.9 Å/s</th>
<th>102 Å/s</th>
<th>383 Å/s</th>
<th>478 Å/s</th>
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<tr>
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<td>0.7</td>
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<td></td>
<td></td>
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</tr>
<tr>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Ref. (Stewart, T.R., 1992)

HCl:H₂O (1:1) (25°C) (AlGa)₀.₅In₀.₅P Dopant selectivity:

<table>
<thead>
<tr>
<th>n</th>
<th>483 Å/s</th>
<th>383 Å/s</th>
<th>0.6 Å/s</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 × 10¹⁸</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Ref. (Stewart, T.R., 1992)
HCl:H₂O (1:5); Al₀.₅In₀.₅P etch rate = 600 Å/min at 25°C; Al₀.₅In₀.₅P selective etch from GaAs; Ref. (Lothian, J.R., 1992c)

HCl:H₂O (1:30); Al₀.₅In₀.₅P etch rate = 600 Å/min at 25°C; Ref. (Lothian, J.R., 1992c)

HCl:H₂O (1:1000) to pH 6.7; GaAs and Al₀.₃Ga₀.₇As selective etch from In₀.₁Ga₀.₉As; selectivity >8; Ref. (Hill, D.G., 1990)

GaN

HCl:H₂O (1:1); GaN surface cleaning; good removal of O and C; Ref. (Smith, L.L., 1996)

HCl:H₂O (1:1); surface oxide removal from AlN and GaN; Ref. (King, S.W., 1998)

HCl:H₂O (1:10); photoelectrochemical etch of GaN; rates of a few hundred Å/min; Ref. (Minsky, M.S., 1996)

HCl; second step following UV laser ablation etch of GaN to remove accumulated Ga drops from surface; Ref. (Zhang, J., 1998)

HCl:Bi(NO₃)₃:H₂O (see Bi(NO₃)₃:HCl:H₂O₂)

HCl:HBr:H₃PO₄ (see HCl:H₃PO₄:HBr)

HCl:CH₃COOH

HCl:CH₃COOH (1:1); InP etch rate at 25°C ~6.0 µm/min; profiles; Ref. (Adachi, S., 1981b)

HCl:CH₃COOH (1:1); InP selective etch from InGaAsP; profiles; Ref. (Adachi, S., 1982c)

HCl:CH₃COOH (1:1); InP; SiO₂ masked etch profile study give rectangular groove grating; Ref. (Westbrook, L.D., 1983)

HCl:CH₃COOH (1:1); Application: selective removal of InP from InGaAs/AlInGaAs structure; Ref. (Bélier, B. 2000)

HCl:CH₃COOH:H₂O₂ (1:1:1); InP etch rate at 25°C ~4.0 µm/min; profiles; Ref. (Adachi, S., 1981b)

HCl:CH₃COOH (1:4); InP material selective etch from InGaAs; gives near vertical sidewalls for nanometer geometries; Ref. (Inamura, E., 1989)

HCl:CH₃COOH (1:1), etch rate = 4.0 µm/min; Etchant undercutting of SiO₂ masks on InP (1 0 0); Ref. (Vozmilova, L.N., 1985)

HCl:CH₃COOH:H₂O (6:4:1); Application: InGaAs/InP mesa etch at 8°C; Ref. (Küsters, A.M., 1993)
CH$_3$COOH:HCl (1:1); selective InP removal from InGaAsP; etch rate $\sim$ 1 $\mu$m/min for fresh solution; rate decreases after 30 min; Ref. (Kallstenius, T., 1999a)

HCl:CH$_3$COOH (1:4); step 2, 5 s, selective RIE damage removal from InP in InGaAsP/InP grooves prior to MOVPE regrowth; Ref. (Nunoya, N., 1999)

HCl:CH$_3$COOH(1:4); selective etch of InP from InGaAs; 220 $\AA$/s; Ref. (Miyamoto, Y., 1998)

HCl (37%):CH$_3$COOH (99.8%):H$_2$O (31:62:7); mesa etchant for AlGaInP/GaAs LED structures; 2.2 $\mu$m/min; gives etch rate dependence on etchant composition; Ref. (Schineller, B., 1998)

HCl:CH$_3$COOH:H$_2$O$_2$ {KKI etch}

HCl:CH$_3$COOH:H$_2$O$_2$ (1:1:1); InGaAsP and InP etch rates are similar; profiles; Ref. (Adachi, S., 1982c)

HCl:CH$_3$COOH:H$_2$O$_2$ (1:1:1) {KKI-111 etch}; InP etch rate = 1.1 $\mu$m/min at 25°C; Ref. (Kambayashi, T., 1980)

HCl:CH$_3$COOH:H$_2$O$_2$ (1:1:1) {KKI etch}; Application: InGaAsP/InP non-selective mesa etch at 25°C; Ref. (Sakai, S., 1979a)

HCl:CH$_3$COOH:H$_2$O$_2$ (1:1:1) {KKI etch}; Application: InGaAsP/InP mesa etch; Ref. (Tobe, M., 1980)

HCl:CH$_3$COOH:H$_2$O$_2$ (1:2:1) {KKI-121 etch}; InP (1 0 0) etch rate = 1.4 $\mu$m/min at 25°C; very smooth, flat etched surfaces

HCl:CH$_3$COOH:H$_2$O$_2$ (1:1:1) {KKI-111 etch}; InP etch rate = 1.1 $\mu$m/min at 25°C; Ref. (Kambayashi, T., 1980)

HCl:CH$_3$COOH:H$_2$O$_2$ (1:1:1) {KKI etch}; Application: InP; SiO$_2$-masked recess etch at 12°C for selective LPE growth of InGaAs; shows profiles; etch rate $\sim$ 3000 $\AA$/min; Ref. (Schilling, M., 1986)

HCl:CH$_3$COOH:H$_2$O$_2$ (1:2:1) {KKI etch}; Application: InGaAsP/InP (1 0 0) non-selective etch; shows etch profiles; Ref. (Iga, K., 1979a,b,c)

HCl:CH$_3$COOH:H$_2$O$_2$ (1:2:1) {KKI etch}; Application: InGaAsP/InP laser mirror etch; Ref. (Adachi, S., 1981c); (Miller, B. I.1980)

HCl:CH$_3$COOH:H$_2$O$_2$ (1:2:1) {KKI etch}; Application: InGaASP/InP non-selective groove etch at 15°C for laser mirror; Ref. (Iga, K., 1980a,b,c, 1982)

HCl:CH$_3$COOH:H$_2$O$_2$ (1:2:1) {KKI-121 etch}; InP (1 0 0) etch rate = 1.4 $\mu$m/min at 25°C; very smooth, flat etched surfaces; Ref. (Kambayashi, T., 1980)

HCl:CH$_3$COOH:H$_2$O (1:2:1); InP groove etch; Ref. (Moriki, K., 1981)
HCl:CH₃COOH:H₂O₂ (1:2:1) {KKI etch}; InGaAsP groove and mesa etch; Ref. (Wakao, K., 1981); (Coldren, L.A., 1983)

HCl:CH₃COOH:H₂O (2:6:1); Application: InP channel etch; Ref. (Moriki, K., 1981)

HCl:CH₃COOH:H₂O₂ (1:2:1); Application: InGaAsP/InP laser cantilever etch for microcleaving; Ref. (Szaplonczay, A., 1987)

HCl:CH₃COOH:H₂O₂ (1:20): 0 < x < 5; etch rates for GaAs, InP and InGaP

HCl:CH₃COOH:H₂O₂ (1:y:1); y > 20 gives slow etch rates and smooth surfaces

HCl:CH₃COOH:H₂O₂ (1:40:1); etch rate dependence on the age of the solution; Ref. (Flemish, J.R., 1993)

HCl:CH₃COOH:H₂O₂ (1:1:1); masked pattern etch profiles on (0 0 1)GaAs; Ref. (Adachi, S., 1983)

CH₃COOH:HCl:H₂O₂ (20:1:1); GaInP surface cleaning; 10 s; prior to photoluminescence measurements; Ref. (Arent, D.J., 1996)

HCl:CH₃COOH:H₂O₂ (1:1:1); etch for GaP photolithographic patterning; polish on (1 1 1); complex relief on (1 1 1) at room temperature. Fresh solution needed; shows time dependent etch rate; discusses etch mechanism; Ref. (Berdinskikh, T., 1998)

HCl:CH₃COOH:H₂O₂ (1:2:2); non-selective etch of InGaAs/InP; rate = 90–130 Å/s at 15°C; Ref. (Maximov, I., 1999)

HCl:CH₃COOH:H₃PO₄ (see HCl:H₃PO₄:CH₃COOH)

HCl:CH₃COOH:(1N K₂Cr₂O₇)

HCl:CH₃COOH:(1N K₂Cr₂O₇) (1:1:1); masked pattern etch profiles on (0 0 1)GaAs; Ref. (Adachi, S., 1983)

HCl: citric acid

HCl: citric acid (4:5); InP photolithography; forms inverted sidewalls and flat bottoms; Ref. (Yeats, R., 1982)

HCl: CrO₃:H₂O

CrO₃:HCl:H₂O; GaAs defect delineation study; shows etch characteristics dependence on composition; gives high defect sensitivity for low HCl/CrO₃ ratios under illumination; Ref. (van de Ven, J., 1986a)
HCl: CuCl

HCl conc.: CuCl (1.0N); GaSb surface etching to determine crystal orientation; Ref. (Godines, J.A., 1994)

HCl: ethanol

HCl: ethanol; InP; etch rate concentration and temperature dependence; mesa sidewall profiles; Ref. (das Neves, S., 1993)

HCl: FeCl₃:H₂O

FeCl₃:HCl:H₂O (27 g:250 ml:350 ml), boiling; GaP dislocation etch pit delineation; 12–18 min; Ref. (Val’kovskaya, M.I., 1967)

0.4N FeCl₃ in HCl; InP (1 0 0) orientation determination from etch pit elongation; 0.4N Fe³⁺ (1 1 1)B etch rate = 0.03 mg/cm²/s; (1 0 0) etch rate = 0.03 mg/cm²/s; Ref. (Tuck, B., 1973)

0.4N FeCl₃:HCl solution; InP (1 0 0) orientation determination; Ref. (Olsen, G.H., 1979, 1981)

HCl: HBr (see HBr: HCl)

HCl: HBr:H₂O₂:H₂O (see HBr:H₂O₂:H₂O:HCl)

HCl: HClO₄:HNO₃: CH₃COOH (see HCl: HNO₃: CH₃COOH:HClO₄)

HCl: HClO₄

HCl: HClO₄ (1:1); InP selective etch from InGaAsP; etch rate = 6 µm/min; Ref. (Fiedler, F., 1982)

HCl: HClO₄: glycerine

Glycerine:HCl:HClO₄ (1:2:2); InP selective etch from InGaAsP; etch rate = 2 µm/min at 20°C; similar rates on n- and Si-InP; with smooth mesa surfaces; Ref. (Fiedler, F., 1982)

Glycerine:HCl:HClO₄ (2:1:4); InP etch rate = 0.6 µm/min; Ref. (Fiedler, F., 1982)

HCl: HF: H₂O: H₂O₂ {NRL etch}

HCl:HF:H₂O₂:H₂O₂ (10 ml:10 ml:40 ml:five drops) {NRL etch}; Application: GaAs surface cleaning for deposition of metal Schottky contacts; Ref. (Christou, A., 1976)

HCl: HF: H₃PO₄ (see HCl: H₃PO₄: HF)
HCl:HIO₃

HCl:HIO₃:H₂O (1:1:ₓ, where 5 < x < 100); non-selective etchant for GaAs/AlGaInP; etch rates from 300 to 2500 Å/min depending on x; good etch morphology and stability with time; Ref. (Zaknoune, M., 1998)

HCl:HNO₃

InP

HCl:HNO₃ (1:2); InP etch rate at 25°C ~7.0 µm/min; profiles; Ref. (Adachi, S., 1981b)

HCl:HNO₃ (2:1); InP etch rate at 25°C ~8.5 µm/min; profiles; Ref. (Adachi, S., 1981b)

HCl:HNO₃ (1:1); InP (1 0 0) etch rate = 40 µm/min; Ref. (Becker, R., 1973)

HCl:HNO₃:H₂O (1:1:2); InP etch rate at 25°C ~0.15 µm/min; profiles; Ref. (Adachi, S., 1981b)

HNO₃:HCl:H₂O (1:1:2); InP (1 0 0) etch rate = 5 µm/min; Ref. (Becker, R., 1973)

HCl:HNO₃:H₂O (2:3:6); InP etch rate = 1 µm/min; non-selective; Ref. (Colliver, D.J., 1976)

HCl:HNO₃:H₂O (2:2:1); InP etch rate = 2 µm/min; non-selective; Ref. (Colliver, D.J., 1976)

HCl:HNO₃:H₂O (1:3:x); InP photoetching through thin electrolyte layer; etch rate is dependent on x; Ref. (Grebel, H., 1989)

HCl:HNO₃:H₂O (1:3:6); InP dislocation etch pit delineation; Ref. (Huber, A., 1975)

HCl:HNO₃:H₂O (1:6:6); Application: InP dislocation etch pit delineation; Ref. (Mullin, J.B., 1970)

HCl:HNO₃:H₂O (1:2:30); InP Fe-doped semi-insulating laser-induced etch; Ref. (Osgood, R.M., 1982)

HNO₃:HCl:H₂O (1:1:100); InP photoetch p–n junction delineation; Ref. (Ruberto, M.N., 1991)

HCl:HNO₃; InP (1 1 1)B etch rate = 0.27 mg/cm²/s; InP (1 0 0) etch rate = 0.08 mg/cm²/s; Ref. (Tuck, B., 1973)

HNO₃:HCl:H₂O (1:1:20); Laser controlled photochemical etch of InP; (negligible dark etch rate); Ref. (Willner, A.E., 1988)

HCl:HNO₃ (1:1), etch rate = 6.0 µm/min; Etchant undercutting of SiO₂ masks on InP (1 0 0); Ref. (Vozmilova, L.N., 1985)

HCl:HNO₃:H₂O (5:8:10); HCl:HNO₃:H₂O (5:2:10); HCl:HNO₃:H₂O (3:8:10); n-InP photoetch with HeNe laser; Ref. (Svorcik, V., 1991); (Svorcik, V., 1988)
HCl:HNO$_3$:H$_2$O (1:2:1); InP pattern etch for OMVPE regrowth; etch rate $\sim 4 \mu$m/min; Ref. (Blaauw, C., 1986)

HCl:HNO$_3$:H$_2$O (1:1:20) electrolyte for photoelectrochemical etch of InP; Application: maskless diffraction grating fabrication; Ref. (Matz, R., 1988)

**InGaAsP/InP**

HCl:HNO$_3$ (1:1); InGaAsP and InP etch rates are similar; profiles; Ref. (Adachi, S., 1982c)

HCl:HNO$_3$ (1:3); InGaAsP/InP non-selective mesa etch; data is given on etch wall profiles; Ref. (Coldren, L.A., 1983)

HCl:HNO$_3$ (1:2); equal etch rate on InP and InGaAsP $= 0.16 \mu$m/s; Ref. (Furuya, K., 1981)

HCl:HNO$_3$; Application: InGaAsP/InP photolithography groove etch profiles for vee-groove laser; Ref. (Imai, H., 1982)

HCl:HNO$_3$:H$_2$O (6:1:6); InGaAsP dislocation etch pit delineation; 90 s at 25°C; Ref. (Theil, F.A., 1979)

HCl:HNO$_3$:H$_2$O (1:1:20); InGaAsP and InP p–n junction delineation photoetch; dopant selective: n-etches under illumination; p-type does not etch; very sharp boundaries; Ref. (Williamson, J., 1992)

HNO$_3$:HCl ($n$:1); InGaAsP selective etch from InP for $n > 5$; does not attack photoresist; Ref. (Yeats, R.E., 1977)

HCl:HNO$_3$ (1:1.2–2); HCl:HNO$_3$:H$_2$O: (1:2:1); Application: InGaAsP/InP laser cantilever etch for microcleaving; Ref. (Szaplonczay, A., 1987)

HNO$_3$:H$_2$O:HCl (6:6:1) at 60°C for 90 s; Defect delineation etchant; Application to InP and InGaAsP; Ref. (Mahajan, S., 1981)

HCl:HNO$_3$:H$_2$O (1:2:3); step 1, 15 s, RIE damage removal from InGaAsP/InP grooves prior to MOVPE regrowth; Ref. (Nunoya, N., 1999)

**GaAs**

HCl:HNO$_3$:H$_2$O (1:1:1); GaAs (0 0 1) orientation determination; Ref. (Faust, J.W., 1960)

HCl:HNO$_3$:H$_2$O (2:1:2); GaAs discrimination of (1 1 1)A from (1 1 1)B Surfaces; Ref. (White, J.G., 1959)

HCl:HNO$_3$:H$_2$O (4:1:50); GaAs photoelectrochemical electrolyte for high aspect ratio features; Ref. (Khare, R., 1992)

HNO$_3$:HCl:H$_2$O (1:4:50); GaAs photoinduced etching to taper the thickness by varying pattern of the UV intensity; Ref. (Hu, M.H., 1997)
GaSb

HCl:HNO₃:H₂O (6:1:6); GaSb unreproducible etch pit delineation; Ref. (Costa, E.M., 1997)

HNO₃:HCl:H₂O (1:1:1); Application: etch pit defect delineation in GaSb; Ref. (Nishinaga, T., 1997)

GaP

HCl:HNO₃ (3:1); GaP etch rate at 30°C = 2 μm/min; Ref. (Kaminska, E., 1981)

HCl:HNO₃ (3:1); GaP etch rate at boiling = 6 μm/min; Ref. (Kaminska, E., 1981)

HCl:HNO₃:H₂O (2:1:2); GaP etch rate at 60°C = 1 μm/min; Ref. (Kaminska, E., 1981)

HCl:HNO₃:H₂O (1:1:2); GaP etch rate at 60°C = 0.45 μm/min; Ref. (Kaminska, E., 1981)

H₂O:HCl:HNO₃ (1:1:5); at 50°C; GaP defect delineation; etch rate = 2–5 μm/min; Ref. (Saul, R.H., 1968)

HCl:HNO₃:H₂O (2:1:2); GaP substrate etch to remove polish damage; Ref. (Uragaki, T., 1976)

HNO₃:HCl (1:1); InP rapid etch, but does not selectively attack metal–InP interfaces; Ref. (Yeats, R.E., 1977)

HNO₃:HCl:H₂O; Application: GaP (1 0 0) substrate cleaning for OMVPE; Ref. (Wang, X.-L., 1993)

HCl:HNO₃ (3:1) (aqua regia); GaP polish on (−1 −1 −1); pitted on (1 1 1) for T = 40°C, complex relief for T = 65°C; Ref. (Berdinskikh, T., 1998)

HCl:HNO₃:H₂O (2:1:2); GaP polish on (−1 −1 −1); pitted on (1 1 1) for T = 60°C; Ref. (Berdinskikh, T., 1998)

GaN

HCl:HNO₃:H₂O (7:1:8); Pt mask removal from GaN; 85°C for 4 min; Ref. (Bardwell, J.A., 1999)

HCl:HNO₃ (3:1); 10 min in boiling aqua regia to remove surface oxide from p-type GaN prior to (NH₄)₂Sₓ surface treatment for Pd low resistivity Ohmic contact; Ref. (Kim, J.K., 1999)

HCl:HNO₃:Br₂ \{RRE etch\}

HNO₃:HCl:Br₂ (20:10:0.25); InP and GaP dislocation delineation; 5 s for (1 1 1); 60 s for (1 0 0); Ref. (Clarke, R.C., 1973)

HCl:HNO₃:Br₂ (10:20:0.25); InP dislocation etch pit delineation; Ref. (Huber, A., 1975)
HNO₃:HCl:Br₂ (20:10:0.25) {RRE etch}; InGaAsP dislocation etch pit delineation; 10 s at 25°C; Ref. (Theil, F.A., 1979)

HCl:HNO₃:Br₂ (40:80:1) {RRE etch} at 25°C for 10 s; Defect delineation etchant; Application to InP and InGaAsP; Ref. (Mahajan, S., 1981)

**HCl:HNO₃:CH₃COOH**

HCl:HNO₃:CH₃COOH (1:1:2); InP etch rate at 25°C ~1.0 μm/min; profiles; Ref. (Adachi, S., 1981b)

HCl:HNO₃:CH₃COOH (1:1:1); InP (1 0 0) etch rate = 5.5 μm/min; Ref. (Becker, R., 1973)

HCl:HNO₃:CH₃COOH (3:1:5); InP (1 0 0) etch rate = 4 μm/min; Ref. (Becker, R., 1973)

HCl:HNO₃:CH₃COOH (3:1:5); GaP etch rate at 21°C = 1.15 μm/min; Ref. (Kaminska, E., 1981)

HCl:HNO₃:CH₃COOH (1:1:1); GaP etch rate at 21°C = 1.2 μm/min fresh solution; Ref. (Kaminska, E., 1981)

HCl:HNO₃:CH₃COOH (1:1:1); GaP etch rate at 21°C = 0.25 μm/min, 30 min stabilized solution; Ref. (Kaminska, E., 1981)

HNO₃:HCl:H₂O:CH₃COOH (3:1:1:1), etch rate = 2.5 μm/min; Etchant undercutting of SiO₂ masks on InP (1 0 0); Ref. (Vozmilova, L.N., 1985)

**HCl:HNO₃:CH₃COOH:HClO₄**

**InP**

CH₃COOH:HClO₄:HNO₃:HCl (1:1:5:1); Application: InP-n substrate preparation etch for ion implantation; Ref. (Armiento, C.A., 1979a)

HCl:HNO₃:CH₃COOH:HClO₄ (1:6:1:1); InP (1 0 0) jet thinning etch; Ref. (Armiento, C.A., 1979b)

HCl:HNO₃:HClO₄:CH₃COOH (1:6:1:1); InP (1 0 0) etch rate = 2.5 μm/min; Ref. (Becker, R., 1973)

HCl:HNO₃:HClO₄:CH₃COOH (1:3:3:2); InP etch rate = 3.2 μm/min; Ref. (Becker, R., 1973)

HCl:HNO₃:CH₃COOH:HClO₄ (3:2:1:3); InP thinning etch; etch rate = 7 μm/min; Ref. (Aytac, S., 1983)

HNO₃:HCl:HClO₄:CH₃COOH (6:1:1:1), etch rate = 3.1 μm/min; Etchant undercutting of SiO₂ masks on InP (1 0 0); Ref. (Vozmilova, L.N., 1985)
**GaP**

HCl:HNO₃:CH₃COOH:HClO₄ (1:6:1:1); GaP etch rate at 21°C = 1.8 μm/min Ref. (Kaminska, E., 1981)

HCl:HNO₃:CH₃COOH:HClO₄ (1:3:2:3); GaP etch rate at 21°C = 6 μm/min from fresh solution; at 21°C = 0.6 μm/min from 30 min stabilized solution; Ref. (Kaminska, E., 1981)

**HCl:HNO₃:HF**

HCl:HNO₃:HF (5:3:4); InP grain boundary delineation; no effect on first-order twins; Ref. (Hershenson, L., 1980)

**HCl:HNO₃:H₂O₂**

HCl:HNO₃:H₂O₂ (1:1:2); InP etch rate at 25°C ~0.5 μm/min; profiles; Ref. (Adachi, S., 1981b)

HNO₃:HCl:H₂O₂; comparison of InP surface smoothness with HCl:CH₃COOH:H₂O₂; Ref. (Kambyashi, T., 1980)

**HCl:HNO₃:H₃PO₄**

HCl:HNO₃:H₃PO₄ (1:1.2–2:1–1.5); Application: InGaAsP/InP laser cantilever etch for microcleaving; Ref. (Szaplonczay, A., 1987)

HCl:HNO₃:H₃PO₄ (1:1:5); InP (1 0 0) groove etch; rectangular shaped along ⟨0 1 1⟩; Ref. (Westphalen, R., 1992)

**HCl:HNO₃:H₃PO₄:H₂SO₄**

HCl:HNO₃:H₃PO₄:H₂SO₄ (1:1.2–2:1–1.5:0.005–0.1); Application: InGaAsP/InP laser mirror etching; Ref. (Szaplonczay, A., 1987)

**HCl:HNO₃:H₂SO₄:H₂O**

HNO₃:HCl:H₂SO₄:H₂O (1:2:2:2); GaP {1 1 1}B, 5 min to remove mechanical polish damage; etch rate is dependent on carrier concentration; Ref. (Hajkova, E., 1972)

HCl:HNO₃:H₂SO₄:H₂O (2:1:2:2); GaP etch rate at 30°C = 1.2 μm/min; at 50°C = 3.2 μm/min; Ref. (Kaminska, E., 1981)

**HCl:HNO₃:isopropanol (pear etch)**

Electrochemical C–V profiling; InP; best results with HCl (37%):HNO₃ (70%):isopropanol (36:24:1000) electrolyte; low free chemical etch rate = 0.66 μm/h; requires low constant flow of electrolyte over sample; Ref. (Green, R.T., 1986)
Pear etch electrolyte for C–V profiling of InP and GaAs materials; Ref. (Faur, M., 1994c)

**HCl:H₂O₂:H₂O**

**InP**

HCl:H₂O₂ (1:1); InP etch rate at 25°C ~2.3 μm/min; profiles; Ref. (Adachi, S., 1981b)

HCl:H₂O₂ (1:1); InP selective etch from InGaAsP; profiles; Ref. (Adachi, S., 1982c)

HCl:H₂O₂ (1:1); InP (1 0 0) orientation determination; Ref. (Keavney, C.J., 1984)

HCl:H₂O₂:H₂O (1:1:1); InP etch rate at 25°C ~0.1 μm/min; profiles; Ref. (Adachi, S., 1981b)

HCl:H₂O₂:H₂O (1:20:50); Surface cleaning effects on GaAs light emission from Schottky contacts; assessment of etching on electronic surface behavior; Ref. (Adachi, H., 1981a)

HCl:H₂O₂:H₂O (40:4:1); III–V non-preferential thinning for TEM specimens; Ref. (Narayanan, H., 1974)

**GaAs**

HCl:H₂O₂:H₂O (1:1:1); GaAs first step surface roughening etch 10 min for (1 0 0) orientation determination; 3 min at 55°C; Ref. (Caridi, E.A., 1984)

HCl:H₂O₂:H₂O (1:1:9) and (1:4:40); GaAs etching anisotropy and cross-sectional profiles; Ref. (Shaw, D.W., 1981)

HCl:H₂O₂:H₂O (40:4:1); GaAs jet etch thinning; gives smooth, uniform etch; Ref. (Biedermann, E., 1966)

HCl:H₂O₂:H₂O (40:4:1); GaAs etching anisotropy and cross-sectional profiles; Ref. (Shaw, D.W., 1981)

HCl:H₂O₂:H₂O (80:4:1); GaAs etching anisotropy and cross-sectional profiles; Ref. (Shaw, D.W., 1981); (Notten, P.H.L., 1986)

HCl:H₂O₂:H₂O (160:4:1); GaAs photolithography profiles; Ref. (Notten, P.H.L., 1986)

HCl:H₂O₂:H₂O; Review of GaAs etching; Ref. (Mukherjee, S.D., 1985)

HCl:H₂O₂:H₂O (1:4:40); Application: AlGaAs/GaAs cross section stain, 5 s; Ref. (Sugg, A.R., 1993); (Maranowski, S.A., 1993)

HCl:H₂O₂:H₂O (40:4:1); field emitter tip formation on GaAs by etching through square mask patterns; Ref. (Ducroquet, F., 1998, 1999)
HCl:H2O2:H2O (1:1:50); GaAs surface cleaning prior to S passivation; Ref. (Lu, E.D., 1996)

**InAs**

HCl:H2O2:H2O (150:1:100); InAs surface cleaning 5 min; leaves surface pitting and chloride contamination; Ref. (Brown, A., 1986)

**GaSb**

HCl:H2O2:H2O (1:1:2); GaSb (1 0 0) orientation determination; Ref. (Faust, J.W., 1960)

HCl:H2O2 (2:1); GaSb unreproducible etch pit delineation; Ref. (Costa, E.M., 1997)

HCl:H2O2:H2O (1:1:2); anisotropic stripe pattern etch on GaSb (1 0 0) at 5°C; Ref. (Wissmann, H., 1999)

**Si**

HCl:H2O2:H2O (3:3:5); Silicon substrate oxidation step, 2 min followed by HF:H2O step for three times prior to loading for CBE growth of GaAs; Ref. (Xing, Y.R., 1993)

HCl:H2O2:H3PO4 (see HCl:H3PO4:H2O2)

**HCl:H2O2:K2Cr2O7**

K2Cr2O7:H2O2:HCl (3:1:2); InGaAsP selective etch from InP; profiles; Ref. (Adachi, S., 1982c)

**HCl:H3PO4**

**InP**

HCl:H3PO4 (1:1); InP etch rate at 25°C \( \approx 4.0 \) μm/min; profiles; Ref. (Adachi, S., 1981b)

H3PO4:HCl (1:1): Application: InP Si3N4 masked mesa etch; Ref. (Tamari, N., 1982b)

H3PO4:HCl (3:1); Application: InP photolithography; faceted grooves; Ref. (Bhat, R., 1991)

H3PO4:HCl (3:1); Application: InP (1 0 0) photolithography; rectangular cross-section rib etch; Ref. (Buckmann, P., 1982)


H3PO4:HCl (1:5); InP (1 0 0) photoresist undercut study; etch profiles; Ref. (Huo, D.T.C., 1988b)

\[
\begin{align*}
\text{HCl:H3PO4 (5:95); InP (1 0 0) etch rate} &= 0.09 \text{ μm/min at 23°C} \\
\text{HCl:H3PO4 (10:90); InP (1 0 0) etch rate} &= 0.24 \text{ μm/min}
\end{align*}
\]
HCl:H₃PO₄ (15:85); InP (1 0 0) etch rate = 0.40 μm/min
HCl:H₃PO₄ (20:80); InP (1 0 0) etch rate = 0.70 μm/min
HCl:H₃PO₄ (25:75); InP (1 0 0) etch rate = 1.05 μm/min
HCl:H₃PO₄ (20:80); InP (1 0 0) etch rate = 3.4 μm/min
HCl:H₃PO₄ (20:80); InP (1 0 0) etch rate = 2.6 μm/min

Ref. (Uekusa, S., 1985)

HCl:H₃PO₄ (1:3); InP; SiO₂ masked etch profile study; Ref. (Westbrook, L.D., 1983)

HCl:H₃PO₄:H₂O (3:1:1); InP etch at 0°C, material selective from InGaAs; shows sidewall deformation for nanometer geometries; Ref. (Inamura, E., 1989)

HCl:H₃PO₄ (5:1); InP; vee-groove etchant with photoresist mask; undercut rate is modified by heating substrate; Ref. (Huo, D.T.C., 1988a)

H₃PO₄:HCl (1:1) is preferred vee-grooved etchant for InP with smaller etch rate (0.1 μm/min at 22°C); Ref. (Edwards-Shea, L., 1985)

HCl:H₃PO₄ (3:1); InP vee-groove etchant at room temperature with photoresist mask; depth etch rate = 0.083 μm/s; undercut etch rate = 0.042 μm/s; shelf time is about 20 h; undercut may be reduced by heating substrate; Ref. (Huo, D.T.C., 1987)

HCl:H₃PO₄ (5:1); InP vee-groove etch (1 1 0) direction; no undercut; Ref. (Huo, D.T.C., 1990)

HCl:H₃PO₄ (5:1); InP (1 0 0) vee-groove etchant with photoresist mask; undercutting with InGaAs; dependence of profile shapes on etch time; Ref. (Klockenbrink, R., 1994)

HCl:H₃PO₄ room temperature etch rate data for (1:19), (1:9), and (1:4); Ref. (Matine, N., 1998)

HCl:H₃PO₄ (1:9); etch rate dependence on temperature; lateral etch behavior at 60°C; Application to self-aligned HBTs; Ref. (Matine, N., 1998)

HCl:H₃PO₄ (3:1); wet chemical etchant is used for vee-groove in InP (1 0 0) in 20 s at RT; Ref. (Tanahashi, T., 1983)
**InP/InGaAs(P)**

HCl:H$_3$PO$_4$ (1:1); InP selective etch from InGaAsP; profiles; Ref. (Adachi, S., 1982c)

HCl:H$_3$PO$_4$ (1:1); InP selective etch from InGaAsP; etch rate = 4.0 $\mu$m/min for bulk InP; etch rate = 6.5 $\mu$m/min for LPE InP layers; Ref. (Colliver, D.J., 1976)

HCl:H$_3$PO$_4$ (1:1); InP selective etch from InGaAsP; gives etch rate dependence for (1 0 0)A and (1 0 0)B on etch composition; Ref. (Phatak, S.B., 1979)

HCl:H$_3$PO$_4$ (1:1); Application: InGaAsP ($l = 0.997 \mu$m) stripe etch; Ref. (Imai, H., 1983)

Cl:H$_3$PO$_4$ (1:3); InP selective etch from InGaAs; Ref. (Dambkes, H., 1984); (Dupuis, R.D., 1991)

HCl:H$_3$PO$_4$ (3:1); Application: InP selective etch from InGaAsP; Ref. (Temkin, H., 1984)

HCl:H$_2$O (3:1); InP selective etch from $\sim$30 Å InGaAs mask layer; InP etch rate at 4°C $\sim$300 Å/s; Ref. (Temkin, H., 1988)

HCl:H$_3$PO$_4$ (2:3); InP bulk etch rate = 2.5 $\mu$m/min; no measurable InGaAsP or InGaAs etching after 30 min; Ref. (Colliver, D.J., 1976)

HCl:H$_3$PO$_4$ (1:4); Application: InP groove etch; gives etch rate dependence on composition; selective from InGaAsP; gives SiO$_2$ masked profiles; Ref. (Turley, S.E.H., 1982)

HCl:H$_3$PO$_4$ (1:8); selective removal of InP from InGaAsP in laser array process; Ref. (Rothman, M.A., 1992)

HCl:H$_3$PO$_4$ (6:4); Application: InP selective etch from InGaAs; Ref. (Houston, P.A., 1987)

<table>
<thead>
<tr>
<th>HCl:H$_3$PO$_4$</th>
<th>InP etch rate (selective from InGaAsP) ($\mu$m/min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1:1) 60°C</td>
<td>27</td>
</tr>
<tr>
<td>(1:4) 60°C</td>
<td>4.8</td>
</tr>
<tr>
<td>(1:6) 60°C</td>
<td>3.0</td>
</tr>
<tr>
<td>(1:1) 20°C</td>
<td>2</td>
</tr>
</tbody>
</table>

Ref. (Fiedler, F., 1982)
HCl:H₃PO₄:H₂O (1:1:1); InP (1 0 0) vee-groove etch; does not erode photoresist; Ref. (Huo, D.T.C., 1989d)

HCl:H₃PO₄; Application: InGaAsP/InP groove etch profiles for vee-groove laser; Ref. (Imai, H., 1982)

HCl:H₃PO₄; Application: InP selective etch from InGaAsP stop layer for laser fabrication; Ref. (Kaminov, I.P., 1979)

HCl:H₃PO₄ (1:1); InP (1 0 0) groove etch; partial vee-shaped {1 1 1}B surface along (0 1 1), and vee-shaped {2 1 1} along (0 1 1); Ref. (Westphalen, R., 1992)

HCl:H₃PO₄ (1:10); Application: InP selective etch from InGaAs using SiN mask for HBT fabrication; Ref. (Ouacha, A., 1993)

HCl:H₃PO₄ (5:1); InP (1 0 0), precise alignment grooves; negligible undercutting with InₓGa₁₋ₓAs masks compared to titanium masks; etch profiles; Ref. (Klockenbrink, R., 1994)

HCl:H₃PO₄ (5:1); vee-groove etching behavior with SiO₂, photoresist and InGaAs masks. Shows groove shape dependence on mask alignment; Ref. (Wang, J., 1998)

HCl:H₃PO₄ (0.5:1); at 25°C in light InP rate is 21 nm/s
HCl:H₃PO₄ (5:1); at 25°C in light InP rate is 151 nm/s; for 20 μm high mesas these give smooth (2 1 1)A side surfaces, but deep pit features on the (1 0 0) bottom surface; Ref. (Eliás, P., 1999)

**InGaP/GaAs**

H₃PO₄:HCl:H₂O (1:1:1); In₀.₅Ga₀.₅P selective etch from GaAs; InGaP etch rate = 900 Å/min at 25°C; data show rate dependence on etch composition; Ref. (Lothian, J.R., 1992a)

H₃PO₄:HCl (1:1); InGaP selective etch from GaAs; Ref. (Razeghi, M., 1991)

H₃PO₄:HCl:H₂O; Application; InGaP selective etch from GaAs; selectivity dependence on composition; Ref. (Ren, F., 1994)

HCl:H₃PO₄ (1:3); Application: InGaP selective etch from GaAs; HBT fabrication; Ref. (Song, J.-I., 1994)

HCl:H₃PO₄ (3:1) and (1:1); selective etch of InGaP from GaAs; Ref. (Arslan, D., 1999)

HCl:H₃PO₄ (1:3); Application: selective etch of InGaP from GaAs; Ref. (Hanson, A.W., 1993)

H₃PO₄:HCl:H₂O (1:1:1); InGaP selectively etched from GaAs; rate is reaction limited at the surface; rate increases with HCl content; Ref. (Lothian, J.R., 1992b)

o-H₃PO₄:HCl (3:1); Application: mesa preparation for InP regrowth; Ref. (Ojha, S.M., 1994)
HCl:H₃PO₄:CH₃COOH

HCl:H₃PO₄:CH₃COOH (1:1:2); InP selective etch from InAlAs; selectivity >85; InP etch rate = 3000 Å/min
HCl:H₃PO₄:CH₃COOH (1:1:1); InP selective etch from InAlAs; selectivity >34 with improved photolithographic pattern definition; InP etch rate = 10,000 Å/min; InAlAs etch rate = 300 Å/min; Ref. (He, Y., 1992)
Cl:H₃PO₄:CH₃COOH (1:1:x, with 0 < x < 6); study of InP etch rate, surface finish and photoresist undercut; Ref. (Ikossi-Anastasiou, K., 1995)

HCl:H₃PO₄:HBr

H₃PO₄:HCl:HBr (1:5:0.1–1); InP (1 0 0) photoresist undercut study; etch profiles; Ref. (Huo, D.T.C., 1988)
HP₃O₄:HCl:HBr (1:1:1); InP vee-groove etch; does not erode photoresist; Ref. (Huo, D.T.C., 1989d)

HCl:H₃PO₄:HF

H₃PO₄:HCl:HF (1:5:0.1–1); InP (1 0 0) photoresist undercut study; etch profiles (HF causes bad undercut); Ref. (Huo, D.T.C., 1988)

HCl:H₃PO₄:HNO₃ (see HCl:HNO₃:H₃PO₄)
HCl:H₃PO₄:HNO₃:H₂SO₄ (see HCl:H₃PO₄:HNO₃:H₃PO₄:H₂SO₄)

HCl:H₃PO₄:H₂O₂

HCl:H₃PO₄:H₂O₂ (1:1:1); InGaAsP and InP etch rates are similar; profiles; Ref. (Adachi, S., 1982c)
H₃PO₄:HCl:H₂O₂ (1:5:0.1–1); InP (1 0 0) photoresist undercut study; etch profiles; Ref. (Huo, D.T.C., 1988)
H₃PO₄:HCl:H₂O₂; comparison of InP surface smoothness with HCl:CH₃COOH:H₂O₂; Ref. (Kambyashi, T., 1980)
HCl:H₃PO₄:H₂O₂ (1:1:1); masked pattern etch profiles on (1 0 0)GaAs; Ref. (Adachi, S., 1983)

HCl:H₃PO₄:K₂Cr₂O₇

HCl:H₃PO₄:(1N K₂Cr₂O₇) (1:1:1); masked pattern etch profiles on (1 0 0)GaAs; Ref. (Adachi, S., 1983)

HCl: H₃PO₄: lactic acid (see lactic acid:H₃PO₄:HCl)
HCl:H₂SO₄:K₂Cr₂O₇

<table>
<thead>
<tr>
<th>1 M K₂Cr₂O₇:H₂SO₄:HCl</th>
<th>GaAs (1 0 0) rate (µm/min)</th>
<th>InP (1 0 0) rate (µm/min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(3:1:0) (60°C)</td>
<td>0.03</td>
<td>None</td>
</tr>
<tr>
<td>(3:1:1) (60°C)</td>
<td>12</td>
<td>0.25</td>
</tr>
<tr>
<td>(3:1:2) (25°C)</td>
<td>2.5</td>
<td>0.5</td>
</tr>
<tr>
<td>(3:1:2) (60°C)</td>
<td>20</td>
<td>1.5</td>
</tr>
<tr>
<td>(3:1:3) (60°C)</td>
<td>30</td>
<td>2.3</td>
</tr>
</tbody>
</table>

Gives GaAs and InP surface quality and groove etch profiles; Ref. (Adachi, S., 1981e)

H₂SO₄:HCl:(1N K₂Cr₂O₇) (1:1:1); masked pattern etch profiles on (1 0 0)GaAs; Ref. (Adachi, S., 1983)

HCl:H₂SO₄:H₂O₂:H₂O

HCl:H₂SO₄:H₂O₂:H₂O (m:1:10:2000, with 0.6 < m < 1.5); rate dependence and selectivity for In₀.₅Ga₀.₅P, InGaAsP and GaAs; Ref. (Ito, H., 1995)

HCl:KI:I₂ (see KI:I₂:HCl)

HCl:KIO₃

HCl:KIO₃ (1:1) with KIO₃ at 0.1 mol/l; non-selective etchant for GaAs/AlGaInP; etch rates from ~1000 Å/min; good etch morphology and stability with time; undercutting of AlGaInP; Ref. (Zaknoune, M., 1998)

HCl:K₂Cr₂O₇

HCl:K₂Cr₂O₇; non-selective etchant for GaAs/AlGaInP; similar to HCl:KIO₃; Ref. (Zaknoune, M., 1998)

HCl:methanol

Electrochemical C–V profiling; InP n- and p-GaAs with HCl (36%) 1 vol.% in methanol electrolyte; Ref. (Akita, K., 1991b)

HCl:methanol (1:10) at RT for 10 s; step in optimum InP cleaning; Ref. (Kurth, E., 1988)

HCl:methanol (1:1); GaN surface cleaning; good removal of O and C; Ref. (Smith, L.L., 1996)

HCl (36% aqueous solution):methanol (from 1:10–1:1000); protects GaAs surface from oxidation to improve photoluminescence intensity; Ref. (Akita, K., 1990)
HCl:NaOCl

1 M NaOCl:HCl (5:1); GaAs photolithography profiles; Ref. (Notten, P.H.L., 1986); (Rideout, V.L., 1972)

NaOCl (aqueous solution):HCl (1:1); masked pattern etch profiles on (1 0 0)GaAs; Ref. (Adachi, S., 1983)

NaOCl:HCl:H₂O (2:2:16); scanning jet polishing of GaP
  NaOCl:HCl:H₂O (10:20:170); scanning jet polishing of GaAs; Ref. (Unvala, B.A., 1972)

HCl: propylene glycol

HCl:propylene glycol (1:2); Application: InP selective etch from InGaAs mask layer; Ref. (Ishibashi, T., 1981)

HClO₄:HCl (see HCl: HClO₄)

HClO₄:HCl:glycerine (see HCl: HClO₄: glycerine)

HClO₄:HCl:HNO₃:CH₃COOH (see HCl: HNO₃: CH₃COOH: HClO₄)

HF

GaAs

HF (50%); GaAs (1 0 0) surface cleaning XPS study; Ref. (Olivier, J., 1990)

HF conc.; measurement of GaAs residual surface oxide; Ref. (Shiota, I., 1977)

HF conc.; pre-etch to remove surface oxides; Ref. (Meneghini, G., 1989)

HF:H₂O (1:3); Application: Si-removal of thermal oxide as a step in Si substrate cleaning for GaAs MBE growth, followed by NH₄OH:H₂O (1:10) for 30 s, followed by HCl:H₂O (1:10) for 30 s, followed by HF dip, followed by DI water rinse and N₂ blow dry; Ref. (Christou, A., 1987)

HF:H₂O (1:10); GaAs and InP photoetch p–n junction delineation; dopant selective; n-etches under illumination; p does not etch; Ref. (Ruberto, M.N., 1991)

HF:H₂O (1:50); Si₃N₄ mask removal; Ref. (Rittenhouse, G.E., 1992)

HF 10%; second step (after KOH) to remove Si mask from GaAs; Ref. (Snow, E.S., 1993)

InAs

HF conc.; InAs surface cleaning 5 min after initial Br₂/methanol etch; followed by DI water rinse; leaves residual Br₂ and F; demonstrates need for high purity water rinse to reduce ionic contaminants; Ref. (Brown, A., 1986)
HF:H₂O (1:1); InAs substrate cleaning for MOCVD; Ref. (Biefeld, R.M., 1986)

**InGa(Al)As**

HF conc.; removal of Ti from InGaAs; Ref. (Kallstenius, T., 1999a)

HF; InGaAlAs/InP surface cleaning for MOCVD regrowth; Ref. (Kollakowski, St., 1998)

**AlGaAs/GaAs**

HF (10%): AlAs selective etch lift-off of a AlGaAs/GaAs layer; selectivity of >107 between AlAs and Al₀.₄Ga₀.₆As; onset of etching occurs for compositions greater than 40–50% aluminum; Ref. (Yablonovitch, E., 1987)

HF; AlGaAs selective etch from GaAs; Ref. (Merz, J.L., 1979)

HF; Ga₀.₃Al₀.₇As selective etch from GaAs; Application: removal of GaAs solar cell layers from the substrate; Ref. (Konagai, M., 1978)

HF oxide dissolution; Ref. (Robach, Y., 1992)

HF, hot; selective removal of AlₓGa₁₋ₓAs from GaAs if x > 0.38; Ref. (Malag, A., 1993)

HF:H₂O (1:10); selective removal of Al₀.₇Ga₀.₃As etch stop layer from wafer bonded GaAs template layer; Ref. (Moran, P.D., 1999)

HF, dilute; selective removal of AlAs from GaAs; selectivity >107; Ref. (Novák, J., 1996)

HF:H₂O (1:10); Application: AlGaAs spacer layer lift-off (10 h) to reveal microlens pattern; Ref. (Peake, G.M., 1997)

HF:H₂O (10 wt.%); selective etch of AlAs layer from GaAs for lift-off separation

HF:H₂O (10 wt.%), AlGaAs/GaAs layer; with a surfactant and antifoaming agent (Morita Chemicals, Ltd.); selective etch of AlAs layer from GaAs for lift-off separation; increase of rate with temperature; Ref. (Sasaki, Y., 1999)

HF conc.; selective undercut pattern in AlGaAs masked by GaAs; Ref. (Schumacher, C., 1999)

HF (10%); GaAs epitaxial layer lift-off by selectively etching a thin Al₀.₈₅Ga₀.₁₅As release layer to separate from the substrate (up to 2 in. diameter); Ref. (van Geelen, A., 1997)

HF (48%); selective removal of AlₓGa₁₋ₓAs from GaAs: AlₓGa₁₋ₓAs etch rates versus x at 80°C; Ref. (Wu, X.S., 1985)

HF; selective removal of Al₀.₅Ga₀.₅As etch stop layer from GaAs layer; Ref. (Zhang, C., 1999)

HF (10%); Application: AlAs selective etch from GaAs; used for lift-off of InGaAs/GaAs layer for TEM analysis; Ref. (Zou, J., 1993)
**AlSb/InAs**

HF; Application: AlSb selective etch from InAs for layer lift-off. InAs layer masked with black wax is removed from GaAs substrate by etch of an intermediate sacrificial AlSb layer. GaSb is attacked by HF but can be lifted off by using a thin InAs etch stop layer; Ref. (Ozbay, E., 1993)

HF:H$_2$O (1:20) or (1:40); Selective etch of sacrificial AlSb layer to lift-off an InAs layer from a GaAs substrate; Ref. (Fastenau, J., 1995)

**InP**

HF:H$_2$O (1:1); InP substrate cleaning; low C and O contamination. Auger analysis; Ref. (Singh, S., 1982)

HF:H$_2$O (1:10); Laser controlled photochemical etch of InP; Ref. (Willner, A.E., 1988)

HF:H$_2$O (1:1); InP etch rate enhanced by Mg ion bombardment damage for maskless patterning; Ref. (Inada, T., 1984)

HF (1%); Ti mask removal from InP; Ref. (Schilling, O., 1993)

HF:H$_2$O (1:4); Ti/SiN mask removal from InP/InGaAsP; Ref. (Qian, Y.H., 1999)

HF dilute; Application: SiN passivation layer removal from InP; Ref. (Ouacha, A., 1993)

HF:H$_2$O (1:30); InP surface oxide cleaning in N$_2$ dry box gas phase polysulfide in N$_2$ from a bubbler; analysis of S on the InP surface; Ref. (Kwok, R.W.M., 1995)

HF; InP surface cleaning for MOVPE regrowth; leaves impurities at interface; Ref. (Miyamoto, Y., 1991)

HF; InP surface oxide removal; surface treatment scanning photoluminescence study; Ref. (Krawczyk, S.K., 1986)

HF (5%) for 10 s followed by H$_2$SO$_4$ (80%) for 60 s to clean InP vee-grooved surface prior to MOVPE regrowth without affecting vee-groove shape; Ref. (Schrimpf, T., 1999)

Focused Ga$^+$ ion beam patterning of InP; followed by HF (ultrasonic bath at 80°C) selective etch of the Ga implanted area to form a grating; Ref. (König, H., 1999)

**Si**

HF:H$_2$O (1:3); Application: Si-removal of thermal oxide as a step in Si substrate cleaning for GaAs MBE growth, followed by NH$_4$OH:H$_2$O (1:10) for 30 s, followed by HCl:H$_2$O (1:10) for 30 s, followed by HF dip, followed by DI water rinse and N$_2$ blow dry; Ref. (Christou, A., 1987)

HF:H$_2$O (1:10); Si photoetch, rate increase of 1000× under illumination; Si etch rate = 26 Å/s; Ref. (Hoffman, H.J., 1989)
HF:H₂O (1:5); Silicon substrate contaminant removal step, 2 min; Ref. (Xing, Y.R., 1993)

**GaN**

HF:H₂O (1:20); GaN surface cleaning; good removal of O and C
   HF:H₂O (1:1); GaN surface cleaning; good removal of O and C; Ref. (Smith, L.L., 1996)

**HF buffered**

**InP**

Buffered HF (NH₄F:HF (10:1)); InGaAsP oxide removal; Ref. (Capasso, F., 1980); (Iga, K., 1980a)

Buffered HF (NH₄F:HF (10:1)); InP etch rate after 60 min at 20°C is unmeasurable; Ref. (Elder, D.I., 1987)

Buffered HF (HF:NH₄F (45:500)); InP etch rate = 0.04 μm/min with no mask undercutting; Ref. (Schmitt, F., 1983)

HF (buffered); Ellipsometry measurements to assess cleanest and smoothest etched surfaces; Ref. (Aspnes, D.E., 1981)

HF buffered (5NH₃F:1HF) is used to etch windows in SiO₂ mask on InP; Ref. (Edwards-Shea, L., 1985)

Buffered HF (i.e. HF:NH₄F, 1:6):H₂O (1:4); Ti removal from InP; 30 s at room temperature removes ~200 Å; Ref. (Liao, H.-H., 1996)

HF buffered; Ti mask removal from vee-groove patterned InP Ref. (Schrimpf, T., 1999)

**GaAs**

HF:NH₄F (1:7); oxide removal agent from GaAs; Ref. (DeSalvo, G.C., 1996)

H₂O:buffered HF (40:1) where buffered HF is H₂O:buffered HF (40:1) where buffered HF is NH₄F (36%):HF (6.4%) (7:1); selective removal of AlAs from GaAs (and of high Al content AlGaAs from low Al content AlGaAs); shows dependence of etch rates (selectivity) on volume ratio; Ref. (Kim, J.-H., 1998)

**GaN/AlN**

HF buffered (7NH₄F:1HF):H₂O (10:1); surface oxide removal from AlN and GaN; Ref. (King, S.W., 1998)

**HF:**AgNO₃:CrO₃:H₂O (see AgNO₃:CrO₃:HF:H₂O {A–B etch})

**HF:**AgNO₃:HNO₃:H₂O (see AgNO₃:HF:HNO₃:H₂O {R–C etch})
HF:CH₃COOH:H₂O₂

HF:CH₃COOH:H₂O₂; electrolyte for photoelectrochemical defect etch pit delineation; Ref. (Faur, M., 1993)

HF:CH₃COOH:KMnO₄

HF:CH₃COOH:KMnO₄ (1:1:1) (0.05 M); AlGaSb striation delineation etch; Ref. (Bischopink, G., 1993)

KMnO₄ (sat.):HF:CH₃COOH (1:1:1); growth striations on (1 1 0) in n-type GaSb; Ref. (Costa, E.M., 1997)

HF:CH₃COOH:KMnO₄ (0.4 M) (1:1:1); Application: striation defect delineation in GaSb after 5.5 min etch; Ref. (Nishinaga, T., 1997)

HF: CrO₃ {Sirtl etch}

Si (HF:CrO₃ — Sirtl)

HF:CrO₃ (5 M) (1:1) {Sirtl etch}; Si etch pit delineation, non-linear etch rate ~ 3.5 µm/min; Ref. (Schimmel, D.G., 1976)

Sirtl etch, modified; GaAs (1 1 1) dislocation etch pit delineation; Ref. (Elliot, A.G., 1987)

HF:CrO₃ (0.15 M) {Alternate Secco etch}; Si etch pit delineation, etch rate ~ 1 µm/min with ultrasonic agitation; Ref. (Schimmel, D.G., 1976)

GaAs (HF:CrO₃ — Sirtl)

CrO₃:HF:H₂O (33 w/o:46 w/o water solution) {Sirtl etch}; GaAs orientation determination from etch pit shape; Ref. (Tarui, Y., 1971)

CrO₃:HF; GaAs etch and photoetch chemical kinetics; Ref. (van de Ven, J., 1986b)

CrO₃:HF:H₂O₂; GaAs (1 0 0) etch and photoetch defect delineation; Ref. (Weyher, J., 1983a,b)

HF:CrO₃ (1:5) diluted with H₂O (1:1) {DSL; diluted Sirtl-like etch with light}; GaAs photoetch, 30 s for etch pit delineation of dislocations; Ref. (Frigeri, C., 1989)

HF:CrO₃:H₂O₂; diluted Sirtl-like (DSL) photoetching; GaAs; identification of etch features with transmission electron microscopy; Ref. (Frigeri, C., 1993)

CrO₃:HF:H₂O₂; diluted Sirtl-like (DSL) photoetching; Application: GaAs defect delineation; Ref. (Frigeri, C., 1991)
CrO$_3$:HF:H$_2$O (DSL, diluted Sirtl-like with light photoetch); defect delineation in GaAs; comparison to EBIC images; Ref. (Frigeri, C., 1990)

Diluted Sirtl etch; GaAs striation delineation etch; Ref. (Pandelisev, K.A., 1990)

CrO$_3$:HF:H$_2$O (DSL, diluted Sirtl-like etch and DSL diluted Sirtl-like with light photoetch); defect delineation in GaAs; comparison to KOH (molten) defect delineation; Ref. (Weyher, J.L., 1986)

CrO$_3$:HF:H$_2$O (1:2:3); GaAs defect delineation; ultrasonic aided; etch rate at 40°C 0.5 μm/min; etch depth 0.5–2 μm to produce etch pits; Ref. (Chen, N., 1993)

DSL (dilute Syrtl like) etch to reveal As precipitates in GaAs for TEM study; Ref. (Weyher, J.L., 1998)

InP

CrO$_3$:HF:H$_2$O {Sirtl etch}; InP defect delineation under white or laser light; Ref. (Weyher, J.L., 1985)

GaSb

CrO$_3$ (5 M aq. sol.):HF (5:1); GaSb etch pit delineation on (1 1 1)A, (1 1 1)B, (1 0 0), (1 1 0), striations on (1 1 1)A and (1 1 0); precipitates on (1 1 1)A, (1 1 1)B, (1 0 0), (1 1 0); Ref. (Costa, E.M., 1997)

HF:CrO$_3$:AgNO$_3$:H$_2$O (see AgNO$_3$:CrO$_3$:HF:H$_2$O {A–B etch})

HF:ethanol

HF:ethanol (10%); InP surface cleaning; surface deoxidation etch; Ref. (Massies, J., 1986)

HF:ethanol (1:9); GaAs and InP deoxidization post etch solution; Ref. (Saletes, A., 1988)

HF:HBr (see HBr:HF)

HF:HCl:H$_3$PO$_4$ (see HCl:H$_3$PO$_4$:HF)

HF:HCl:HNO$_3$ (see HCl:HNO$_3$:HF)

HF:HCl:H$_2$O:H$_2$O$_2$ (see HCl:HF:H$_2$O:H$_2$O$_2$ {NRL etch})

HF:HNO$_3$:HCl (see HCl:HNO$_3$:HF)

HF:HNO$_3$:H$_2$O

HF:HNO$_3$:H$_2$O (1:1:1); masked pattern etch profiles on (0 0 1)GaAs; Ref. (Adachi, S., 1983)
HF (40%):HNO₃ (65%):H₂O (5:24:64); selective removal of titanium mask from InP; 10 s at 20°C; Ref. (Bönsch, P., 1998)

HF:HNO₃:H₂O (1:1:2); field emitter tip formation on GaAs by etching through square mask patterns; Ref. (Ducroquet, F., 1998, 1999)

**HF:HNO₃:H₂O₂**

HF:HNO₃:H₂O₂ (1:1:1); masked pattern etch profiles on (0 0 1)GaAs; Ref. (Adachi, S., 1983)

**HF:H₂O:AgNO₃:CrO** (see AgNO₃:CrO₃:HF:H₂O {A–B etch})

**HF:H₂O:H₂O₂:HCl** (see HCl:HF:H₂O:H₂O₂)

**HF:H₂O₂:H₂O**

InSb (HF:H₂O₂:H₂O)

HF:H₂O₂:H₂O (1:1:4); InSb surface cleaning for AES studies; Ref. (Auret, F.D., 1982)

HF:H₂O₂:H₂O (1:1:4); InSb, InAs, GaAs (0 0 1) orientation determination; Ref. (Faust, J.W., 1960)

GaAs (HF:H₂O₂:H₂O)

HF:H₂O₂:H₂O (1:1:10); GaAs photoetch dislocation etch pit delineation; Ref. (Nishizawa, J., 1979)

HF:H₂O₂:H₂O mixtures; GaAs; etch rate and sidewall profile dependence on etchant composition; Ref. (Takebe, T., 1993)

HF:H₂O₂:H₂O (1:10:21.2); field emitter tip formation on GaAs by etching through square mask patterns; Ref. (Ducroquet, F., 1999)

HF:H₂O₂:H₂O (1:20:100); field emitter tip formation on GaAs by etching through square mask patterns; Ref. (Ducroquet, F., 1999)

HF:H₂O₂:H₂O (1:9:5); Application: mesa etch for concave sidewalls of ~70° near mesa top on GaAs ⟨1 0 0⟩ stripe patterns; Ref. (Konkar, A., 1998)

**InP (HF:H₂O₂:H₂O)**

HF:H₂O₂ (1:20); InP surface cleaning for MBE regrowth gives high surface defect density; Ref. (Passenberg, W., 1997)

**InGaAs(P)**

HF:H₂O₂:H₂O (1:1:10); InGaAs selective etch from InP; InGaAs etch rate = 6300 Å/min; Ref. (Elder, D.I., 1983, 1984)
HF:H₂O₂:H₂O (1:1:20); InGaAs selective etch from InP; InGaAs etch rate = 3000 Å/min; Ref. (Elder, D.I., 1983, 1984)

H₂O:H₂O₂:HF (8:3:2) to remove SiO₂ mask and In droplets from LPE step; Ref. (Prince, F.C., 1980)

HF:H₂O₂:H₂O (1:1:10); InGaAsP/InP interface delineation; Ref. (Susa, N., 1981)

HF:H₂O₂:H₂O (1:1:10); Application: InGaAs diffused p–n junction cross-section delineation; 20–15 s under illumination; Ref. (Yamamoto, Y., 1980)

AlAs

HF:H₂O₂:H₂O (1:1:10); AlAs selective etch from InP as a sacrifice layer to lift-off InP epilayer from the substrate; Ref. (Bailey, S.G., 1995)

GaSb

HF:H₂O₂:H₂O (2:1:20); Selective etch of GaSb from InAs stop layer; Ref. (Fastenau, J., 1995)

HF: H₂O₂: H₂SO₄ (see H₂SO₄:H₂O₂:HF)

HF:H₂O₂:H₂O:butylthiobutane

H₂O₂:(HF + H₂O + 0.4% butylthiobutane) (1:1); InSb {1 1 1}Sb dislocation delineation; Ref. (Gatos, H.C., 1961)

HF:HNO₃

InSb

HF:HNO₃:H₂O (1:1:4); InSb (0 0 1) orientation determination; Ref. (Faust, J.W., 1960)

HF:HNO₃ (1:1); InSb (0 0 1) orientation determination; Ref. (Faust, J.W., 1960)

HF:HNO₃ (1:1); InSb polish etch, 2–5 s, following mechanical polishing to delineate dislocation etch pits; Ref. (Venables, J.D., 1958)

InAs

HF:HNO₃:H₂O (1:3:2); InAs p–n junction delineation; 1–3 min; Ref. (Sharma, B.L., 1966)

GaSb

HF:HNO₃:H₂O (1:1:1); GaSb (0 0 1) orientation determination; Ref. (Faust, J.W., 1960)
**GaAs**

HNO$_3$:HF (1:3); GaAs layer delineation; Ref. (Colliver, D.J., 1976)

HNO$_3$:HF:H$_2$O (1:3:4); GaAs layer delineation; Ref. (Colliver, D.J., 1976)

HNO$_3$:HF:H$_2$O (3:1:5); GaAs layer delineation; Ref. (Colliver, D.J., 1976)

HF:HNO$_3$:H$_2$O (1:3:4); GaAs first step etch followed by second step A–B etch to reveal growth striations in LEC material; Ref. (Miyazawa, S., 1982)

HNO$_3$:HF:H$_2$O (3:1:4); GaAs delineation of growth striae; 2 min at 20°C; Ref. (Plaskett, T.S., 1965)

HF:HNO$_3$:H$_2$O (2:2:1); GaAs surface cleaning analysis by Auger analysis and Au layer epitaxy behavior; Ref. (Vermaak, J.S., 1977)

HF:HNO$_3$:H$_2$O (4:1:50); Application: GaAs photoetch for waveguide fabrication; AlGaAs/GaAs Ar-laser-induced etch rate = 750 μm/min; Ref. (Willner, A.E., 1989)

**InGaAs(P)**

HF:HNO$_3$; Application: InGaAsP/InP LPE layer cross-section delineation; Ref. (Akiba, S., 1980)

**Si and Ge**

HF:HNO$_3$:H$_2$O (15:10:300) {p-etch (Si)}; Application: SiO$_2$ preferential etch of electron beam irradiated pattern mask on Si; irradiated area etch rate is 3 × non-irradiated area; Ref. (Hoole, A.C.F., 1992)

HF:HNO$_3$:H$_2$O; Germanium etch rate dependence on composition; Ref. (McKeown, P.J.A., 1962)

HF:HNO$_3$:H$_2$O (15:10:300) {p-etch (Si)}; Application: patterning of electron beam irradiated SiO$_2$ mask; Ref. (Pan, X., 1992)

HF:HNO$_3$ (155:1) {Schimmel etch}; Si etch pit delineation, non-linear etch rate ~ 1.8 μm/min, n-substrate with illumination; Ref. (Schimmel, D.G., 1976)

HF:HNO$_3$:H$_2$O; Silicon etch kinetics; dependence on concentrations; Ref. (Schwartz, B., 1976b)

**HF:HNO$_3$:CH$_3$COOH**

**InSb**

HF:HNO$_3$:CH$_3$COOH (1:2:5); InSb surface cleaning for AES studies; Ref. (Auret, F.D., 1982)

CH$_3$COOH:HNO$_3$:HF (15:30:15) {CP-4 etch}; InSb surface cleaning for AES studies; Ref. (Auret, F.D., 1982)
Si

HF:HNO₃:CH₃COOH (8:2:1); Application: Si substrate cleaning for GaAs MBE growth; Ref. (Koch, S.M., 1987)

HF:HNO₃:CH₃COOH (1:3:1) {Dash etch}; Si etch pit delineation, non-linear etch rate ∼ 0.1 μm/min, n-substrate with illumination; Ref. (Schimmel, D.G., 1976)

HNO₃:CH₃COOH:HF (3:2:2); Si wafer chemical polish prior to etch pit study; Ref. (Secco d’Aragona, F., 1972)

HF:HNO₃:CH₃COOH (1:1:1); masked pattern etch profiles on (0 0 1)GaAs; Ref. (Adachi, S., 1983)

GaSb

HNO₃:HF:CH₃COOH (6:2:1); GaSb polycrystalline material cleaning prior to Czochralski growth; Ref. (Stepanek, B., 1992)

HF:HNO₃:CH₃COOH (2:18:40); GaSb first step prior to defect delineation etch; Ref. (Doerschel, J., 1992)

CH₃COOH:HNO₃:HF (20:9:1); GaSb {1 1 1} first step etch pit defect delineation for 1 min, followed by Br₂/methanol (5%) for 11 min; Ref. (Stepanek, B., 1992)

CP-4 40% diluted in H₂O; GaSb etch pit delineation only on (1 1 1)A; Ref. (Costa, E.M., 1997)

CH₃COOH:HNO₃:HF (40:18:2); GaSb mesa etch; room temperature for 40 s; Ref. (Kodama, M., 1994)

CH₃COOH:HNO₃:HF (40:18:2), followed by HCl:HNO₃ (30:1) at 5°C for 10 s; GaSb mesa etch for oxygen-free, low p–n junction leakage; Ref. (Kodama, M., 1994)

HF:HNO₃:CH₃COOH:Br₂ {CP-4 etch}

HF:HNO₃:CH₃COOH:Br (15:25:15:0.3); InSb surface cleaning for AES studies; Ref. (Auret, F.D., 1982)

HNO₃:HF:CH₃COOH:Br₂ (75:15:15:0.06); InAs (0 0 1) orientation determination; Ref. (Faust, J.W., 1960)

HNO₃:HF:CH₃COOH:Br₂ (75:15:15:0.06); InSb {1 1 1}A and {1 1 1}B etch figures for determining orientation polarity; Ref. (Warekois, E.P., 1959)

HNO₃:HF:CH₃COOH:Br₂ (5:3:3:0.06); {CP-4 etch}; Si non-preferential etch; Ref. (Tijburg, R., 1976a)
HF:HNO₃:H₂O:K₃Fe(CN)₆

HF:HNO₃:H₂O (50:1:50) + 5 mg K(FeCN)₆; Application: InGaAs/InP cleaved cross-section later delineation; Ref. (Coleman, J.J., 1978)

HF:HNO₃:H₂O₄

HF:HNO₃:H₂O₄ (1:1:1); masked pattern etch profiles on (0 0 1)GaAs; Ref. (Adachi, S., 1983)

HF:HNO₃:H₂O:AgNO₃ (see AgNO₃:HF:HNO₃:H₂O {RC etch})

HF:HNO₃:lactic acid (see lactic acid:HNO₃:HF)

HF:H₂SO₄:H₂O₂ (see H₂SO₄:H₂O₂:HF)

HF:H₃PO₄

HF (4%) (in isopropanol:H₂O (1:5) as wetting agent); 5 s native oxide removal from InGaAs; Ref. (Duran, H.C., 1999)

HF:2-propanol; InGaAlAs/InP surface cleaning for MOCVD regrowth; Ref. (Kollakowski, St., 1998)

H₃PO₄:HF (1:1); electrolytes for photoelectrochemical defect etch pit delineation; Ref. (Faur, M., 1993)

HF:K₂Cr₂O₇ {Secco etch}

HF:K₂Cr₂O₇ (0.15 M) (2:1) {Secco etch}; Application: Si wafer defect delineation; Ref. (Kesan, V.P., 1991)

HF:K₂Cr₂O₇ (0.15 M) {Secco etch}; Si etch pit delineation, etch rate = 1.5 μm/min with ultrasonic agitation; Ref. (Schimmel, D.G., 1976)

HF:K₂Cr₂O₇ (0.15 M) (2:1) {Secco etch}; Study: Si dislocation etch pit delineation; etch rate = 1.5 μm/min; Ref. (Secco d’ Aragona, F., 1972)

HF:KF

KF (0.75N):HF (0.75N); Application: InGaAs/InP photochemical etch; n-substrate wafer is biased to deplete the surface; incident light generates holes which assist oxidation to promote etching; 175 μm in 4 h; etch depth stops at p-InGaAs; diameter continues to widen; Ref. (Forrest, S.R., 1982)

HF:KOH

HF (2 M):KOH (0.5 M) solution electrolyte; InP and InGaAsP holographic photoetch for diffraction gratings on a biased sample with a depletion region at its surface; Ref. (Lum, R.M., 1985)
HF:methanol

HF (5% in methanol); Ellipsometry measurements to assess cleanest and smoothest etched surfaces; Ref. (Aspnes, D.E., 1981)

HF:methanol (1:10); Application: InP native oxide removal; 2 min ultrasonic; Ref. (Hu, Y.Z., 1993)

HF:methanol (1:1); GaN surface cleaning; best removal of O and C; Ref. (Smith, L.L., 1996)

HF:KOH

HF (2 M):KOH (0.5 M); electrolyte for InP etching; Ref. (Chu, G.C., 1986)

HF: tartaric acid:HNO₃ (see tartaric acid:HNO₃:HF)

HgCl₂:dimethylformamide

HgCl₂ (100 g):dimethylformamide (500 ml); In droplet removal from LPE InP surfaces; use ultrasonic agitation to free Hg reaction by-product from surface; Ref. (Astles, M.G., 1973)

HgCl₂ (100 g):dimethylformamide (500 ml); In droplet removal from LPE InP, InGaAs, InGaAsP surfaces; use ultrasonic agitation to free Hg reaction by-product from surface. (saturated HgCl₂:DMF):NaOH (10:1) gives maximum In removal; Ref. (Walker, D.M., 1980)

HNO₃

InP

HNO₃: InP surface oxidation; surface treatment scanning photoluminescence study; Ref. (Krawczyk, S.K., 1986)

HNO₃: XPS study of InP surface oxides following chemical treatment; Ref. (Hollinger, G., 1985)

HNO₃; oxidizes but does not etch InP; Ref. (Yeats, R.E., 1977)

HNO₃; InGaAsP selective etch from InP; Ref. (Olsen, G.H., 1979)

HNO₃ reacts little with arsenides but has no effect on InP; Ref. (Phatak, S.B., 1979)

HNO₃; 50 Å anodic oxide growth on InP; Ref. (Eftekhari, G., 1993)

HNO₃; InP oxidation; 200 Å under illumination; Ref. (Robach, Y., 1992)

HNO₃; photoelectrochemical etching of p-InP; dependence on carrier concentrations and etch pit densities; study of photoetch mechanism; Ref. (Quinlan, K.P., 1997)
HNO₃:H₂O; study of photoelectrochemical etching of p-InP; dependence on light intensity, HNO₃ concentration, and potential; Ref. (Quinlan, K.P., 1996)

HNO₃:H₂O (1:10–100); GaAs and AlGaAs non-selective etch under illumination
HNO₃:H₂O (1:200); GaAs selective etch from AlGaAs under illumination
HNO₃:H₂O (1:300–1000); weak etching for both GaAs and AlGaAs with trench at boundary between illuminated and dark regions; Ref. (Fink, Th., 1993a)

HNO₃:H₂O (1:20); GaAs n-type photoelectrochemical etch; no measurable etch without illumination; similar etch rates for AlGaAs; applied bias shows a current minimum as a GaAs/AlGaAs interface is crossed during etching; surface roughness limits assessment of MQW; Ref. (Fink, Th., 1993b)

HNO₃ (12 M); HNO₃ (12 M):sulfamic acid (0.1 M); p-InP etch mechanism study; Ref. (Quinlan, K.P., 1999)

GaP

HNO₃; GaP oxidation/etching under illumination; chemical kinetics; Ref. (Hsieh, H.F., 1992)

GaAs

HNO₃:H₂O (1:20); GaAs n-type etch rate = 12 μm/min, Si-type etch rate = 10 μm/min, p-type etch rate = 1.0 μm/min; Ref. (Podlesnik, D.V., 1984)

HNO₃ (65%); GaAs oxidation under illumination; Ref. (Michel, C., 1982)

HNO₃:H₂O (1:20); Photoetching of deep features in GaAs; role of optical waveguiding; Ref. (Podlesnik, D.V., 1986)

HNO₃:H₂O (1:20); GaAs and AlGaAs photoetch with AlAs stop layer; hole confinement to the GaAs buried layer results in its lateral etching; Ref. (Ruberto, M.N., 1989)

HNO₃:H₂O (1:20); GaAs photoetching p–n junction delineation; dopant selective: n-etching under illumination; p does not etch; no GaAs dark etching; Ref. (Ruberto, M.N., 1991)

HNO₃ (10% solution); GaAs Cr-doped semi-insulating laser-induced etch; Ref. (Tisone, G.C., 1983)

HNO₃:AgNO₃:HF:H₂O (see AgNO₃:HF:HNO₃:H₂O [RC etch])

HNO₃:Br₂:HCl (see HCl:HNO₃:Br₂)

HNO₃:CH₃COOH

HNO₃:CH₃COOH (1:1); masked pattern etch profiles on (0 0 1)GaAs; Ref. (Adachi, S., 1983)
HNO₃:CH₃COOH:HCl (see HCl:HNO₃:CH₃COOH)
HNO₃:CH₃COOH:HClO₄:HCl (see HCl:HNO₃:CH₃COOH:HClO₄)
HNO₃:CH₃COOH:HF (see HF:HNO₃:CH₃COOH)
HNO₃:CH₃COOH:H₂O₂
HNO₃:CH₃COOH:H₂O₂ (1:1:1); masked pattern etch profiles on (0 0 1)GaAs; Ref. (Adachi, S., 1983)
HNO₃:HBr (see HBr:HNO₃)
HNO₃:HCl (see HCl:HNO₃)
HNO₃:HCl:CH₃COOH (see HCl:HNO₃:CH₃COOH)
HNO₃:HCl:CH₃COOH:HClO₄ (see HCl:HNO₃:CH₃COOH:HClO₄)
HNO₃:HCl:HF (see HCl:HNO₃:HF)
HNO₃:HCl:H₂O₂ (see HCl:HNO₃:H₂O₂)
HNO₃:HCl:H₃PO₄:H₂SO₄ (see HCl:HNO₃:H₃PO₄:H₂SO₄)
HNO₃:HCl:H₂SO₄:H₂O (see HCl:HNO₃:H₂SO₄:H₂O)
HNO₃:HCl:isopropanol (see HCl:HNO₃:isopropanol)
HNO₃:HF (see HF:HNO₃)
HNO₃:HF:CH₃COOH (see HF:HNO₃:CH₃COOH)
HNO₃:HF:CH₃COOH:Br₂ (see HF:HNO₃:CH₃COOH:Br₂)
HNO₃:HF:HCl (see HCl:HNO₃:HF)
HNO₃:HF:lactic acid (see lactic acid:HNO₃:HF)
HNO₃:HF:H₂O:K₃Fe(CN)₆ (see HF:HNO₃:H₂O:K₃Fe(CN)₆)
HNO₃:HF:H₂O₂ (see HF:HNO₃:H₂O₂)
HNO₃:HF:H₃PO₄ (see HF:H₃PO₄:HNO₃)
HNO₃:H₂O₂
HNO₃:H₂O₂ (1:1); InP {1 1 0} defect delineation etch at 100°C; etch rate ~ 2.5 μm/min; Ref. (Srnanek, R., 1993)

HNO₃:H₂O₂ (1:1); masked pattern etch profiles on (0 0 1)GaAs; Ref. (Adachi, S., 1983)

HNO₃:H₂O₂ (1:1); attacks photoresists; Ref. (Otsubo, M., 1976)

HNO₃:H₂O₂ (1:5); InAs cleaning; 1–2 min at 75°C; Ref. (Sharma, B.L., 1966)

HNO₃:H₂O₂:tartaric acid (see tartaric acid:HNO₃:H₂O₂)

HNO₃:H₃PO₄:H₂O (see H₃PO₄:HNO₃:H₂O)

HNO₃:lactic acid (see lactic acid:HNO₃)

HNO₃:tartaric acid (see tartaric acid:HNO₃)

H₂O

H₂O (deoxygenated, deionized); GaAs treatment for oxide-free surface; Ref. (Hirota, Y., 1995)

H₂O; GaAs (0 0 1) surfaces treated with ultrasonic running deionized water show complete removal of arsenic and gallium oxides following etch in H₂SO₄ or NH₄OH; Ref. (Hirota, Y., 1992)

H₂O; dissolution of oxides from GaAs; Ref. (Hirota, Y., 1991)

H₂O; photochemical reaction on GaAs to unpin the Fermi level; Ref. (Ives, N.A., 1987)

H₂O; GaAs photowash surface passivation; reduces surface state density; Ref. (Shen, H., 1990)

H₂O₂

H₂O₂ (30%); oxidation of GaAs followed by Ref. (DeSalvo, G.C., 1996)

H₂O₂:H₂O (1:1); 2 min oxidation of GaAs surface features, followed by HCl:H₂O (1:1) 2 min etch removal of oxide; Ref. (Moran, P.D., 1999)

H₂O₂; InP surface oxidation; surface treatment scanning photoluminescence study; Ref. (Krawczyk, S.K., 1986)

H₂O₂ electrolyte for Anodization; Application: GaAs anodize strip thinning of layers for FETs; Ref. (Rode, D.L., 1974)

H₂O₂:Br₂:HBr (see Br₂:HBr:H₂O₂)

H₂O₂:adipic acid:NH₄ON (see adipic acid:NH₄ON:H₂O₂)
H₂O₂:Bi(NO₃)₃:HCl (see Bi(NO₃)₃:HCl:H₂O₂)

H₂O₂:citric acid (see citric acid:H₂O₂)

H₂O₂:citric acid:ethyleneglycol (see citric acid:H₂O₂:ethyleneglycol)

H₂O₂:CH₃COOH:HCl (see HCl:CH₃COOH:H₂O₂ {KKI etch})

H₂O₂:CH₃COOH:HF (see HF:CH₃COOH:H₂O₂)

H₂O₂:CH₃COOH:H₃PO₄ (see H₃PO₄:CH₃COOH:H₂O₂)

H₂O₂:HBr (see HBr:H₂O₂)

H₂O₂:HBr:H₂O:HCl (see HBr:H₂O₂:H₂O:HCl)

H₂O₂:HCl:H₂O (see HCl:H₂O₂:H₂O)

H₂O₂:HCl:CH₃COOH (see HCl:CH₃COOH:H₂O₂ {KKI etch})

H₂O₂:HCl:K₂Cr₂O₇ (see HCl:H₂O₂:K₂Cr₂O₇)

H₂O₂:HCl:HF:H₂O (see HCl:HF:H₂O:H₂O₂ {NRL etch})

H₂O₂:HCl:HNO₃ (see HCl:HNO₃:H₂O₂)

H₂O₂:HCl:H₃PO₄ (see HCl:H₃PO₄:H₂O₂)

H₂O₂:HF:CH₃COOH (see HF:CH₃COOH:H₂O₂)

H₂O₂:HF:H₂O (see HF:H₂O₂:H₂O)

H₂O₂:HF:H₂O:butylthiobutane (see HF:H₂O₂:H₂O:butylthiobutane)

H₂O₂:HF:H₂SO₄ (see H₂SO₄:HF:H₂O₂)

H₂O₂:HNO₃ (see HNO₃:H₂O₂)

H₂O₂:HNO₃:H₃PO₄ (see HNO₃:H₃PO₄:H₂O₂)

H₂O₂:H₂O:H₂SO₄ (see H₂SO₄:H₂O₂:H₂O)

H₂O₂:H₂O:HCl:HBr (see HBr:H₂O₂:H₂O:HCl)

H₂O₂:H₃PO₄ (see H₃PO₄:H₂O₂)

H₂O₂:H₃PO₄:HCl (see HCl:H₃PO₄:H₂O₂)
H$_2$O$_2$:H$_3$PO$_4$:methanol (see H$_3$PO$_4$:H$_2$O$_2$:methanol)

H$_2$O$_2$:H$_2$SO$_4$:H$_2$O (see H$_2$SO$_4$:H$_2$O$_2$:H$_2$O \{Caro’s etch\})

H$_2$O$_2$:H$_2$SO$_4$:HF (see H$_2$SO$_4$:H$_2$O$_2$:HF)

H$_2$O$_2$:methanol:H$_3$PO$_4$ (see H$_3$PO$_4$:H$_2$O$_2$:methanol)

H$_2$O$_2$:NaOH (see NaOH:H$_2$O$_2$)

H$_2$O$_2$:NaOH:NH$_4$OH (see NaOH:H$_2$O$_2$:NH$_4$OH)

H$_2$O$_2$:NH$_4$OH (see NH$_4$OH: H$_2$O$_2$)

H$_2$O$_2$:NH$_4$OH:adipic acid (see adipic acid:NH$_4$OH:H$_2$O$_2$)

H$_2$O$_2$:oxalic acid (see oxalic acid:H$_2$O$_2$)

H$_2$O$_2$:succinic acid (see succinic acid:H$_2$O$_2$)

H$_3$PO$_4$

InP

H$_3$PO$_4$ (85%); InP (1 0 0) etch rate at 90°C = 0.15 µm/min; Ref. (Becker, R., 1973)

H$_3$PO$_4$; etch for (1 0 0): InP, GaInP, GaP, GaAsP; Ref. (Gottschalch, V., 1979b)

H$_3$PO$_4$ (10%); InP etch rate = 0.27 µm/min with no mask undercutting; Ref. (Schmitt, F., 1983)

H$_3$PO$_4$;H$_2$O (1:9); n-InP photochemical etching study using 488 nm Ar + laser; photoetch rate for via holes is 300 times greater for 0.002% duty cycle than for 100%; photoetch rate is controlled by local saturation; Ref. (Lowes, T.D., 1993b)

H$_3$PO$_4$;H$_2$O (1:9); n-InP photoetch study; etch rates are enhanced two to five times by added Cu metal ions; Ref. (Lowes, T.D., 1993a)

GaAs

H$_3$PO$_4$ does not attack GaAs; Ref. (Phatak, S.B., 1979)

H$_3$PO$_4$;H$_2$O; acidic electrolyte for GaAs anodization; Ref. (Schwartz, B., 1976a)

H$_3$PO$_4$; Al$_2$O$_3$ mask removal etch; 4 min at 50°C; Ref. (Tarui, Y., 1971)

H$_3$PO$_4$;H$_2$O, pH = 2.6–3.0, Anodization electrolyte; GaAs thinning; Ref. (Niehaus, W.C., 1976)
H₃PO₄:H₂O (1:4) and (1:10); oxide removal agent from GaAs; Ref. (DeSalvo, G.C., 1996)

H₃PO₄:H₂O (1:4); GaAs oxide removal prior to etching and InGaAs oxide removal following the above etch; Ref. (Hill, D.G., 1990)

H₃PO₄; AlGaAs native oxide removal at 60°C; Ref. (Watanabe, H., 1993a)

InAs/GaSb

H₃PO₄ non-selective etch for InAs/GaSb/AlGaSb; Ref. (Yoh, K., 1991)

GaP

H₃PO₄ (85%); GaP (1 1 1)B etch rate at 180°C = 15 µm/min; gives etch rate dependence on temperature, time, and orientation; gives cross-sectional profiles; Ref. (Uragaki, T., 1976)

GaN/AlN

H₃PO₄ (85%); GaN etchant at T = 100–200°C; gives etch rate and morphology dependence on temperature; Ref. (Morimoto, Y., 1974)

H₃PO₄ (85%); GaN epilayer etch at 190°C for etch figure growth assessment; Ref. (Shintani, A., 1976)

H₃PO₄ (85%); AlN dissolution; Ref. (Pauleau, Y., 1982)

H₃PO₄ (85%); AlN etch rate at 60°C is dependent on layer quality; Ref. (Sheng, T.Y., 1988)

H₃PO₄ (14.61 M); study of etching Al₂O₃ dielectric films; etch rate dependence on temperature and concentration; Ref. (Zhou, B., 1996)

H₃PO₄; transverse (i.e. sidewall) etch for GaN; no etch in the (0 0 0 1) direction; Ref. (Stocker, D.A. 2000)

H₃PO₄:Br₂:H₂O (see Br₂:H₃PO₄:H₂O)

H₃PO₄:CH₃COOH:HCl (see HCl:H₃PO₄:CH₃COOH)

H₃PO₄:CH₃COOH:H₂O₂

H₃PO₄:CH₃COOH:H₂O₂ (1:1:1); masked pattern etch profiles on (0 0 1)GaAs; Ref. (Adachi, S., 1983)

Displaced H₃PO₄:C₂H₅OH:H₂O₂ (1:1:1); masked pattern etch profiles on (0 0 1)GaAs; Ref. (Adachi, S., 1983)
H₃PO₄:HBF₄:H₂O

H₃PO₄:HBF₄:H₂O (2:1:10); Al contact removal from GaAs; Ref. (Christou, A., 1976)

H₃PO₄:HBr (see HBr:H₃PO₄ {Huber etch})

H₃PO₄:HBr:HCl (see HCl:H₃PO₄:HBr)

H₃PO₄:HBr:K₂Cr₂O₇ (see HBr:H₃PO₄:K₂Cr₂O₇)

H₃PO₄:HCl (see HCl:H₃PO₄)

H₃PO₄:HCl:CH₃COOH (see HCl:H₃PO₄:CH₃COOH)

H₃PO₄:HCl:HNO₃ (see HCl:HNO₃:H₃PO₄)

H₃PO₄:HCl:HNO₃:H₂SO₄ (see HCl:HNO₃:H₃PO₄:H₂SO₄)

H₃PO₄:HF (see HF:H₃PO₄)

H₃PO₄:HF:HCl (see HCl:H₃PO₄:HF)

H₃PO₄:HF:HNO₃ (see HF:HNO₃:H₃PO₄)

H₃PO₄:HNO₃:HCl (see HCl:HNO₃:H₃PO₄)

H₃PO₄:HNO₃:H₂O₂ (see HNO₃:H₃PO₄:H₂O₂)

H₃PO₄:HNO₃:H₂O

o-H₃PO₄:HNO₃:H₂O (5:30:1); Application: chemical growth of native oxide on InP for use as solar cell surface coating; Ref. (Faur, M., 1994a)

o-H₃PO₄:HNO₃:H₂O₂:H₂O; InP thinning etch; with concentration dependent etch rates from 5 to 110 nm/min; Ref. (Faur, M., 1991b)

HNO₃:H₃PO₄ (1:1); masked pattern etch profiles on (0 0 1)GaAs; Ref. (Adachi, S., 1983)

HNO₃:H₃PO₄:H₂O₂

HNO₃:H₃PO₄:H₂O₂ (1:1:1); masked pattern etch profiles on (0 0 1)GaAs; Ref. (Adachi, S., 1983)

H₃PO₄:H₂O₂

InP

H₃PO₄:H₂O₂ (1:1); lattice defect delineation with preferential photoetching; Ref. (Gottschalch, V., 1982)
InGaAs

H₃PO₄:H₂O₂ (1:1); lattice defect delineation with preferential photoetching; Ref. (Gottschalch, V., 1982)

H₃PO₄:H₂O₂ (5:1); Application: InGaAs selective etch from InP; pattern for OMVPE overgrowth; Ref. (Kim, J.S., 1992)

H₃PO₄:H₂O₂:H₂O (1:1:8); Application: InGaAs notch etch for FET; etch rate = 0.47 μm/min; Ref. (Gammel, J.C., 1981); (Ohno, H., 1982)

H₃PO₄:H₂O₂:H₂O (3:1:50); InGaAs thinning, etch rate = 10 Å/s at 20°C; for differential Hall measurements; Ref. (Kamada, M., 1989); (Mori, Y., 1988)

H₃PO₄:H₂O₂:H₂O (38:1:1)? (or (1:1:38))?; Application: InGaAs FET gate channel etch; Ref. (Liao, A.S.H., 1982)

H₃PO₄:H₂O₂:H₂O (1:38); Application: InGaAs FET channel recess; Ref. (Cheng, C.L., 1984)

H₃PO₄:H₂O₂:H₂O (1:1:38); Application: InGaAs and InAlAs etch rate = 1000 Å/min at 21.5°C; does not attack InP; Ref. (Ohno, H., 1982)

H₃PO₄:H₂O₂:H₂O (1:1:38); Application: InP mesa fabrication; Ref. (Bélier, B., 2000)

H₃PO₄:H₂O₂:H₂O (1:1:8); Selective etch of InGaAs mask patterns on InP; at 25°C in light, 120 nm InGaAs etches through in ~25 s

H₃PO₄:H₂O₂:H₂O (1:1:32); Selective etch of InGaAs mask patterns on InP; at 25°C in light, 120 nm InGaAs etches through in ~60 s; Ref. (Eliás, P., 1999)

H₃PO₄:H₂O₂:H₂O (1:1:38); Application: InGaAs slow thinning etch; Ref. (Silberg, E., 1982)

H₃PO₄:H₂O₂ (2:1); InGaAs etch rate = 3.3 μm/min; InAlAs etch rate = 3 μm/min
H₃PO₄:H₂O₂ (5:1); InGaAs etch rate = 2.4 μm/min; InAlAs etch rate = 1.5 μm/min
H₃PO₄:H₂O₂ (10:1); InGaAs etch rate = 0.7 μm/min; InAlAs etch rate = 0.5 μm/min
H₃PO₄:H₂O₂:H₂O (1:8:1); InGaAs etch rate = 1.6 μm/min; InAlAs etch rate = 1.5 μm/min
H₃PO₄:H₂O₂:H₂O (1:8:40); InGaAs etch rate = 0.4 μm/min; InAlAs etch rate = 0.6 μm/min
H₃PO₄:H₂O₂:H₂O (1:8:60); InGaAs etch rate = 0.2 μm/min; InAlAs etch rate = 0.16 μm/min

Gives InGaAs (1 0 0) etch rate dependence on orientation; shows etch profiles: For InGaAs only Br₂/methanol forms positive angle sidewalls on both (1 1 0) directions, giving good morphology and mesa shapes; same for InAlAs except also H₃PO₄:H₂O₂ (10:1) does not exhibit sidewall crystal habits; Ref. (Stano, A., 1987)

H₃PO₄:H₂O₂:H₂O (1:1:8); InGaAs selective etch from InAlAs; Ref. (Adesida, I., 1993a)

H₃PO₄:H₂O₂:H₂O (1:1:20); Application: InGaAs selective etch from InP for MISFET gate recess; Ref. (Schubert, E.F., 1988)
H₃PO₄:H₂O₂:H₂O (1:1:40); Application: InGaAs selective etch from InP for HEMT gate recess at 20°C; Ref. (Küsters, A.M., 1993)

H₃PO₄:H₂O₂:H₂O (1:1:20); Application: InAlAs/InGaAs/InP mesa etch; Ref. (Tsai, H.H., 1994)

H₃PO₄:H₂O₂:H₂O (1:1:150); gate recess etch in InGaAs/InAlAs/InP HEMTs; Ref. (Duran, H.C., 1999); (Cheung, R., 1996)

H₃PO₄:H₂O₂:H₂O (1:1:8); Application: removal of REI residual InGaAs at bottom corner recesses; Ref. (Ojha, S.M., 1994)

**GaAs**

Photochemical dislocation etch pit delineation and cleaved cross-section layer delineation:
- H₃PO₄:H₂O₂ (10:1); GaAs (1 0 0) 3 min under illumination
- H₃PO₄:H₂O₂ (10:1); Ga₀.₉₈In₀.₀₂As (1 0 0) 3 min under illumination
- H₃PO₄:H₂O₂ (10:1); AlGaAs (1 0 0) 3 min under illumination; Ref. (Gottschalch, V., 1979)

H₃PO₄:H₂O₂ (10:1); and H₃PO₄:H₂O₂:H₂O (10:1:1); Surface cleaning effects on GaAs light emission from Schottky contacts; assessment of etching on electronic surface behavior; Ref. (Adachi, H., 1981a)

H₃PO₄:H₂O₂:H₂O (3:4:1); GaAs; uniform, high, isotropic etch rate for etching via holes; Ref. (Yenigalla, S.P., 1982)

H₃PO₄:H₂O₂:H₂O (3:1:50); Application: GaAs MESFET mesas; Ref. (Hashemi, M.M., 1992)

H₃PO₄:H₂O₂:H₂O (3:1:50); GaAs etch rate $\leq 0.18 \mu m/min$ at 24°C
- H₃PO₄:H₂O₂:H₂O (1:9:210); GaAs etch rate $= 0.2 \mu m/min$ at 24°C
- H₃PO₄:H₂O₂:H₂O (7:3:3); GaAs etch rate $= 2 \mu m/min$ at 24°C
- H₃PO₄:H₂O₂:H₂O (1:9:1); GaAs etch rate $= 3 \mu m/min$ at 24°C.

No dependence on GaAs doping is seen; shows etch rate dependence on concentration, temperature and GaAs orientation; Ref. (Mori, Y., 1978)

H₃PO₄:H₂O₂:H₂O (1:1:100); Application: GaAs slow recess etch; showing etch profiles with little anisotropy; Ref. (Demeester, P., 1988)

H₃PO₄:H₂O₂:H₂O (1:1:100), 18 < x < 50; GaAs etch rate study shows proportional dependence on H₂O₂ concentration; low etch rates are surface reaction limited and show flat bottomed profiles; high etch rates are H₂O₂-diffusion limited and show enhanced etching at mask edges; Ref. (Kohn, E., 1980)

H₃PO₄:H₂O₂:H₂O; Review with GaAs etching summary; Ref. (Mukherjee, S.D., 1985)

H₃PO₄:H₂O₂:H₂O; Application: GaAs patterned substrate cleaning prior to OMVPE regrowth; attacks both GaAs and oxides; Ref. (York, P.K., 1992)
H$_3$PO$_4$:H$_2$O$_2$:H$_2$O (1:9:3); GaAs (1 0 0) groove etch, reverse-mesa shaped groove along (0 1 1); Ref. (Westphalen, R., 1992)

H$_3$PO$_4$:H$_2$O$_2$:H$_2$O (4:1:90); GaAs selective etch from AlGaAs; Ref. (Watanabe, H., 1993b)

H$_3$PO$_4$:H$_2$O$_2$:H$_2$O (4:1:90); Application: n-GaAs selective etch from Al$_{0.4}$Ga$_{0.6}$As at 25°C; Ref. (Watanabe, H., 1993a)

H$_3$PO$_4$:H$_2$O$_2$:H$_2$O (1:1:1); GaAs and AlGaAs mesa etch; Ref. (Pearton, S.J., 1993d,e, 1994c)

H$_3$PO$_4$:H$_2$O$_2$:H$_2$O (1:1:25); Application: GaAs mesa etch; Ref. (Li, F., 1993)

H$_3$PO$_4$:H$_2$O$_2$:H$_2$O (1:1:1); masked pattern etch profiles on (0 0 1)GaAs; Ref. (Adachi, S., 1983)

H$_3$PO$_4$:H$_2$O$_2$:H$_2$O (1:1:10); Application: non-selective etch of AlGaAs/GaAs and InAlGaAs/InAlAs; Ref. (Cho. H.K., 1999)

H$_3$PO$_4$:H$_2$O$_2$:H$_2$O (2:1:10); anisotropic etch of GaAs substrate supporting cantalever stripes; Ref. (Arslan, D., 1999)

H$_3$PO$_4$:H$_2$O$_2$:H$_2$O (1:1:10); selective etch of GaAs from InGaP; Ref. (Hegde, S.M., 1994); (Brown, G.J., 1994)

H$_3$PO$_4$:H$_2$O$_2$:H$_2$O (3:1:50); sharpening of dry etched field emitter tips; Ref. (Ducroquet, F., 1999)

H$_3$PO$_4$:H$_2$O$_2$:H$_2$O (3:1:50); Application: selective etch of GaAs from InGaP; Ref. (Kobayashi, T., 1989)

H$_3$PO$_4$:H$_2$O$_2$:H$_2$O (4:1:180); non-selective etch for GaAs/AlGaAs; Ref. (Moon, E.-A., 1998)

H$_3$PO$_4$:H$_2$O$_2$:H$_2$O (1:13.8:13.2) at 0°C; Application: anisotropic GaAs etch for forming micromachined triangular cross-section structures; depth etch rate is 1 μm/min; undercutting etch rate is 0.25 μm/min; etch becomes isotropic with increasing temperature; Ref. (Ribas, R.P., 1998)

H$_3$PO$_4$:H$_2$O$_2$:H$_2$O (7:3:3)

Chemical beveling of GaAs by lifting a sample through a constant flow of etchant; Ref. (Srnanek, R., 1997b)

H$_3$PO$_4$:H$_2$O$_2$:H$_2$O (10:1:1); shaping of GaAs microtips for scanning tunneling microscopy; shape dependence on H$_3$PO$_4$ concentration and etch temperature; Ref. (Yamaguchi, K., 1996)

Anodization; GaAs using H$_2$O$_2$ electrolyte with pH adjusted by H$_3$PO$_4$ or NH$_4$OH; Ref. (Logan, R.A., 1973b)
H₃PO₄: H₂O₂: H₂O (3:1:40); GaAs etch rate = 100 nm/min; isotropic etch; Ref. (Papadopoulo, A.C., 1990)

H₃PO₄: H₂O₂: H₂O; Application: first step stairstep groove etchant for AlAs/GaAs multilayer structures for quantum wire MOCVD growth; Ref. (Kicin, S., 1999)

**GaP**

Photochemical dislocation etch pit delineation and cleaved cross-section layer delineation:
- H₃PO₄: H₂O₂ (1:1); GaP (1 0 0), 15 min under illumination
- H₃PO₄: H₂O₂ (1:1); GaAs₀₂P₀₈ (1 0 0) 10 min under illumination
- H₃PO₄: H₂O₂ (10:1); GaAs₀₈P₀₄ (1 0 0) 15 min under illumination; Ref. (Gottschalch, V., 1979)

H₃PO₄: H₂O₂: HCl (see HCl: H₃PO₄: H₂O₂)

H₃PO₄: H₂O₂: methanol

CH₃OH: H₃PO₄: H₂O₂ (3:1:1); Application: GaAs mesa etch; Ref. (Merz, J.L., 1976)

H₃PO₄: H₂O₂: CH₃OH (2:1:1); Application: AlGaAs/GaAs mesa etch; near identical etch rates for GaAs and Al₧Ga₁₋ₓAs for x < 0.33; Ref. (Peng, L.-M., 1992)

H₃PO₄: H₂O₂: CH₃OH (28:16:84); non-selective GaAs and AlGaAs; Ref. (Fricke, K., 1994)

H₃PO₄: CH₃OH: H₂O₂ (1:1:1); masked pattern etch profiles on (0 0 1)GaAs; Ref. (Adachi, S., 1983)

H₃PO₄: H₂SO₄

H₃PO₄: H₂SO₄ (1:3); hot solution to clean sapphire substrates for MOVPE growth of GaN; Ref. (Amano, H., 1989)

H₃PO₄: H₂SO₄ (1:3); Surface cleaning (hot) of Al₂O₃ (0 0 0 1) substrates for GaN growth by MOVPE; Ref. (Asaki, I., 1989)

H₂SO₄: H₃PO₄ (3:1); sapphire substrate cleaning: 140°C for 10 min; Ref. (Kim, J.-H., 1999)

H₃PO₄: H₂SO₄ (1:4); GaN defect delineation etch; 230°C for 10 min; Ref. (Ono, Y., 1998)

H₂SO₄: H₃PO₄ (3:1); surface preparation of Al₂O₃ (0 0 0 1) substrates at 160°C for GaN growth by MBE; Ref. (Xiao, H.Z., 1994)

H₂SO₄: H₃PO₄: H₂O (1:1:1); masked pattern etch profiles on (0 0 1)GaAs; Ref. (Adachi, S., 1983)

H₃PO₄: H₂SO₄ (1:3); hot solution to clean sapphire substrates for MOVPE growth of GaN; Ref. (Akasaki, I., 1989)

H₃PO₄: K₂Cr₂O₇: HBr (see HBr: H₃PO₄: K₂Cr₂O₇)
H$_2$PO$_4$:K$_2$Cr$_2$O$_7$:H$_2$O

K$_2$Cr$_2$O$_7$:H$_3$PO$_4$:H$_2$O; Application: AlGaAs selective etch from GaAs; Ref. (Ren, F., 1994)

$\alpha$-H$_3$PO$_4$:NH$_3$F$_2$ (UNIEL) (see NH$_3$F$_2$: $\alpha$-H$_3$PO$_4$)

H$_2$SO$_4$

InP

H$_2$SO$_4$:H$_2$O (1:5); InP surface cleaning for photoresist ash removal following O$_2$ plasma prior to InP regrowth; Ref. (Kim, J.S., 1992)

H$_2$SO$_4$ (10%); InP etch rate $\sim$ 8 $\mu$m/min; undercutting of oxide mask; Ref. (Schmitt, F., 1983)

H$_2$SO$_4$; GaAs and InP XPS surface study giving binding energies and Ga/As and In/P surface compositions after etching; Ref. (Bertrand, P.A., 1981)

H$_2$SO$_4$ (2 M); Photoelectrochemical etch electrolyte; III–V semiconductor mask patterning by focused Ga ion beam damage; using photoelectrochemical etching of non-damaged areas on n-type GaAs, InP, InGaAs, InGaAsP; Ref. (Cummings, K.D., 1986)

H$_2$SO$_4$ (2 M); electrolyte for InGaAsP and InP; Ref. (Chi, G.C., 1986)

H$_2$SO$_4$ (0.25 M); oxide-free InP interface for STM surface imaging; Ref. (Robach, Y., 1992)

H$_2$SO$_4$:H$_2$O; H$_2$SO$_4$:H$_2$O$_2$:H$_2$O; identification of composition and crystalline phases of surface oxides on etched InP using X-ray diffraction; H$_2$O$_2$ plays no significant role in etch of InP; Ref. (Liu, H.C., 1999)

H$_2$SO$_4$; treatment of InP to remove RIE etch polymer by-products; Ref. (Yamamoto, N., 1998)

H$_2$SO$_4$:H$_2$O etched InP; study of surface oxides by glancing angle X-ray diffraction

H$_2$SO$_4$; 1 min cleaning step for InP/InGaAlAs/InGaAs heterostructure detectors prior to sulfide passivation in preparation for MOCVD regrowth step; Ref. (Kollakowski, St., 1998)

H$_2$SO$_4$; 1 min cleaning step for InP/InGaAlAs/InGaAs heterostructure detectors prior to sulfide passivation in preparation for MOCVD regrowth step; Ref. (Lemm, Ch., 1997)

H$_2$SO$_4$ (1.3 mol/l); (photo)electrochemical and etching properties of n- and p-In$_{0.53}$Ga$_{0.47}$As; Ref. (Theuwis, A., 1997)

GaAs

H$_2$SO$_4$:H$_2$O (1:8); GaAs deoxidation for 1 min; Ref. (Hue, X., 1998)
H₂SO₄:H₂O (1:80); GaAs surface cleaning for MOCVD regrowth; Ref. (Jones, A.M., 1998)

H₂SO₄ (10%); oxide removal from GaAs; Ref. (Kagadei, V.A., 1999)

H₂SO₄:H₂O₂:H₂O (8:1:40); Application: mesa etch for {1 1 1}A sidewalls on GaAs [1 –1 0] stripe patterns; Ref. (Konkar, A., 1998)

InAs

H₂SO₄ (0.2 M); electrolyte for photo-selective etch of n-InAs; Ref. (Harris, D., 1994)

H₂SO₄ electrolyte for photoelectrochemical etch of InAs; optimum light-versus dark-etch selectivity with 0.2 M H₂SO₄

GaP

Electrochemical dissolution study of GaP in electrolytes of NaOH, K₃Fe(CN)₆, H₂SO₄; Ref. (Memming, R., 1968)

AlGaInP

Compositional selectivity: (x in (AlₓGa₁₋ₓ)₀.₅In₀.₅P undoped)

<table>
<thead>
<tr>
<th>Etch rates (Å/s)</th>
<th>x = 0</th>
<th>x = 0.4</th>
<th>x = 0.7</th>
<th>x = 1</th>
</tr>
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<tbody>
<tr>
<td>H₂SO₄ (60°C)</td>
<td>2.5</td>
<td>29</td>
<td>97</td>
<td>217</td>
</tr>
<tr>
<td>H₂SO₄ (70°C)</td>
<td>6.3</td>
<td>53</td>
<td>171</td>
<td>373</td>
</tr>
<tr>
<td>HCl:H₂O (1:1) (25°C)</td>
<td>2.9</td>
<td>102</td>
<td>383</td>
<td>478</td>
</tr>
</tbody>
</table>

(AlGa)₀.₅In₀.₅P dopant selectivity

<table>
<thead>
<tr>
<th>Etch rates (Å/s)</th>
<th>n = 1 × 10¹⁸</th>
<th>Undoped</th>
<th>p = 5 × 10¹⁷</th>
</tr>
</thead>
<tbody>
<tr>
<td>H₂SO₄ (60°C)</td>
<td>148</td>
<td>97</td>
<td>7.0</td>
</tr>
<tr>
<td>H₂SO₄ (70°C)</td>
<td>181</td>
<td>171</td>
<td>163</td>
</tr>
<tr>
<td>HCl:H₂O (1:1) (25°C)</td>
<td>483</td>
<td>383</td>
<td>0.6</td>
</tr>
</tbody>
</table>

Ref. (Stewart, T.R., 1992)

H₂SO₄:Ce²⁺ (see Ce²⁺:H₂SO₄)

H₂SO₄:CH₃COOH:H₂O

H₂SO₄:CH₃COOH:H₂O (1:1:1); masked pattern etch profiles on (0 0 1)GaAs; Ref. (Adachi, S., 1983)
H$_2$SO$_4$:HCl:HNO$_3$:H$_2$O (see HCl:HNO$_3$:H$_2$SO$_4$:H$_2$O)

H$_2$SO$_4$:HCl:K$_2$Cr$_2$O$_7$ (see HCl:H$_2$SO$_4$:K$_2$Cr$_2$O$_7$)

H$_2$SO$_4$:H$_2$O$_2$:H$_2$O {Caro’s etch}

InP

H$_2$SO$_4$:H$_2$O$_2$ (5:1); InP substrate cleaning; removal of surface contaminants and oxides prior to RIE. Reactive ion etching; Cl$_2$; InP; Ref. (van Roejen, R., 1991)

H$_2$SO$_4$:H$_2$O$_2$:H$_2$O (1:1:1); InP second step free etch of 30 $\mu$m for elongated etch pit delineation for (1 0 0) orientation determination; 5 min at 85°C; Ref. (Caridi, E.A., 1984)

H$_2$SO$_4$:H$_2$O$_2$:H$_2$O (1:1:1); Application: InP etch at 50°C using SiO$_2$ pattern mask; Ref. (Osaka, F., 1980)

H$_2$SO$_4$:H$_2$O$_2$:H$_2$O (1:1:1); gives groove etch profiles; Ref. (Adachi, S., 1981e)

H$_2$SO$_4$:H$_2$O$_2$:H$_2$O (2:1:1); InP etch rate = 500 Å/min at 20°C; surface study; Ref. (Massies, J., 1986)

H$_2$SO$_4$:H$_2$O$_2$:H$_2$O (2:1:1); etch procedures to obtain the best morphologies; Ref. (Saletes, A., 1988)

H$_2$SO$_4$:H$_2$O$_2$:H$_2$O (3:1:1); followed by Br$_2$/methanol (0.5%); InP substrate cleaning for MBE growth; Ref. (Bahl, S.R., 1991)

H$_2$SO$_4$:H$_2$O$_2$:H$_2$O (3:1:1); surface quality compared to K$_2$Cr$_2$O$_7$:H$_2$SO$_4$:HCl; Ref. (Adachi, S., 1981e)

H$_2$SO$_4$:H$_2$O$_2$:H$_2$O (3:1:1); InP (1 0 0) etch rate = 0.25 $\mu$m/min; Ref. (Becker, R., 1973)

H$_2$SO$_4$:H$_2$O$_2$:H$_2$O (3:1:1); InP substrate cleaning for LPE; Ref. (Iga, K., 1979c)

H$_2$SO$_4$:H$_2$O$_2$:H$_2$O (3:1:1); Application: InP substrate cleaning first step for MBE, followed by Br$_2$/methanol, followed by 5 min DI water rinse to form protective oxide; Ref. (Maruno, S., 1987)

H$_2$SO$_4$:H$_2$O$_2$:H$_2$O (3:1:1); second step of InP vee-groove etch; removes defects from exposed {1 1 1}A surfaces; broadens the radius of the vee; Ref. (Kappelt, M., 1996)

H$_2$SO$_4$:H$_2$O$_2$:H$_2$O (4:1:1); InP etch rate = 500 Å/min; Ref. (Bhat, R., 1988)

H$_2$SO$_4$:H$_2$O$_2$:H$_2$O (4:1:1); InP surface cleaning; Ref. (Hyder, S.B., 1979)

H$_2$SO$_4$:H$_2$O$_2$:H$_2$O (4:1:1); Application: InP substrate cleaning for LPE followed by surface treatment in Br$_2$:HBr:H$_2$O (1:17:300); etch rate = 0.8 $\mu$m/min for 2–4 min; Ref. (Saxena, R.R., 1980)
H₂SO₄:H₂O₂:H₂O (5:1:1); InP surface etch prior to OMVPE growth, 2 min at 60°C; Ref. (Mori, Y., 1988)

H₂SO₄:H₂O₂:H₂O (5:1:1); InP substrate cleaning, first step, followed by Br₂/methanol; InP substrate cleaning, second step, followed by KOH; InP substrate cleaning, third step, followed by DI water rinse; Ref. (Narayan, S.Y., 1981)

H₂SO₄:H₂O₂:H₂O (5:1:1); Application: InP(Zn) thinning etch for two-step MOVPE regrowth; Ref. (Ebbinghaus, G., 1991)

H₂SO₄:H₂O₂:H₂O (5:1:1); InP substrate cleaning, OMVPE growth; 3 min at 60°C; Ref. (Kamada, M., 1989)

H₂SO₄:H₂O₂:H₂O (5:1:1); InP(Fe) thinning, etch rate \( \approx 500 \text{ Å/min} \) at 25°C to remove damage from Si-implanted InP prior to MBE regrowth; Ref. (Praseuth, J.P., 1991)

H₂SO₄:H₂O₂:H₂O (5:1:1); Auger analysis; Ref. (Singh, S., 1982)

H₂SO₄:H₂O₂:H₂O (5:1:1) {Caro’s etch}; Application: InP substrate cleaning first step, followed by Br₂/methanol (1%); Application: InP substrate cleaning second step for VPE; Ref. (Towe, E.D., 1982)

H₂SO₄:H₂O₂:H₂O (7:1:1); Application: InP substrate cleaning for MBE; oxidizing etch shows little or no carbon contamination (C < 1% monolayer); oxide is removed in MBE by heating above 500°C in As flux; Ref. (Davies, G.J., 1980)

H₂SO₄:H₂O₂:H₂O (10:1:1); Application: InP substrate cleaning for LPE; needs careful H₂O rinse to remove S contamination; Ref. (Trapp, K.D.C., 1983)

H₂SO₄:H₂O₂:H₂O (1:8:1); InP 1 min substrate cleaning followed by 3 min Br₂/methanol; Ref. (Kamiya, Y., 1986)

H₂SO₄:H₂O₂:H₂O (100:0.92:5); InP surface cleaning prior to Br₂/methanol removal of surface polish damage; (1 0 0) etch rate = 0.02 μm/min; (1 1 1)B etch rate = 0.06 μm/min gives etch rate dependence on H₂O₂ concentration; Ref. (Nishitani, Y., 1979)

H₂SO₄:H₂O₂:H₂O (5:1:1); Application: InP surface cleaning prior to oxidation; 4 min; Ref. (Eftekhari, G., 1993)
H$_2$SO$_4$:H$_2$O$_2$:H$_2$O (7:1:1); InP surface preparation etch for flat, damage-free surface; Ref. (Katsura, S., 1993)

H$_2$SO$_4$:H$_2$O$_2$:H$_2$O etched InP; study of surface oxides by glancing angle X-ray diffraction; Ref. (Liu, H.C., 1999)

H$_2$SO$_4$:H$_2$O$_2$:H$_2$O (8:1:1); InP surface cleaning; room temperature for 5 min to remove native oxide overlayer; longer times does not improve oxide removal but causes contamination and roughening; Ref. (Losurdo, M., 1996)

H$_2$SO$_4$:H$_2$O$_2$:H$_2$O (1:1:40); InP surface cleaning for MOVPE regrowth; impurities at interface; Ref. (Miyamoto, Y., 1991)

H$_2$SO$_4$:H$_2$O$_2$:H$_2$O (1:4:50); InP surface cleaning for MBE regrowth; best morphology. UV light/ozone InP surface oxidation; surface cleaning for MBE regrowth; Ref. (Passenberg, W., 1997)

H$_2$O$_2$ acidic solutions; etch and photoetch mechanism study on n- and p-InP; Ref. (Theuwis, A., 1996)

H$_2$SO$_4$:H$_2$O$_2$ (5:1); InP substrate cleaning; removal of surface contaminants and oxides prior to RIE; Ref. (van Rooijen, R., 1991)

H$_2$SO$_4$:H$_2$O$_2$:H$_2$O; identification of composition and crystalline phases of surface oxides on etched InP using X-ray diffraction; H$_2$O$_2$ plays no significant role in etch of InP; Ref. (Liu, H.C., 1999)

**InGaAs**

H$_2$SO$_4$:H$_2$O$_2$:H$_2$O (3:1:1); InGaAs selective etch from InP; Ref. (Dupuis, R.D., 1991); (Susa, N., 1980a,c, 1981); (Takeda, Y., 1980)

H$_2$SO$_4$:H$_2$O$_2$:H$_2$O (3:1:1); InGaAs etch rate = 2.5 µm/min; InAlAs etch rate = 3 µm/min; Ref. (Stano, A., 1987)

H$_2$SO$_4$:H$_2$O$_2$:H$_2$O (3:1:1); Application: InGaAs/GaAs mesa etch; Ref. (Susa, N., 1980b)

H$_2$SO$_4$:H$_2$O$_2$:H$_2$O (3:1:1); InGaAs/InP mesa etch; Ref. (Susa, N., 1980a)

H$_2$SO$_4$:H$_2$O$_2$:H$_2$O (4:1:1); InGaAs selective etch from InP; Ref. (Ishibashi, T., 1981)

H$_2$SO$_4$:H$_2$O$_2$:H$_2$O (5:1:1); InGaAs etch rate = 1.9 µm/min; InAlAs etch rate = 2.5 µm/min; Ref. (Stano, A., 1987)

H$_2$SO$_4$:H$_2$O$_2$:H$_2$O (5:1:1); InGaAs surface cleaning for OMCVD InP regrowth; Ref. (Frei, M.R., 1991)

H$_2$SO$_4$:H$_2$O$_2$:H$_2$O (8:1:1); InGaAs etch rate = 1.2 µm/min; selective from InP; Ref. (Stano, A., 1987)
H₂SO₄:H₂O₂:H₂O (10:1:1); Application: InGaAs mesa etch for photodiode fabrication; Ref. (Kanbe, H., 1980)

H₂SO₄:H₂O₂:H₂O (10:1:1); InGaAs selective etch from InP; Ref. (Sankaran, R., 1976)

H₂SO₄:H₂O₂:H₂O (1:8:1); Application: InGaAs selective etch from InP; Ref. (Antell, G.R., 1984)

H₂SO₄:H₂O₂:H₂O (1:8:1); Application: InGaAs/InP mesa etch; Ref. (Matsushima, Y., 1979)

H₂SO₄:H₂O₂:H₂O (1:6:10); Application: InGaAs mesa etch at 50°C; etch rate = 20 μm/min; Ref. (Pearsall, T.P., 1978)

H₂SO₄:H₂O₂:H₂O (3:5:50) InGaAs selective etch from InP; Ref. (Houston, P.A., 1987)

H₂SO₄:H₂O₂:H₂O (1:10:220); Application: InGaAs/InAlAs mesa etch; selective from InP stop layer; Ref. (Bahl, S.R., 1991, 1992)

H₂SO₄:H₂O₂:H₂O (1:8:100); InGaAs/InP mesa p–n junction surface treatment to reduce excess surface recombination; Ref. (Frei, M.R., 1991)

H₂SO₄:H₂O₂:H₂O (1:8:5000); InGaAs etch rate = 20 Å/s; good etch prior to InP OMVPE regrowth; Ref. (Yablonovitch, E., 1992)

H₂SO₄:H₂O₂:H₂O (1:1:10); InGaAs selective etch from ~30 Å InP mask layer; using direct-write lithography on the thin semiconductor mask with focused Ga ion beam; Ref. (Temkin, H., 1988)

H₂SO₄:H₂O₂:H₂O (1:1:20); Application: InGaAs slow etch, etch rate = 0.25 μm/min at 20°C; photolithography gives positively tapered sidewalls for both (0 1 1) and (0 1 1); Ref. (Dambkes, H., 1984)

H₂SO₄:H₂O₂:H₂O (1:1:10) {10 < x < 100}; InGaAs surface study; behavior depends on solution pH; Ref. (Aspnes, D.E., 1982b)

H₂SO₄:H₂O₂:H₂O (1:1:10); InGaAs/InP interface delineation; Ref. (Steventon, A.G., 1981)

H₂SO₄:H₂O₂:H₂O (1:1:50); Application: InGaAs, removal of sputter damage following oxide removal; Ref. (Steventon, A.G., 1981)

H₂SO₄:H₂O₂:H₂O (1:1:x) {10 < x < 500}; InGaAs mesa photodiode etch; low dark current; InGaAs surface behavior depends on solution pH; Ref. (Stocker, H.J., 1983)

H₂SO₄:H₂O₂:H₂O (1:1:50); InGaAs etch rate = 2200 Å/min; Ref. (Stocker, H.J., 1983)

InGaAs selective etches from InP:

H₂SO₄:H₂O₂:H₂O (1:1:10); InGaAs etch rate = 9000 Å/min
H₂SO₄:H₂O₂:H₂O (1:1:20); InGaAs etch rate = 4500 Å/min
H₂SO₄:H₂O₂:H₂O (1:1:60); InGaAs etch rate = 700 Å/min; Ref. (Elder, D.I., 1983, 1984)
$\text{H}_2\text{SO}_4:\text{H}_2\text{O}_2:\text{H}_2\text{O}$; InGaAs mesa etch; Ref. (Pearsall, T.P., 1980)

$\text{H}_2\text{SO}_4:\text{H}_2\text{O}_2:\text{H}_2\text{O}$ (1:1:10); Application: InGaAs/AlGaAs MQW laser using 30 Å InGaP etch stop layer; Ref. (Hobson, W.S., 1992)

$\text{H}_2\text{SO}_4:\text{H}_2\text{O}_2:\text{H}_2\text{O}$ (1:10:220); selective etch of InGaAs layer with InP etch-stop layer for HFET; Ref. (Greenberg, D.R., 1992)

$\text{H}_2\text{SO}_4:\text{H}_2\text{O}_2:\text{H}_2\text{O}$ (1:1:10); InGaAs selective etch from InAlAs; Ref. (Adesida, I., 1993a)

$\text{H}_2\text{SO}_4:\text{H}_2\text{O}_2:\text{H}_2\text{O}$ (1:1:20); Application: InGaAs selective etch from InP; Ref. (Ouacha, A., 1993)

$\text{H}_2\text{SO}_4:\text{H}_2\text{O}_2:\text{H}_2\text{O}$ (1:1:40); selective InAlAs/InGaAs HFET mesa etch from InP; Ref. (Daumann, W., 1997)

$\text{H}_2\text{SO}_4:\text{H}_2\text{O}_2(1.3\ \text{mol/l})$; electrochemical and etching properties and mechanism of n- and p-In$_{0.53}$Ga$_{0.47}$As and InP; conduction band studies; Ref. (Theuwis, A., 1997)

**InGaAsP**

$\text{H}_2\text{SO}_4:\text{H}_2\text{O}_2:\text{H}_2\text{O}$ (3:1:1); Application: InGaAsP selective etch from InP; Ref. (Chen, P.C., 1981); (Abe, Y., 1981); (Fritzche, D., 1981); (Utaka, K., 1980a,b)

<table>
<thead>
<tr>
<th>$\text{H}_2\text{SO}_4:\text{H}_2\text{O}_2:\text{H}_2\text{O}$</th>
<th>InGaAsP rate (µm/min)</th>
<th>InP rate (µm/min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(3:1:1) 20°C</td>
<td>0.7</td>
<td>0.014</td>
</tr>
<tr>
<td>3:1:1 30°C</td>
<td>1.6</td>
<td>0.035</td>
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<tr>
<td>(3:1:1) 20°C</td>
<td>0.6</td>
<td>0.012</td>
</tr>
<tr>
<td>(3:1:1) 30°C</td>
<td>–</td>
<td>0.030</td>
</tr>
</tbody>
</table>

Ref. (Fiedler, F., 1982)

$\text{H}_2\text{SO}_4:\text{H}_2\text{O}_2:\text{H}_2\text{O}$ (3:1:1); InGaAsP ($l = 1.52$ µm) stripe etch; Ref. (Imai, H., 1983)

$\text{H}_2\text{SO}_4:\text{H}_2\text{O}_2:\text{H}_2\text{O}$ (5:1:1); Application: InGaAsP selective etch from InP; Ref. (Olsen, G.H., 1979); (Nishi, H., 1979)

$\text{H}_2\text{SO}_4:\text{H}_2\text{O}_2:\text{H}_2\text{O}$ (5:1:1); Application: InGaAsP surface preparation for Schottky contact; Ref. (Yamazoe, Y., 1981)

$\text{H}_2\text{SO}_4:\text{H}_2\text{O}_2:\text{H}_2\text{O}$ (8:1:1); Application: InGaAsP selective etch from InP; Ref. (Wallin, J., 1992)

$\text{H}_2\text{SO}_4:\text{H}_2\text{O}_2:\text{H}_2\text{O}$ (10:1:1); Application: InGaAsP selective etch from InP; Ref. (Nelson, R.J., 1980); (Wright, P.D., 1982); (Ng, W., 1981); (Chen, T.R., 1982)

$\text{H}_2\text{SO}_4:\text{H}_2\text{O}_2:\text{H}_2\text{O}$ (1:1:10); In$_{0.73}$Ga$_{0.27}$As$_{0.63}$P$_{0.37}$ (1 0 0) etch rate = 1000 Å/min; Ref. (Ferrante, G.A., 1983)
H$_2$SO$_4$:H$_2$O$_2$:H$_2$O (1:1:10); In$_{0.83}$Ga$_{0.17}$As$_{0.39}$P$_{0.61}$ (1 0 0) etch rate = 420 Å/min; Ref. (Ferrante, G.A., 1983)

H$_2$SO$_4$:H$_2$O$_2$:H$_2$O (1:1:10); In$_{0.90}$Ga$_{0.10}$As$_{0.04}$P$_{0.96}$ (1 0 0) etch rate = 75 Å/min; Ref. (Ferrante, G.A., 1983)

H$_2$SO$_4$:H$_2$O$_2$:H$_2$O; InGaAsP first-order grating etch for laser; Ref. (Kawanishi, H., 1979)

H$_2$SO$_4$:H$_2$O$_2$:H$_2$O (1:8:1); Application: InGaAs/InP mesa etch for pin-FET; Ref. (Smith, D.R., 1980)

H$_2$SO$_4$:H$_2$O$_2$:H$_2$O (2:3:2); InGaAsP selective etch from InP; Ref. (Stone, J., 1981)

H$_2$SO$_4$:H$_2$O$_2$:H$_2$O (3:1:1); Application: InGaAsP/GaAs etched mirror lasers; Ref. (Ishikawa, J., 1989)

H$_2$SO$_4$:H$_2$O$_2$:H$_2$O (7:1:1); InP surface cleaning for MBE; Ref. (Katsura, S., 1993)

H$_2$SO$_4$:H$_2$O$_2$:H$_2$O (1:1:40); 30 s cleaning of InGaAsP after RIE; Ref. (Madhan Raj, M., 1999a)

H$_2$SO$_4$:H$_2$O$_2$:H$_2$O (1:1:40); step 1 in damage removal from RIE etched InGaAsP/InP; 0°C for 70 s; Ref. (Madhan Raj, M., 1999b)

H$_2$SO$_4$:H$_2$O$_2$:H$_2$O (1:1:40); step 3, 15 s, selective RIE damage removal from InGaAsP in InGaAsP/InP grooves prior to MOVPE regrowth; Ref. (Nunoya, N., 1999)

**GaAs**

H$_2$SO$_4$:H$_2$O$_2$:H$_2$O; review of GaAs etch characteristics; Ref. (Williams, R., 1990b)

H$_2$SO$_4$:H$_2$O$_2$:H$_2$O; H$_2$O$_2$:H$_2$O$_2$:H$_2$O (1:1); GaAs etch rate = 5.0 μm/min; Ref. (Colliver, D.J., 1976)

Surface cleaning effects on GaAs light emission from Schottky contacts; assessment of etching on electronic surface behavior for:

- H$_2$SO$_4$:H$_2$O$_2$:H$_2$O (20:1:1)
- H$_2$SO$_4$:H$_2$O$_2$:H$_2$O (1:1:250); Ref. (Adachi, H., 1981a)

H$_2$SO$_4$:H$_2$O$_2$:H$_2$O (1:1:n, 10 < n < 50); laser-induced photochemical wet etching of GaAs; formation of ripples; Ref. (Tsukada, N., 1983)

H$_2$SO$_4$:H$_2$O$_2$:H$_2$O (1:1:1); gives groove etch profiles; Ref. (Adachi, S., 1981e)

H$_2$SO$_4$:H$_2$O$_2$:H$_2$O (1:1:1); masked pattern etch profiles on (0 0 1)

GaAs; Ref. (Adachi, S., 1983)

H$_2$SO$_4$:H$_2$O$_2$:H$_2$O (2:1:1); GaAs and InP etch procedures to obtain the best morphologies; Ref. (Saletes, A., 1988)
H$_2$SO$_4$·H$_2$O$_2$·H$_2$O (2:1:1); Application: rapid GaAs substrate thinning, 300 µm under continuous swirling at 60°C for <15 s; Ref. (Dimroth, F., 1997)

H$_2$SO$_4$·H$_2$O$_2$·H$_2$O (3:1:1); GaAs etch rate = 3.1 µm/min; Ref. (Colliver, D.J., 1976)

H$_2$SO$_4$·H$_2$O$_2$·H$_2$O (3:1:1); Application: AlGaAs mesa etch at 50°C; Ref. (Zhu, Y., 1991)

H$_2$SO$_4$·H$_2$O$_2$·H$_2$O (3:1:1); Application: GaAs substrate cleaning for MBE; at 48°C for 1 min followed by heating in air at 250–300°C for 3–5 min to form a protective stable oxide as protection against contamination; Ref. (Fronius, H., 1987)

H$_2$SO$_4$·H$_2$O$_2$·H$_2$O (3:1:1); GaAs selective n- from p-photoetching; Ref. (Kuhn-Kuhnenfeld, F., 1972)

H$_2$SO$_4$·H$_2$O$_2$·H$_2$O (3:1:1); GaAs surface cleaning analysis by Auger analysis and Au layer epitaxy behavior; Ref. (Vermaak, J.S., 1977)

H$_2$SO$_4$·H$_2$O$_2$·H$_2$O (3:1:1); GaAs removal of polish damage; 15 min at 45°C; Ref. (Stirland, D.J., 1978)

H$_2$SO$_4$·H$_2$O$_2$·H$_2$O (3:1:1); GaAs planar surface etch prior to study of HCl treatment; Ref. (Matsushita, K., 1998)

H$_2$SO$_4$·H$_2$O$_2$·H$_2$O (4:1:1); GaAs patterned substrate cleaning for MBE; Ref. (Kapon, E., 1987)

H$_2$SO$_4$·H$_2$O$_2$·H$_2$O (4:1:1); Measurement of residual surface oxide; Ref. (Shiota, I., 1977)

H$_2$SO$_4$·H$_2$O$_2$·H$_2$O (5:1:1); GaAs substrate cleaning for MBE; surface analysis; Ref. (Massies, J., 1985)

H$_2$SO$_4$·H$_2$O$_2$·H$_2$O (5:1:1); GaAs substrate cleaning for 20 s at 20°C; Ref. (El Jani, B., 1982a)

H$_2$SO$_4$·H$_2$O$_2$·H$_2$O (5:1:1); GaAs (1 0 0) surface cleaning XPS study; Ref. (Olivier, J., 1990)

H$_2$SO$_4$·H$_2$O$_2$·H$_2$O (5:1:1); GaAs native oxide removal, 2 min; Ref. (Kaneshiro, C., 1997)

H$_2$SO$_4$·H$_2$O$_2$·H$_2$O (5:1:1) at 50°C for 1 min; surface study by AES and XPS; Ref. (Yoon, H.J., 1992)

H$_2$SO$_4$·H$_2$O$_2$·H$_2$O (5:1:1); Application: GaAs surface cleaning for CVD and LPE overgrowth on carbon film masked substrate; Ref. (Olsen, G.H., 1976)

H$_2$SO$_4$·H$_2$O$_2$·H$_2$O (5:1:1); GaAs surface cleaning/polish prior to applying Al$_2$O$_3$ etch mask; Ref. (Tarui, Y., 1971)

H$_2$SO$_4$·H$_2$O$_2$·H$_2$O (7:1:1); Application: GaAs substrate cleaning for MBE, 1 min; Ref. (Akatsu, Y., 1987)

H$_2$SO$_4$·H$_2$O$_2$·H$_2$O (8:1:1); GaAs etch rate = 2.8 µm/min; Ref. (Colliver, D.J., 1976)
H$_2$SO$_4$:H$_2$O$_2$:H$_2$O (10:1:1); GaAs substrate cleaning for MOCVD; Ref. (Biefeld, R.M., 1986)

H$_2$SO$_4$:H$_2$O$_2$:H$_2$O (x:1:1), 10 < x < 250; GaAs etch rate study shows proportional dependence on H$_2$O$_2$ concentration; low etch rates are surface reaction limited and show flat bottomed profiles; high etch rates are H$_2$O$_2$-diffusion limited and show enhanced etching at mask edges; Ref. (Kohn, E., 1980)

H$_2$SO$_4$:H$_2$O$_2$:H$_2$O (10:2.8:10); GaAs (1 0 0) photolithography ridge and groove etch showing profiles; Ref. (Arent, D.J., 1989)

H$_2$SO$_4$:H$_2$O$_2$:H$_2$O (1:8:1); Application: GaAs etch; Ref. (Hurwitz, C.E., 1975)

H$_2$SO$_4$:H$_2$O$_2$:H$_2$O (1:8:8); GaAs (1 0 0) photolithography substrate patterning etch profiles; Ref. (Arent, D.J., 1989)

H$_2$SO$_4$:H$_2$O$_2$:H$_2$O (1:8:40); GaAs dovetail mesa etch; Ref. (Colas, E., 1990)

H$_2$SO$_4$:H$_2$O$_2$:H$_2$O (1:8:40); Application: GaAs (1 0 0) mesa etch; Ref. (Colas, E., 1991)

H$_2$SO$_4$:H$_2$O$_2$:H$_2$O (1:8:40); Application; GaAs (1 0 0) photolithography channel etch; Ref. (Kapon, E., 1987)

H$_2$SO$_4$:H$_2$O$_2$:H$_2$O (1:8:40); Application: GaAs (1 0 0) photolithography channel etch at 24°C; [0 1 1] and [0 1 1] cross-sectional profiles; Ref. (Tsang, W.T., 1977)

H$_2$SO$_4$:H$_2$O$_2$:H$_2$O (1:8:40); Application: GaAs vee-groove etch; 90 min for 1.2 µm wide stripe with (111)A sidewalls; Ref. (Kim, T.G., 1997)

H$_2$SO$_4$:H$_2$O$_2$:H$_2$O (18:1:1); GaAs etch rate = 2.1 µm/min; Ref. (Colliver, D.J., 1976)

H$_2$SO$_4$:H$_2$O$_2$:H$_2$O (9:9:2); GaAs etch rate = 8.7 µm/min; Ref. (Colliver, D.J., 1976)

GaAs (1 0 0); study of etch rate dependence on temperature; etch rates and surface morphologies at 0°C are given as a ternary diagram:

- H$_2$SO$_4$:H$_2$O$_2$:H$_2$O (1:4:0); GaAs (1 0 0) etch rate = 10 µm/min at 20°C
- H$_2$SO$_4$:H$_2$O$_2$:H$_2$O (1:1:1); GaAs (1 0 0) etch rate = 8.8 µm/min at 20°C
- H$_2$SO$_4$:H$_2$O$_2$:H$_2$O (5:1:1); GaAs (1 0 0) etch rate = 1.4 µm/min at 20°C
- H$_2$SO$_4$:H$_2$O$_2$:H$_2$O (5:1:20); GaAs (1 0 0) etch rate = 0.60 µm/min at 20°C
- H$_2$SO$_4$:H$_2$O$_2$:H$_2$O (40:1:1); GaAs (1 0 0) etch rate = 0.37 µm/min at 20°C

Orientation dependence of etch rate and etch profiles are given for:

- H$_2$SO$_4$:H$_2$O$_2$:H$_2$O (1:8:1); GaAs (1 0 0) etch rate = 8.8 µm/min at 20°C
- H$_2$SO$_4$:H$_2$O$_2$:H$_2$O (8:1:1); GaAs (1 0 0) etch rate = 1.3 µm/min at 20°C; Ref. (Iida, S., 1971)
H₂SO₄:H₂O₂:H₂O (1:8:1); GaAs photolithography; use of undercutting of a metal layer as a fabrication step; Ref. (Wada, O., 1976)

H₂SO₄:H₂O₂:H₂O (5:5:1); Application: GaAs 5 min surface cleaning for ion implantation; Ref. (Kamiya, Y., 1986)

H₂SO₄:H₂O₂:H₂O (10:15:15); destroys the Au mask layer; Ref. (Merz, J.L., 1976)

H₂SO₄:H₂O₂:H₂O; etching summary in a review of GaAs etching; Ref. (Mukherjee, S.D., 1985)

H₂SO₄:H₂O₂:H₂O (1:1.3:25); GaAs (1 0 0) Cr-doped semi-insulating, laser-induced etching for via holes and diffraction gratings; Ref. (Osgood, R.M., 1982)

H₂SO₄:H₂O₂:H₂O (1:1:100); GaAs; UV illuminated etch for deep features, via holes, etc.; higher etch rates than for visible light; UV etch rates at 10 W/cm² are: n-type = 18 μm/min; Si-type = 13 μm/min; and p-type = 0.8 μm/min; Ref. (Podlesnik, D.V., 1984)

H₂SO₄:H₂O₂:H₂O (1:1:100); GaAs laser-enhanced maskless grating etch; Ref. (Podlesnik, D.V., 1983)

H₂SO₄:H₂O₂:H₂O; GaAs; discussion of reaction chemistry; Ref. (Ruberto, M.N., 1991)

GaAs etching anisotropy and cross-sectional profiles for:
  H₂SO₄:H₂O₂:H₂O (1:8:1)
  H₂SO₄:H₂O₂:H₂O (1:8:40)
  H₂SO₄:H₂O₂:H₂O (1:8:80)
  H₂SO₄:H₂O₂:H₂O (1:8:160)
  H₂SO₄:H₂O₂:H₂O (1:8:1000)
  H₂SO₄:H₂O₂:H₂O (4:1:5)
  H₂SO₄:H₂O₂:H₂O (8:1:1)
  H₂SO₄:H₂O₂:H₂O (3:1:1); Ref. (Shaw, D.W., 1981)

H₂SO₄:H₂O₂:H₂O (8:1:100); GaAs thinning etch; Ref. (Sin, Y.K., 1991)

H₂SO₄:H₂O₂:H₂O; GaAs n-type photoetching behavior; Ref. (van de Ven, J., 1991)

H₂SO₄:H₂O₂:H₂O; photoelectrochemical etch electrolyte for n- and p-GaAs; etch study; Ref. (Plieth, W.J., 1989)

H₂SO₄:H₂O₂:H₂O (10:1:1); GaAs striation pattern delineation in semi-insulating LEC material; 20–30 min at 10°C under illumination; Ref. (Fujisaki, Y., 1993)

H₂SO₄:H₂O₂:H₂O (1:1:50); photochemical, maskless grating etch; Application: GaAs submicrometer optical gratings; Ref. (Matz, R., 1986)

H₂SO₄:H₂O₂:H₂O (3:1:1); GaAs (1 0 0) vee-groove {1 1 1}A surface along ⟨0 1 1⟩; Ref. (Westphalen, R., 1992)
H$_2$SO$_4$:$H_2$O$_2$:H$_2$O (4:1:1) GaAs surface preclean prior to H oxide reduction; Ref. (Petit, E.J., 1994)

H$_2$SO$_4$:$H_2$O$_2$:H$_2$O (4:1:1); GaAs substrate cleaning for OMVPE growth; 2 min at 50°C; Ref. (Takagishi, S., 1992)

H$_2$SO$_4$:$H_2$O$_2$:H$_2$O (10:13:250); Photoetch of GaAs; Ref. (Mottet, S., 1983)

H$_2$SO$_4$:$H_2$O$_2$:H$_2$O (4:1:1); Application: AlGaAs/GaAs mesa etch; Ref. (Sugg, A.R., 1993); (Maranowski, S.A., 1993)

H$_2$SO$_4$:$H_2$O$_2$:H$_2$O (4:1:1); GaAs (1 0 0), AFM surface study shows undulations; Ref. (Song, Z., 1995)

H$_2$SO$_4$:$H_2$O$_2$:H$_2$O (1:4:60); AlGaAs/GaAs; in situ measurement of growth rate temperature dependence; Ref. (Wipiejewski, T., 1993)

H$_2$SO$_4$:$H_2$O$_2$:H$_2$O (1:8:80); Application: Al$_{0.1}$Ga$_{0.9}$As contact layer removal for waveguide fabrication; Ref. (Caracci, S.J., 1993)

H$_2$SO$_4$:$H_2$O$_2$:H$_2$O (1:8:80); Application: vee-groove etch of GaAs, quasi (1 1 1)A sidewalls; with Si$_3$N$_4$ mask; Ref. (Constantin, C., 1999)

H$_2$SO$_4$:$H_2$O$_2$:H$_2$O (1:8:80); Application: selective removal of GaAs from InAlP stop layer; 1 min; Ref. (Holmes, A.L., 1995)

H$_2$SO$_4$:$H_2$O$_2$:H$_2$O (7:1:1); GaAs surface cleaning for MBE growth of GaSb layers; Ref. (Tadayon, B., 1995)

H$_2$SO$_4$:$H_2$O$_2$:H$_2$O; GaAs surface cleaning for electrical contacts inferior to low energy Ar ion beam cleaning; Ref. (Starkeev, G., 1993)

H$_2$SO$_4$:$H_2$O$_2$:H$_2$O (3:1:1); study of sulfur contamination of GaAs from etchant; Ref. (Butcher, K.S.A., 1996)

H$_2$SO$_4$:$H_2$O$_2$:H$_2$O (3:1:1); GaAs etch rate ~ 1000 Å/s at 0°C; Ref. (Müller, H., 1975)

H$_2$SO$_4$:$H_2$O$_2$:H$_2$O (3:1:1); polishing etch for thinning GaAs; Ref. (Novák, J., 1996)

H$_2$SO$_4$:$H_2$O$_2$:H$_2$O (20:1:1); GaAs striation delineation etch.
H$_2$SO$_4$:$H_2$O$_2$:H$_2$O (15:1:1); GaAs striation delineation etch
H$_2$SO$_4$:$H_2$O$_2$:H$_2$O (8:1:1); GaAs striation delineation etch; Ref. (Pandelisev, K.A., 1990)

H$_2$SO$_4$:$H_2$O$_2$:H$_2$O (1:8:1); Application: anisotropic GaAs etch for forming micromachined triangular cross-section structures; depth etch rate is 7 μm/min; undercutting etch rate is 4 μm/min
H$_2$SO$_4$:$H_2$O$_2$:H$_2$O (1:8:0); Application: anisotropic GaAs etch for forming micromachined triangular cross-section structures; depth etch rate is 10 μm/min; undercutting etch rate is 6 μm/min; Ref. (Ribas, R.P., 1998)
H$_2$SO$_4$·H$_2$O$_2$·H$_2$O (1:8:500); GaAs etched surface contains elemental As; Ref. (Shun, J., 1991)

H$_2$SO$_4$·H$_2$O$_2$·H$_2$O (1:8:600); GaAs RIE damage removal; Ref. (Ooi, B.S., 1994)

H$_2$SO$_4$·H$_2$O$_2$·H$_2$O (5:1:1); jet thinning of GaAs for TEM; Ref. (Weyher, J.L., 1998)

H$_2$O$_2$/$\text{H}_2\text{SO}_4$ and $\text{S}_2\text{O}_8^{2-}$/$\text{H}_2\text{SO}_4$ aqueous solution electrolytes; Study: GaAs photochemical etch behavior; Ref. (van De Ven, J., 1990b)

**GaSb**

H$_2$SO$_4$·H$_2$O$_2$ (5:1); GaSb etch pit delineation on (1 1 1)A, (1 1 1)B, (1 0 0), (1 1 0), striations on (1 1 1)A and (1 1 0); precipitates on (1 1 1)A, (1 0 0), (1 1 0); Ref. (Costa, E.M., 1997)

**InAs/AlSb**

H$_2$SO$_4$·H$_2$O$_2$·H$_2$O (1:8:80); Application: InAs/AlSb mesa etch; Ref. (Brown, E.R., 1994)

**InGaP/GaAs**

H$_2$SO$_4$·H$_2$O$_2$·H$_2$O (5:1:1); Application: GaAs selective etch from InGaP; Ref. (Olsen, G.H., 1978)

H$_2$SO$_4$·H$_2$O$_2$·H$_2$O (1:8:200); Application: selective etch of GaAs from InGaP; Ref. (Hanson, A.W., 1993)

H$_2$SO$_4$·H$_2$O$_2$·H$_2$O (1:8:80); selective removal of InGaAs from InGaP in MQW laser fabrication; Ref. (Jones, A.M., 1998)

**GaN**

H$_2$SO$_4$·H$_2$O$_2$·H$_2$O (1:1:10); removal of iron nitride pattern mask from GaN; Ref. (Lee, H., 1998)

**H$_2$SO$_4$·H$_2$O$_2$·HF**

H$_2$SO$_4$·H$_2$O$_2$·HF (3:2:2); heats spontaneously to 90°C

H$_2$SO$_4$·H$_2$O$_2$·HF (1:4:1)

H$_2$SO$_4$·H$_2$O$_2$·HF (1:1:2); best shape pits for crystal orientation

For GaP etch pit delineation use at 60–90°C for 3–15 min; for GaAs room temperature etch rate ~ 6 μm/min; Ref. (Kuhn-Kuhnenfeld, F., 1976)

HF·H$_2$SO$_4$·H$_2$O$_2$ (1:1:1); masked pattern etch profiles on (0 0 1)GaAs; Ref. (Adachi, S., 1983)

**H$_2$SO$_4$·H$_3$PO$_4$** (see H$_3$PO$_4$·H$_2$SO$_4$)

**H$_2$SO$_4$·(NH$_4$)$_2$S$_2$O$_8$·H$_2$O** (see (NH$_4$)$_2$S$_2$O$_8$·H$_2$SO$_4$·H$_2$O)

**H$_2$SO$_4$·K$_2$Cr$_2$O$_7$·HCl** (see HCl·H$_2$SO$_4$·K$_2$Cr$_2$O$_7$)
H₂SO₄:KI: I₂ (see I₂:KI:H₂SO₄)

H₂SO₄:KMnO₄:H₂O (see KMnO₄:H₂SO₄:H₂O)

H₂SO₄:methanol

H₂SO₄:methanol (3 ml:250 ml); electrolyte for InGaAs; Ref. (Chi, G.C., 1986)

H₂SO₄:NaSCN

Photoetch of p-GaAs; 0.1 M H₂SO₄:0.1 M NaSCN solution electrolyte; maximum etch rate = 1300 Å/min; Ref. (Ostermayer, F.W., 1981)

Huber etch (see H₃PO₄:HBr)

I₂:H₂O

Saturated I₂ water; GaP etch rate is negligible; Ref. (Milch, A., 1976)

I₂:KI (see KI:I₂)

I₂:methanol

I₂/methanol; InSb; Ref. (Fuller, C.S., 1962)

Iodic acid

Iodic acid (5 wt.% solution); InP (1 0 0) etch rate = 67 Å/min; smooth, uniform surfaces; thinning etch; Ref. (Clawson, A.R., 1978)

Iodic acid (10 wt.% solution); InP (1 0 0) etch rate = 350 Å/min; does not attack photoresists; leaves a black residue on InAs and InGaAs; Ref. (Clawson, A.R., 1978)

Iodic acid:H₂O (10 wt.% solution); InP surface preparation AES study for Schottky contacts; Ref. (Hökelek, E., 1982)

Iodic acid:H₂O (10% solution); Application: InP groove etch with Si₃N₄ mask; Ref. (Yu, K.L., 1981)

Iodic acid (20 wt.% solution); InP (1 0 0) etch rate = 750 Å/min; Ref. (Clawson, A.R., 1978)

Iodic acid solutions; InP etch and photoetch chemical kinetics; Ref. (Vermeir, I.E., 1992)

Iodic acid:lactic acid (see lactic acid:iodic acid)

Isopropanol:Br₂ (see Br₂:isopropanol)

Isopropanol:citric acid:thiourea (see citric acid:thiourea:isopropanol)
Isopropanol:HCl:HNO₃

Isopropanol:H₂O₃

Isopropanol:H₂O (1:5); wetting agent post etch rinse; Ref. (Cheung, R., 1996)

Isopropanol:KBr:Br₂ (see HCl:HNO₃:isopropanol KBr:Br₂)

KBr:Br₂ (see Br₂:KBr)

KCl

KCl (1 M); electrolyte for photoelectrochemical etch of GaAs; Application: sawtooth grating fabrication; Ref. (Carrabba, M.M., 1986)

KCl electrolyte for photoelectrochemical etch; GaAs; Application: sawtooth gratings using photoresist mask; Ref. (Li, J., 1988)

KCl; electrolyte for photoetching of n-GaAs; Ref. (Haisty, R.W., 1961)

KCN

KCN (20%) solution; Application: GaAs, Si, Ge; cleaning of metallic ions from surface prior diffusion; Ref. (Hall, R.N., 1964)

K₂Cr₂O₇:CH₃COOH:HBr (see HBr:CH₃COOH:K₂Cr₂O₇)

K₂Cr₂O₇:HBr:CH₃COOH (see HBr:CH₃COOH:K₂Cr₂O₇)

K₂Cr₂O₇:HBr:H₃PO₄ (see HBr:H₃PO₄:K₂Cr₂O₇)

K₂Cr₂O₇:HCl (see HCl:K₂Cr₂O₇)

K₂Cr₂O₇:HCl:H₂O₂ (see HCl:H₂O₂:K₂Cr₂O₇)

K₂Cr₂O₇:HCl:H₂SO₄ (see HCl:H₂SO₄:K₂Cr₂O₇)

K₂Cr₂O₇:HF (see HF:K₂Cr₂O₇ {Secco etch})

K₂Cr₂O₇:H₃PO₄:HBr (see H₃PO₄:HBr:K₂Cr₂O₇)

K₂Cr₂O₇:H₃PO₄:H₂O (see H₃PO₄:K₂Cr₂O₇:H₂O)

K₂Cr₂O₇:H₂SO₄:HCl (see HCl:H₂SO₄:K₂Cr₂O₇)

K₂SO₈:KOH (see KOH:K₂SO₈)
**KF:HF** (see HF:KF)

**K₃Fe(CN)₆**

0.05 M K₃Fe(CN)₆ pH = 13; GaAs photolithography profiles; Ref. (Notten, P.H.L., 1986)

0.5 M K₃Fe(CN)₆ pH = 13; GaAs photolithography profiles; Ref. (Notten, P.H.L., 1986)

K₃Fe(CN)₆ at pH = 14; p-GaAs (1020 cm⁻³) selective etch from p-GaAs (1018 cm⁻³); Ref. (Kelly, J.J., 1988)

Electrochemical dissolution study of GaP in electrolytes of NaOH, K₃Fe(CN)₆, H₂SO₄; Ref. (Memming, R., 1968)

K₃Fe(CN)₆ (0.05 M); selective removal of In₀.₅₃Ga₀.₄₇As and In₀.₇₂Ga₀.₂₈As₀.₆₁P₀.₃₉ from InP; selectivity ~200; electrochemical study of etch mechanism; Ref. (Theuwis, A., 1999b)

**K₃Fe(CN)₆:**K₄Fe(CN)₆

K₃Fe(CN)₆:K₄Fe(CN)₆ (with NaOH or HCl to buffer pH); GaAs selective etch from AlGaAs for pH >9; AlGaAs selective etch from GaAs for pH between 5 and 9; Ref. (Logan, R.A., 1973a)

K₃Fe(CN)₆:K₄Fe(CN)₆:3H₂O (14.8 g:19.0 g:200 ml H₂O; buffered with 3 ml HCl:H₂O {1:1000} to pH = 6.7); GaAs and Al₀.₃Ga₀.₇As selective etch from In₀.₁Ga₀.₉As; selectivity >8; Ref. (Hill, D.G., 1990)

**K₃Fe(CN)₆:**KOH (see KOH:K₃Fe(CN)₆)

**K₃Fe(CN)₆:**HF:HNO₃:H₂O (see HF:HNO₃:H₂O:K₃Fe(CN)₆)

**KI:I₂:H₂O**

Au contact removal

KI:I₂:H₂O; Application: photolithography etchant for Au/Zn contact layer from InP; Ref. (Adachi, S., 1981c)

KI:I₂:H₂O; Application: removal Au implantation mask from InGaP; etch rate = 150 Å/s; Ref. (Hamisch, Y., 1992)

KI:I₂:H₂O (113 g:65 g:100 ml); Au contact and masklayer removal from GaAs. H₂O₂:NaOH (1:5); GaAs etch gives rough surface texture; Ref. (Merz, J.L., 1976)

KI:I₂:H₂O (113 g:65 g:100 ml); Au contact/mask layer etch from GaAs; Ref. (Merz, J.L., 1979)

I₂:KI:H₂O (25 g:50 g:500 ml); photolithographic pattern etch in deposited Au layer; Ref. (Uragaki, T., 1976)
KI:I₂:H₂O; Au mask removal from InP; Ref. (Ils, P., 1993)

I₂:KI:H₂O (100 g:400 g:400 ml); gold etchant from semiconductor surface; Ref. (Glang, R., 1970)

I₂:KI:H₂O (56 g:112 g:500 ml); gold etchant from semiconductor surface; Ref. (Park, S., 1997)

AlGaAs/GaAs (KI:I₂)

KI:I₂ (0.3 mol/l KI + 0.04 mol/l I₂, with pH = 9.4); GaAs selective etch from AlGaAs; etch rate = 1 μm/min; Ref. (Tijburg, R.P., 1976b)

KI:I₂ (0.3 mol/l KI + 0.1 mol/l I₂, with pH = 9); AlₓGa₁₋ₓAs (x < 0.15) selective etch from GaAs; with pH = 11 is GaP selective etch from InGaP or AlGaAs; Ref. (Tijburg, R.P., 1976b)

I₂:KI; AlGaAs/GaAs etchant selectivity dependence on I₂/KI ratio and on pH; Ref. (Tijburg, R., 1976a)

I₂:KI:H₂O (0.1:10:90); n-GaAs photoetchant for maskless laser-induced patterning; Ref. (Haynes, R.W., 1980)

I₂:KI:H₂O (1:10:89); photochemical etchant for n-GaAs laser-induced maskless grating etching; Ref. (Aoyagi, Y., 1985)

KI:I₂:H₂O (27.8 g:16.25 g:25 ml) with pH adjusted by adding an equal amount of H₂SO₄ (diluted with H₂O to pH = 2.9); selective etch of Al₀.₃Ga₀.₇As from GaAs; selectivity of 137 at 20°C and 330 at 3°C; Ref. (Lau, W.S., 1997)

I₂:KI:H₂O (65 g:113 g:100 g); selective removal of AlₓGa₁₋ₓAs from GaAs if x > 0.1; Ref. (Malag, A., 1993)

KI:I₂:H₃PO₄ (pH <2); Application: selective AlGaAs etch to transfer and undercut the GaAs mask pattern onto underlying GaAs for shadowed MOVPE regrowth; Ref. (Peake, G.M., 1997)

I₂:KI:HCl

I₂:KI:HCl; study of etch and photoelectrochemical etch of InP (0 0 1); Ref. (Vermeir, I.E., 1996)

I₂:KI:H₂SO₄

I₂:KI:H₂SO₄; study of etch and photoelectrochemical etch of Al₀.₂₅Ga₀.₇₅As and GaAs on etch conditions; Ref. (Verpoort, P.I., 1995)

KKI etch (see HCl:CH₃COOH:H₂O₂)

KMnO₄:acetone

KMnO₄:acetone (1:25); anodization electrolyte for GaAs and GaAs₀.₆P₀.₄; Ref. (Stoneham, E.B., 1974)
**KMnO₄:H₂SO₄:H₂O**

KMnO₄:H₂SO₄:H₂O (100 mg:10 ml:40 ml); polish etch for ZnSe; etch rate \( \sim 1 \mu\text{m/min} \); Ref. (Tamura, H., 1994)

**KOH (molten)**

KOH molten; Application: GaAs (1 0 0) dislocation etch pit delineation; Ref. (Elliot, A.G., 1987)

KOH molten at 350°C; GaAs (1 0 0) dislocation etch pit delineation; Ref. (Takenaka, T., 1978)

KOH molten at 300°C; GaAs dislocation etch pit delineation; Ref. (Stirland, D.J., 1978)

KOH molten at 450°C; GaAs defect etch pit delineation; Ref. (Sewell, J.S., 1989); (Look, D.C., 1989)

KOH molten at 400°C; GaAs (1 0 0) 10 min for defect etch pit delineation; Ref. (Stirland, D.J., 1986)

KOH molten at 350°C; GaAs defect etch pit delineation; relationship of pit density to structural defects; Ref. (Tartaglia, J.M., 1991)

KOH molten at 400°C for 3–4 s; GaAs epilayer etch pit dislocation delineation; Ref. (Uen, W.Y., 1993)

KOH molten at 350°C; defect delineation; for 5–10 min to reveal etch pits; Ref. (Takagishi, S., 1992)

KOH molten; GaAs epilayer etch pit defect delineation; \( \sim 3 \mu\text{m} \) etch depth; Ref. (Takagishi, S., 1993)

KOH molten (400°C); GaAs {1 0 0}; dislocation etch pit delineation; 30 min; Ref. (Angilello, J., 1975)

KOH molten; GaN dislocation etch pit delineation; 10 min at 360°C; Ref. (Kozawa, T., 1996)

**KOH:HF** (see HF:KOH)

**KOH:H₂O**

**InP**

KOH:H₂O (45% solution); InP native oxide removal prior to acid etch to assure smooth etch morphology; does not attack InP; Ref. (Clawson, A.R., 1978)

KOH; InP substrate cleaning, third step, followed by DI water rinse; Ref. (Narayan, S.Y., 1981)

KOH (0.1 M), electrolyte for anodic oxidation of n-InP; Ref. (Quinlan, K.P., 1994)
GaSb

KOH:H₂O (45% solution); GaSb first step prior to defect etching; 2 min under continuous stirring at room temperature; Ref. (Stepanek, B., 1992)

GaAs

1 M KOH aqueous solution; GaAs n-type voltage-controlled photoetching at 26°C; self-limiting to thickness of the depletion layer for FETs; Ref. (Hoffmann, H.J., 1981)

KOH:H₂O (1:10); GaAs n-type laser-induced etch; Ref. (Osgood, R.M., 1982)

KOH:H₂O (1:20); GaAs; UV illuminated etch for deep features, via holes, etc.; higher etch rates than for visible light; UV etch rates at 10 W/cm² are: n-type = 8 nm/min; Si-type = 6 nm/min; and p-type = 0.5 nm/min; Ref. (Podlesnik, D.V., 1984)

Anodic etching with a mechanically scanned jet of KOH (20%) electrolyte with the etching current controlled by IR transmitted intensity to achieve uniform thickness; Ref. (Thrush, E.J., 1978)

KOH; electrolyte for Schottky contact in ECV profiling; Ref. (Ambridge, T., 1974a,b,c, 1975, 1980)

KOH; electrolyte for photoetching of n-GaAs; Ref. (Haisty, R.W., 1961)

KOH; maskless laser-induced etching of n-GaAs; Ref. (Lee, C., 1990)

KOH electrolyte for photoetch of micrometer size features in GaAs using a scanned focused laser beam; Ref. (Rauh, R.D., 1985)

KOH:H₂O (1 and 5%); Photoetch of n-GaAs; no etch without illumination; does not attack AuGe contacts; Application: focused laser beam microetching; Ref. (Mottet, S., 1983)

KOH (1 M); selective photoetch of n-GaAs from stop layer of low-temperature MBE grown GaAs:As; Ref. (Chen, E.H., 1995)

KOH (1 M); selective etch of Si mask on GaAs from STM direct write oxidized Si pattern; 2 s at 60°C. Does not attack GaAs; Ref. (Snow, E.S., 1993)

KOH electrolytes; Photoelectrochemical etching of GaAs; Ref. (Svorcik, V., 1988)

InN:GaN

KOH:H₂O (33 wt.% solution); InN etch rate at 50°C = 220 Å/min; Ref. (Guo, Q.X., 1992)

KOH:H₂O (1:3); photoelectrochemical etch of GaN; rates of several μm/min Ref. (Minsky, M.S., 1996)

KOH (0.5 M); electrolyte for photoinduced electrochemical smoothing-etch for GaN surfaces; Ref. (Rotter, T., 1999)
KOH (0.1 M) electrolyte for photoenhanced electrochemical etching of GaN; Ref. (Stocker, D.A., 1999)

KOH (10–1N) Free etch and mechano-chemical polishing of GaN; Ref. (Weyher, J.L., 1997)

KOH (5 g in 200 ml H₂O); electrolyte for electrochemical pattern etching of GaN and AlGaN; Ref. (Yoshida, S., 1997)

KOH (0.005–0.04 M); photoelectrochemical etch of n-GaN selectively from intrinsic GaN and p-GaN; Ref. (Youtsey, C., 1998)

KOH molten (360°C); etch pit delineation in GaN layers; SEM and TEM observations; Ref. (Shojima, K., 2000)

KOH (0.1 M) electrolyte for photoenhanced electrochemical etching of GaN; Ref. (Stocker, D.A., 1999)

KOH (molten); transverse (i.e. sidewall) etch for GaN; no etch in the (0 0 0 1) direction. KOH (30%) in ethylene glycol; transverse (i.e. sidewall) etch for GaN; no etch in the (0 0 0 1) direction; Ref. (Stocker, D.A., 2000)

Si

KOH:H₂O (5 g:20 ml); Si anisotropic etch at 65°C, stops at {1 1 1} planes; Ref. (Hoole, A.C.F., 1992)

KOH (40%) at 60°C: Application: Si selective etch from B-doped >1 x 10²⁰ cm⁻³ Si layers; Ref. (Rittenhouse, G.E., 1992)

KOH:H₂O₂:H₂O

1N KOH:H₂O₂:H₂O (1:1:10); masked pattern etch profiles on (0 0 1)GaAs; Ref. (Adachi, S., 1983)

KOH:H₂O₂:NH₄OH

1N KOH:H₂O₂:NH₄OH (5:1:1); masked pattern etch profiles on (0 0 1)GaAs; Ref. (Adachi, S., 1983)

KOH:K₃Fe(CN)₆

InP

KOH:K₃Fe(CN)₆:H₂O (6 g:4 g:50 ml); Application: InP cleaved cross-section layer delineation; ~5 min at 20°C; Ref. (Clarke, R.C., 1973); (Hales, M.C., 1970); (Takenaka, T., 1978); (Kim, J.S., 1992); (Astles, M.G., 1973)
K₃Fe(CN)₆·H₂O (15 g:100 ml) = part 1, and KOH:H₂O (15 g:100 ml) = part 2:part 1:part 2 (3:1); InP etch pit defect delineation under illumination for 10 min, etch rate \( \sim 0.14 \mu m/min \) for both (1 1 0) and (1 1 0); Ref. (SrнŠek, R., 1993)

K₃[Fe(CN)₆] (10 g):KOH (15 g):H₂O (270 ml); photochemical dopant selective n-InP from p-InP; smooth surfaces; Ref. (Kallstenius, T., 1999b)

FeCN:KOH:H₂O; cleaved cross-section layer delineation stain for SEM study; Ref. (Bertone, D., 1999)

K₃Fe(CN)₆·KOH:H₂O (1 g:1 g:16 g); InP/InGaAs layer delineation under illumination; Ref. (Nordell, N., 1992b)

InGaAs(P)/InP

KOH:K₃Fe(CN)₆·H₂O (6 g:4 g:50 ml); Application: InGaAs/InP cleaved cross-section layer delineation; etches InGaAs selectively; etch rate \( \sim 2 \mu m/min \) This works best for multilayer delineation where the top layer is InP; etch rate is too fast to use on InGaAs layer directly; Ref. (Hyder, S.B., 1979)

KOH:K₃Fe(CN)₆·H₂O (6 g:4 g:50 ml); Application: InP cleaved cross-section layer delineation; \( \sim 5 \) min at 20°C; selectively etches InGaAsP on InP; Ref. (Clarke, R.C., 1970); (Rezek, E.A., 1980)

KOH:K₃Fe(CN)₆·H₂O (6 g:4 g:50 ml); selectively etches InGaAsP on InP; Ref. (Coldren, L.A., 1983); (Li, G., 1981); (Chen, T.R., 1982)

KOH:K₃Fe(CN)₆·H₂O (24 g:16 g:140 ml); InGaAsP selective etch from InP; etch rate = 4.1 \mu m/min; InP etch rate < 0.05 \mu m/min; (Fresh solution mixed daily); Ref. (Conway, K.L., 1982)

KOH:K₃Fe(CN)₆·H₂O; Application: InGaAsP/InP cleaved cross-section layer delineation; Ref. (Itaya, Y., 1979); (Ng, W.W., 1981); (Sakai, K., 1981); (Hsieh, J.J., 1976)

KOH:K₃Fe(CN)₆·H₂O(10 g:0.2 g:50 ml); Application: InGaAsP strip mesa etch for DH lasers; selective etch from InP; Ref. (Liau, Z.L., 1982)

KOH:K₃Fe(CN)₆·H₂O (8 g:0.5 g:100 ml); InGaAsP p–n junction delineation; A–B etch tried but too fast attack; Ref. (Lourenco, J.A., 1983)

KOH:K₃Fe(CN)₆·H₂O (8 g:0.5 g:100 ml); 10 min etching InGaAsP under illumination to reveal defects; etch rate \( \sim 1.5 \mu m/h \); not useful on Zn-doped p-layers; Ref. (Lourenco, J.A., 1984)

KOH:K₃Fe(CN)₆·H₂O (8 g:12 g:100 ml) solution used for InGaAsP selective etch from InP; Ref. (Lourenco, J.A., 1984)

KOH:K₃Fe(CN)₆·H₂O; Application: InGaAs/InP and p–n junction cleaved cross-section layer delineation; Ref. (Ando, H., 1981)
KOH:K$_3$Fe(CN)$_6$:H$_2$O (6 g:4 g:50 ml); Application: p–n junction photochemical delineation for Zn diffusion assessment in InGaAsP/InP structures; Ref. (Hou, D.T.C., 1990)

KOH:K$_3$Fe(CN)$_6$:H$_2$O (6 g:4 g:50 g); InGaAsP/InP layer delineation; Ref. (Huo, D.T.C, 1989e)

K$_3$Fe(CN)$_6$:KOH:H$_2$O (10 g:10 g:100 ml) p–n junction delineation; Ref. (Williamson, J.B., 1993)

**GaAlAs/GaAs**

KOH:K$_3$Fe(CN)$_6$:H$_2$O (12 g:9 g:70 ml); Application: GaAlAs/GaAs cleaved cross-section layer delineation; Ref. (Colas, E., 1990)

KOH:K$_3$Fe(CN)$_6$ [(120 g KOH + 500 ml H$_2$O):(80 g K$_3$Fe(CN)$_6$ + 500 ml H$_2$O)]; GaAs layer delineation; Ref. (Colliver, D.J., 1976)

K$_3$Fe(CN)$_6$:KOH:H$_2$O (8 wt.%:12 wt.%:100 wt.%); AlGaAs/GaAs layer delineation; Ref. (Zhu, Y., 1991)

**GaP**

KOH:K$_3$Fe(CN)$_6$ (1:5); GaP etch rate at 21°C = 0.2 μm/min; Ref. (Kaminska, E.A., 1981)

KOH:K$_3$Fe(CN)$_6$ (2:1); GaP etch rate at 21°C = 0.3 μm/min; Ref. (Kaminska, E.A., 1981)

KOH:K$_3$Fe(CN)$_6$:H$_2$O (3:1:60); GaP etch rate at 21°C = 0.03 μm/min; Ref. (Kaminska, E.A., 1981)

KOH:K$_3$Fe(CN)$_6$:H$_2$O (6 g:4 g:50 ml) boiling; GaP dislocation etch pit delineation; 1–2 min; Ref. (Val’kovskaya, M.I., 1967)

KOH:K$_3$Fe(CN)$_6$; etch for GaP; etch rate dependence on solution concentrations and temperature; Ref. (Plauger, L.R., 1974)

H$_2$O:KOH:K$_3$Fe(CN)$_6$ (50 ml:6 g:4 g); 1–2 min at 100°C; etch rate = 20–25 μm/h; Ref. (Saul, R.H., 1968)

**KOH:K$_2$S$_2$O$_8$**

KOH solution + 0.02 M K$_2$S$_2$O$_8$; photoenhanced etching of GaN using a Pt mask; Ref. (Bardwell, J.A., 1999)

**KOH:methanol**

KOH:methanol (2.5 g:200 ml); InP surface cleaning study for Schottky contacts; Ref. (Dunn, J., 1988)
**KOH:NaOH**

KOH:NaOH (50 mol%:50 mol%): GaAs defect delineation etch; used at 170°C eutectic melting temperature; keeps surfaces smooth compared to molten KOH; shows defects in nominally zero-dislocation GaAs; Ref. (Lessoff, H., 1984)

NaOH–KOH eutectic, molten; GaAs etch pit defect delineation; 30 min at 350°C, etch rate ~0.08 μm/min; when used in sequence with A–B etch more information is revealed than with either etch individually; Ref. (Nordquist, P.E.R., 1993)

**KOH:tartaric acid** (see tartaric acid:KOH)

**Lactic acid:HNO₃**

Lactic acid:HNO₃ (10:1); InP (1 0 0) etch rate <8 Å/min; Ref. (Clawson, A.R., 1978)

Lactic acid:HNO₃ (10:1); InSb surface cleaning for AES studies; Ref. (Auret, F.D., 1982)

Lactic acid:HNO₃ (10:1); InSb substrate cleaning for MOCVD; Ref. (Biefeld, R.M., 1986)

**Lactic acid:HNO₃:HF**

Lactic acid:HNO₃:HF (50:8:2); Safety caution: This etchant evolves heat and gas when stored which can explosively burst capped containers; Ref. (Bubar, S.F., 1966)

Lactic acid:HNO₃:HF (50:8:2); InSb surface cleaning for LPE; no carbon contamination; Ref. (Holmes, D.E., 1980)

**Lactic acid:H₂O₂:HF**

Lactic acid:H₂O₂:HF (50:8:2); InGaAs etch rate = 7200 Å/min Ref. (Elder, D.I., 1983)

**Lactic acid:H₃PO₄:HCl**

HCl:H₃PO₄:lactic acid (1:1:x, with 0 < x < 6); study of InP etch rate, surface finish and photoresist undercut. Smoother InP surfaces; Ref. (Ikossi-Anastasiou, K., 1995)

HCl:H₃PO₄:lactic acid (x:y:z); gives etch rate dependence on composition; incorporation of lactic acid reduces size and number of etch pits on bottom (1 0 0) plane; higher lactic acid increases roughness of (2 1 1)A and (1 0 0) surfaces. Requires final 2% Br₂/methanol polish to reduce roughness; Ref. (Elías, P., 1999)

**Lactic acid:iodic acid:H₂O**

Lactic acid (CH₃CHOHCOOH):iodic acid (HIO₃):H₂O (1.5:1:2); InP etch rate of 2 Å/s; specular surfaces; diffusion limited, isotropic etch; Ref. (Ikossi-Anastasiou, K., 1995)
**Maleic acid**

InGaAs selective etch from InAlAs and InAlAs selective etch from AlAs; Ref. (Broekaert, T.P.E., 1992b)

**Malonic acid:H$_2$O$_2$**

Use of organic acids and AlAs etch stop layers for InGaAlAs/InP structures:
- Organic acid solutions: MA = malonic acid: H$_2$O (75 g:1 l), pH = 6.1
- Etchant solutions (for InGaAs selective etch from InAlAs and InAlAs selective etch from AlAs)

MA: H$_2$O$_2$ (25:1):

<table>
<thead>
<tr>
<th>Material</th>
<th>Etch rate (nm/min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>In$<em>{0.53}$Ga$</em>{0.47}$As</td>
<td>100</td>
</tr>
<tr>
<td>In$<em>{0.52}$Al$</em>{0.48}$As</td>
<td>6</td>
</tr>
<tr>
<td>AlAs</td>
<td>1.23</td>
</tr>
</tbody>
</table>

Ref. (Broekaert, T.P.E., 1992a,b)

**Methanol:**Br$_2$ (see Br$_2$:methanol)

**Methanol:**Br$_2$:H$_3$PO$_4$ (see Br$_2$:methanol:H$_3$PO$_4$)

**Methanol:**Cl$_2$ (see Cl$_2$:methanol)

**Methanol:**HCl (see HCl:methanol)

**Methanol:**HF (see HF:methanol)

**Methanol:**H$_3$PO$_4$:H$_2$O$_2$ (see H$_3$PO$_4$:H$_2$O$_2$:methanol)

**Methanol:**I$_2$ (see I$_2$:methanol)

**Methanol:**KOH (see KOH:methanol)

**Monoethanolamine solution with NH$_4$OH:H$_2$O** (see NH$_4$OH:H$_2$O)

**Na$_2$CO$_3$**

0.1 M Na$_2$CO$_3$; GaAs photolithography profiles; Ref. (Rideout, V.L., 1972)

GaAs photolithography profiles for 0.1 M Na$_2$CO$_3$; Ref. (Notten, P.H.L., 1986)

**NaOCl**

NaOCl:H$_2$O (1:5); GaAs jet etch thinning; etch gives a grainy structure; Ref. (Biedermann, E., 1966)
NaOCl; GaAs etch-polish to remove surface polish damage; Ref. (Fronius, H., 1987)

NaOCl:H₂O (1:20); GaAs chemi-mechanical polishing solution; Ref. (Rideout, V.L., 1972)

NaOCl:H₂O; GaAs chemomechanical polishing; Ref. (Khoukh, A., 1987)

Chlorox:H₂O (1:4) {where Chlorox household bleach is 5.25% NaOCl solution}; Application: GaAs selective etch from AlGaAs; Ref. (Yang, Y.J., 1987)

NaOCl(aqueous solution); masked pattern etch profiles on (0 0 1)GaAs; Ref. (Adachi, S., 1983)

NaClO (5% solution); AlGaAs/GaAs stained, chemi-mechanical beveled cross-section quantum well layer delineation; Ref. (Holonyak, N., 1979)

NaClO:(CH₃CO)₂O:KOH:H₂O; solution for mechano-chemical polishing of AlGaAs (1 1 1)A flat surfaces; Ref. (Sawafuji, Y., 1999)

NaOCl:HCl (see HCl:NaOCl)

NaOCl:NaOH

1 M NaOCl in 0.1 M NaOH; GaAs photolithography profiles; Ref. (Rideout, V.L., 1972)

GaAs photolithography profiles for 1 M NaOCl in 0.1 M NaOH; Ref. (Notten, P.H.L., 1986)

NaOH

NaOH:H₂O (1:2); Surface cleaning effects on GaAs light emission from Schottky contacts; assessment of etching on electronic surface behavior; Ref. (Adachi, H., 1981a)

NaOH:H₂O (33 wt.% solution); InN etch rate at 50°C = 65 Å/min; Ref. (Guo, Q.X., 1992)

Electrochemical etch; GaAs; NaOH electrolyte; removal of p-substrate from n-layer; Ref. (Nuese, C.J., 1970)

Electrochemical dissolution study of GaP in electrolytes of NaOH, K₃Fe(CN)₆, H₂SO₄; Ref. (Memming, R., 1968)

1 M NaOH is electrolyte; n-InP defect delineation electrochemical etch under illumination; Ref. (Yamamoto, A., 1981)

NaOH electrolyte; photochemical etching of n-GaSb; aerated solution to oxidize Sb; matte gray, faceted surface; Ref. (Propst, E.K., 1993)

NaOH:H₂O (1:1); GaN etch at 5–90°C; Ref. (Chu, T.L., 1971)

NaOH (20%); Al etchant; 60–90°C; Ref. (Glang, R., 1970)
NaOH (3N); electrolyte for electrochemical etching of GaP; selective removal of p-type material from n-type; Ref. (Meek, R.L., 1972)

NaOH (0.1 mol/l); anodic etching of GaN films results in accumulated gallium oxide deposits and slow etch rates; Ref. (Ohkubo, M., 1998)

NaOH (0.1N) electrolyte for etching GaN; Ref. (Pankove, J.I., 1972)

NaOH Free etch and mechano-chemical polishing of GaN; Ref. (Weyher, J.L., 1997)

NaOH:H2O2

NaOH:H2O2 (1 M:0.8 M); XPS study of InP surface oxides following chemical treatment; Ref. (Hollinger, G., 1985)

NaOH:H2O2:H2O (12:1:10); GaAs and InP; no erosion of photoresists; Ref. (Adachi, S., 1981e)

NaOH:H2O2:H2O (2:x:100), 1 < x < 10; GaAs etch rate study shows proportional dependence on H2O2 concentration; low etch rates are surface reaction limited and show flat bottomed profiles; high etch rates are H2O2-diffusion limited and show enhanced etching at mask edges; Ref. (Kohn, E., 1980)

H2O2:NaOH (1:5); GaAs etch gives rough surface texture; Ref. (Merz, J.L., 1976)

NaOH:H2O2 (1:1); Measurement of residual surface oxide; Ref. (Shiota, I., 1977)

NaOH (1N):H2O2 (1:1) at 30°C for 1 min; Surface study by AES and XPS of GaAs; Ref. (Yoon, H.J., 1992)

NaOH:H2O2:H2O (1:3:30); GaAs Schottky contact study; Ref. (Adachi, H., 1981a)

NaOH:H2O2:H2O (1:3:150); GaAs Schottky contact study; Ref. (Adachi, H., 1981a)

Electrochemical C–V profiling; p–n AlGaAs with 1 M NaOH electrolyte (gives poor results); Ref. (Cabaniss, G.E., 1988)

H2O2:NaOH (3:1); GaAs (0 0 1) orientation determination; Ref. (Faust, J.W., 1960)

1N NaOH:H2O2:H2O (1:1:10); masked pattern etch profiles on (0 0 1)GaAs; Ref. (Adachi, S., 1983)

NaOH:H2O2:NH4OH

NaOH:H2O2:NH4OH (5:1:1); Application: GaAs/AlGaAs laser mirror etch; Ref. (Itoh, K., 1977)

1N NaOH:H2O2:NH4OH (5:1:1); masked pattern etch profiles on (0 0 1)GaAs; Ref. (Adachi, S., 1983)
NaOH:KOH (see KOH:NaOH)

NaOH:NaCl

NaOH (0.1 mol/l):NaCl (0.2 mol/l); anodic etching of GaN films with reduced surface deposits and accelerated etch rates; Ref. (Ohkubo, M., 1998)

NaOH (0.1 mol/l):NaCl (0.03 mol/l); electrolyte for photoinduced electrochemical etching of GaN; Ref. (Ohkubo, M., 1999)

NaOH:NaOCl (see NaOCl:NaOH)

NaH2PO4

Sodium dihydrogen orthophosphate (0.3 M); electrolyte for photoelectrochemical enhancement of defect structure on GaAs surfaces; Ref. (Faktor, M.M., 1978)

NaSCN:H2SO4 (see H2SO4:NaSCN)

Na2S:H2O

Na2S:H2O (1:9); sulfide passivation of GaAs, InP, GaP; Ref. (Bessolov, V.N., 1995b)

Na2S:H2O (2 and 0.4 M); sulfide passivation of GaAs; Ref. (Berkovits, V.L., 1998)

Na2S:isopropanol (1:9); surface passivation of GaAs; reduces surface recombination and increases photoluminescence efficiency; comparison to passivation with Na2S:H2O (1:9) Na2S:ethylene glycol (1:9); Ref. (Bessolov, V.N., 1995a)

Na2S solution passivation of GaAs surfaces; dependence on the solvent dielectric constant; comparison of water, ethylene glycol, ethanol, isopropanol, butanol and tert-butanol. Photoluminescence efficiency increases as surface oxygen is replaced with sulfur; Ref. (Bessolov, V.N., 1996)

Na2S alcohol solutions; Study of passivation efficiency; Ref. (Bessolov, V.N., 1997a)

Na2S:isopropanol (1:9); sulfidization to reduce optical degradation in InGaAs/AlGaAs laser mirrors; Ref. (Bessolov, V.N., 1995c)

Sulfide passivation study on GaAs; dependence on sulfur activity and solvent dielectric constant. (NH4)2S (20%) Na2S:H2O (60%) S2Cl2:CCl4 (1:10) (NH4)2S:i-C3H7OH (20 v/o in isopropanol) (NH4)2S:i-C4H9OH (10 v/o in tert-butanol) Na2S:i-C3H7OH Na2S:i-C4H9OH; Ref. (Bessolov, V.N., 1998)

NaS solution GaAs sulfidization; Ref. (Shun, J., 1991) Na2S:isopropanol (saturated solution); sulfur passivation of InGaAsP/InP laser diodes; reduced surface recombination; Ref. (Hakimi, R., 1997)
(NH₄)₂C₄H₄O₆H (ammonium tartarate)

3 M ammonium tartarate; GaAs, electrolyte for electrochemical C–V profiling; Ref. (Akatsu, Y., 1987); (Faur, M., 1993c)

NH₃F₂:o-H₃PO₄ (UNIEL etch)

NH₃F₂:o-H₃PO₄ (UNIEL); Electrolyte for EC-V profiling InP and GaAs; Ref. (Faur, M., 1994b)

NH₄F:HF (see HF:NH₄F)

(NH₄)₂HPO₄:H₂O

(NH₄)₂HPO₄:H₂O; (neutral electrolyte) for anodization of GaAs; Ref. (Schwartz, B., 1976a)

NH₄OH

NH₄OH and NH₄OH:H₂O (1:1); Surface cleaning effects on GaAs light emission from Schottky contacts; assessment of etching on electronic surface behavior; Ref. (Adachi, H., 1981a)

Br₂/methanol; InGaAs surface treatment followed by H₂O rinse and H₂O:NH₄OH (1:1) gives best contaminant-free interface; Ref. (Aspnes, D.E., 1982a)

NH₄OH:H₂O electrochemical etch with pH = 10.6–13.4; GaAs delineation of striations, dislocations and twins; Ref. (Green, L.I., 1977)

NH₄OH; InP oxide removal; Surface treatment scanning photoluminescence study; Ref. (Krawczyk, S.K., 1986)

NH₄OH:H₂O (1:1); GaAs oxide stripping etch; Ref. (Niehaus, W.C., 1976)

NH₄OH:H₂O; basic electrolyte for GaAs anodization; Ref. (Schwartz, B., 1976a)

NH₄OH:H₂O (1:10–50); Application: GaAs patterned substrate cleaning prior to OMVPE regrowth; attacks primarily surface oxides; Ref. (York, P.K., 1992)

NH₄OH:H₂O (1:1); III–V pre-etch surface oxide removal; Ref. (Aspnes, D.E., 1981)

NH₄OH dilute; GaSb and AlGaSb selective etch from InAs; Ref. (Yoh, K., 1991)

NH₄OH electrochemical etch; GaAs; dislocation etch pit delineation; comparison with A–B etch and molten KOH etch; Ref. (Wagner, W.R., 1981)

NH₄OH (30% aq.):H₂O₂ (30% aq.) (3:100); AlGaAS on GaAs layer delineation; a few seconds; Ref. (Nagmune, Y., 1993)

NH₄OH:H₂O with DI water rinse; removal of dry etch residues; Ref. (Pearton, S.J., 1993c)
NH$_4$OH:H$_2$O (1:15); Application: GaAs native oxide removal, 15 s; Ref. (Jeong, Y.-H., 1994)

NH$_4$OH:H$_2$O (1:18); GaAs surface oxide removal prior to MBE overgrowth; Ref. (Reed, J.D., 1995)

NH$_4$OH:H$_2$O (1:20); Application: GaAs surface cleaning for Ohmic contact deposition; 30 s then spin dried for native oxide removal; Ref. (Ren, F., 1994)

NH$_4$OH:H$_2$O (3%); native oxide removal from GaAs to demonstrate that plasma etch rates do not depend on initial presence of oxides; Ref. (Bailey III, A.D., 1995)

NH$_4$OH:H$_2$O (1:10); GaAs surface oxide removal prior to other etching; Ref. (Carter-Coman, C., 1997)

NH$_4$OH:H$_2$O (1:10); oxide removal from InAlAs; 20 s; prior to deposition of silicon nitride passivation layer; Ref. (Decorby, R.G., 1997)

NH$_4$OH:H$_2$O (1:1); oxide removal agent from GaAs; Ref. (DeSalvo, G.C., 1996)

Monoethanolamine solution with NH$_4$OH:H$_2$O (1:5); treatment of GaAs prior to Ohmic contact metallization; Ref. (Kagadei, V.A., 1999)

NH$_4$OH:H$_2$O (1:1) deoxidation of GaAs, GaSb and InAs surfaces, 10 min, N$_2$ dried; Ref. (Lin, J.-L., 1995)

NH$_4$OH: H$_2$O (1:20); oxide removal from GaAs for bonding to Si; Ref. (Peake, G.M., 1999)

NH$_4$OH:H$_2$O (1:5); initial oxide removal from GaAs prior to etching; Ref. (Schneider, M., 1987)

NH$_4$OH:EDTA (see NH$_4$OH:EDTA)

NH$_4$OH:H$_2$O$_2$

GaAs

NH$_4$OH:H$_2$O$_2$:H$_2$O (10:1:10) Application: GaAs (1 0 0) substrate cleaning for MBE; Ref. (Arent, D.J., 1989)

NH$_4$OH:H$_2$O$_2$:H$_2$O (3:1:120); Application: GaAs surface cleaning, 1 min followed by H$_2$O rinse followed by HCl:H$_2$O (1:1); 2 min oxide removal; Ref. (Auret, F.D., 1992)

NH$_4$OH:H$_2$O$_2$:H$_2$O (1:4:20) GaAs etch rate = 1.8 $\mu$m/min; Ref. (Colliver, D.J., 1976)

NH$_4$OH:H$_2$O$_2$ (1:700); GaAs chemi-mechanical polishing solution; Ref. (Dyment, J.C., 1971)

NH$_4$OH:H$_2$O$_2$:H$_2$O (20:7:973); GaAs (1 1 1)B etch rate = 0.2 $\mu$m/min; GaAs (1 0 0) etch rate = 0.12 $\mu$m/min; GaAs (1 1 1)A etch rate = 0.037 $\mu$m/min; shows much less SiO$_2$ mask undercutting than with NaOH:H$_2$O$_2$ etchant; Ref. (Gannon, J.J., 1974)
NH₄OH:H₂O₂:H₂O (1:1:x), 16 < x < 50; GaAs etch rate study shows proportional dependence on H₂O₂ concentration; low etch rates are surface reaction limited and show flat bottomed profiles; high etch rates are H₂O₂-diffusion limited and show enhanced etching at mask edges; Ref. (Kohn, E., 1980)

HN₄OH:H₂O₂:H₂O; Review of GaAs etching and surface preparation; Ref. (Mukherjee, S.D., 1985)

NH₄OH:H₂O₂:H₂O (10:5:1000); GaAs (1 0 0) surface cleaning XPS study; Ref. (Olivier, J., 1990)

NH₄OH:H₂O₂:H₂O (2:1:10); GaAs substrate cleaning for OMVPE; Ref. (Olson, J.M., 1989)

NH₄OH:H₂O₂:H₂O; attacks photoresists; Ref. (Otsubo, M., 1976)

NH₄OH:H₂O₂:H₂O (1:1:2); GaAs surface cleaning analysis by Auger analysis and Au layer epitaxy behavior; Ref. (Vermaak, J.S., 1977)

NH₄OH:H₂O₂:H₂O (20:7:1000); GaAs vee-grooves through a Si₃N₄ mask; Ref. (Yeats, R.E., 1977)

H₂O₂; H₂O₂:NH₄OH, pH ~ 7; and H₂O; Application: GaAs surface oxidation for study of effects on laser degradation; Ref. (Schwartz, B., 1972)

NH₄OH:H₂O₂ (pH ~7.6); Application: GaAs selective substrate removal; Ref. (Sugg, A.R., 1993)

NH₄OH:H₂O₂:H₂O (1:1:20); GaAs surface treatment to remove damage, 2 min at RT; Ref. (Hirot a, Y., 1993, 1995)

NH₄OH:H₂O₂:H₂O (1:2:1 wt%), diluted 1:100 by H₂O; GaAs pattern etch through Si mask; Ref. (Snow, E.S., 1993)

NH₄OH:H₂O₂:H₂O (1:1:5); masked pattern etch profiles on (0 0 1)GaAs; Ref. (Adachi, S., 1983)

NH₄OH:H₂O₂:H₂O (1:1:8)); field emitter tip formation on GaAs by etching through square mask patterns; Ref. (Ducroquet, F., 1999)

NH₄OH:H₂O₂:H₂O (2:1:12); Application: GaAs substrate cleaning for OMVPE growth, 1 min Ref. (Lee, S.H., 1997)

NH₄OH:H₂O₂:H₂O (1:1:20); selective removal of polycrystalline GaAs from Si mask; Ref. (Peake, G.M., 1999)

AlGaAs/GaAs

NH₄OH:H₂O₂:H₂O (5:3:80); Application: GaAs/AlGaAs for 6 s; photolithography isolation of Hall bars; Ref. (Ghanbari, R.A., 1992)

NH₄OH:H₂O₂:H₂O (1:1:400); AlGaAs surface cleaning 15 s etch prior to loading for AlGaAs regrowth; Ref. (Guel, G., 1992)
H₂O₂ with NH₄OH added to adjust pH from 7.2 to 8.6; GaAs selective etch from Al₀.₁₆Ga₀.₈₄As with selectivity > 30 at pH = 8.4; Ref. (Kenefick, K., 1982)

NH₄OH:H₂O₂ (1:60); GaAs selective removal from AlGaAs by jet thinning; GaAs etch rate at 0°C = 60 μm/h with selectivity of 60; Ref. (Lepore, J.J., 1980)

NH₄OH:H₂O₂ (1:225) {pH = 7.04}; Application: GaAs selective removal from Al₀.₂₅Ga₀.₇₅As; GaAs etch rate = 6 μm/h with selectivity of 10; Ref. (Logan, R.A., 1973a)

NH₄OH:H₂O₂ (1:225) {pH = 7}; Application: GaAs selective etch from AlGaAs; Ref. (Merz, J.L., 1979)

NH₄OH:H₂O₂:H₂O (3:1:50); AlGaAs/GaAs thinning etch; real-time etch rate monitoring by optical interferometry of AlGaAs/GaAs and InGaAsP/InP structures; Ref. (Chand, N., 1993)

NH₄OH:H₂O₂ (1:170); Application: GaAs selective etch from Al₀.₄₂Ga₀.₅₈As; Ref. (Fricke, K., 1994)

NH₄OH:H₂O₂:H₂O (2:0.7:100); Application: Al₀.₄₂Ga₀.₅₈As selective etch from GaAs; Ref. (Fricke, K., 1994)

NH₄OH:H₂O₂:H₂O (20:2:100); AlGaAs/GaAs; in situ measurement of growth rate dependence on solution stirring; Ref. (Wipiejewski, T., 1993)

NH₄OH:H₂O₂:H₂O (1:3:16); Application: selective removal of GaAs from AlGaAs; Ref. (Ankri, D., 1982)

NH₄OH:H₂O₂; GaAs substrate removal using AlAs or AlGaAs etch stop layers; Ref. (Carter-Coman, C., 1997)

NH₄OH:H₂O₂:H₂O (30:1:72 wt.%); selective removal of GaAs substrate from Al₀.₇Ga₀.₃As etch stop layer; Ref. (Moran, P.D., 1999)

NH₄OH:H₂O₂ (1:30); Application: selective removal of GaAs from AlGaAs etch stop layer for micromachining; undercutting etch rate is 2 μm/min; non-uniform etching after 5 min

NH₄OH:H₂O₂ (1:50); Application: selective removal of GaAs from AlGaAs etch stop layer for micromachining; undercutting etch rate is 1 μm/min; non-uniform etching after 5 min Ref. (Ribas, R.P., 1998)

NH₄OH:H₂O₂:H₂O (1:10:10); selective patterning of a GaAs mask on AlGaAs; Ref. (Schumacher, C., 1999)

NH₄OH:H₂O₂ (1:30); selective etch of Al₀.₆Ga₀.₄As sacrificial layer for micromachining GaAs; Ref. (Uennisishi, Y., 1994)

NH₄OH:H₂O₂; selective removal of GaAs substrate from Al₀.₇Ga₀.₃As etch stop layer; Ref. (Zhang, C., 1999)
NH₄OH:H₂O₂:H₂O (4:1:2000); 30 Å surface etch following dry etch of InGaAs/AlGaAs; Ref. (Ko, K.K., 1992)

Anodization; GaAs using H₂O₂ electrolyte with pH adjusted by H₃PO₄ or NH₄OH; Ref. (Logan, R.A., 1973b)

**GaAs/InGaP**

NH₄OH:H₂O₂:H₂O (10:4:500); Application: GaAs selective etch from InGaP for FET fabrication; Ref. (Razeghi, M., 1991)

NH₄OH:H₂O₂:H₂O; Application: selective removal of GaAs from InGaP; Ref. (Ginoudi, A., 1992)

NH₄OH:H₂O₂ (pH = 8.4); Application: selective etch of GaAs from InGaP; Ref. (Lu, S.S., 1992)

**InGaAs/GaAs**

H₂O₂ buffered with NH₄OH (pH = 7); InGaAs selective etch from GaAs; at 21°C InGaAs etch rate = 740 Å/min; GaAs etch rate = 67 Å/min; Ref. (Gréus, Ch., 1991); (Schmidt, A., 1992)

H₂O₂:NH₄OH (250:1), pH = 7.3; GaAs selective etch from InGaAs, selectivity > 50; attacks photoresists; SiO₂ photolithographic mask defined by buffered HF etch; Ref. (Hill, D.G., 1990)

H₂O₂:NH₄OH (10:1); InGaAs surface cleaning prior to anodization; Ref. (Shirafuji, J., 1982)

NH₄OH:H₂O₂:H₂O; InGaAs dislocation etch pit delineation; Ref. (Susa, N., 1981)

NH₄OH:H₂O₂:H₂O (3:1:130); mesa etch for AlGaAs/InGaAs; 3000 Å/min Ref. (Berg, E.W., 1998)

NH₄OH:H₂O₂:H₂O (1:1:20); Application: selective pattern etch through GaAs mask layer onto AlGaAs spacer layer; Ref. (Peake, G.M., 1997)

NH₄OH:H₂O₂:H₂O (20:7:973); Application: anisotropic GaAs etch for forming micromachined triangular cross-section structures; depth etch rate is 0.5 μm/min; undercutting etch rate is 0.15 μm/min

NH₄OH:H₂O₂:H₂O (20:7:73); Application: anisotropic GaAs etch for forming micromachined triangular cross-section structures; depth etch rate is 0.6 μm/min; undercutting etch rate is 0.6 μm/min; Ref. (Ribas, R.P., 1998)

NH₄OH:H₂O₂:H₂O (1:1:50); GaAs substrate cleaning prior to RIE; Ref. (Juang, Y.Z., 1994)

**InGaAs/InAlAs**

NH₄OH:H₂O₂ (1:30); InGaAs selective etch from InAlAs; Ref. (Adesida, I., 1993a)
InAs

\( \text{NH}_4\text{OH}:\text{H}_2\text{O}_2 \) (1:1); Application: InAs and InSb substrate cleaning; used boiling to remove organic residues; Ref. (Holmes, D.E., 1980)

Si

\( \text{NH}_4\text{OH}:\text{H}_2\text{O}_2 \) Si surface cleaning; Ref. (Rittenhouse, G.E., 1992)

\( \text{NH}_4\text{OH}:\text{H}_2\text{O}_2: \text{adipic acid} \) (see adipic acid:\( \text{NH}_4\text{OH}:\text{H}_2\text{O}_2 \))

\((\text{NH}_4)_2\text{S}_x\)

InP

\((\text{NH}_4)_2\text{S}_x\); InP surface passivation study; Ref. (Maeda, F., 1993)

\((\text{NH}_4)_2\text{S}_x\); Application: surface passivation of InGaP; InGaP/GaAs surface recombination study; Ref. (Pearston, S.J., 1993d)

\((\text{NH}_4)_2\text{S}_x\); InP surface passivation, study of Schottky contact stability; Ref. (1998)

\((\text{NH}_4)_2\text{S}_x\); InP surface passivation, study of Schottky contact stability; Ref. (Ahaitouf, A., 1998)

\((\text{NH}_4)_2\text{S}\); Application: InGaAsP laser facet passivation; Ref. (DeChiaro, L.F., 1992)

S passivation of InP in \( \text{S}_2\text{Cl}_2, (\text{NH}_4)_2\text{S}, \) and sulfide-containing \( \text{Br}_2: \text{methanol} \) solutions; Ref. (Gao, L.J., 1995)

\((\text{NH}_4)_2\text{S}_x \) (6.0–7.5% sulfur concentration); room temperature for 10 min; followed by \( \text{H}_2\text{SO}_4 \) treatment to reduce surface impurities; process acronym is (ACE); surface preparation of InP mesa devices for InP MOVPE regrowth; study of regrown interface quality; Ref. (Yamamoto, N., 1998)

Sulfur passivation of InP; anodization in \((\text{NH}_4)_2\text{S}_x \) solution; study of surface stability; Ref. (Han, I.K., 1997)

\((\text{NH}_4)_2\text{S}_x \); sulfidization of InP surfaces; ammonium polysulfide solution prepared by dissolving about 2–2.5 g free sulfur into 25 ml of commercially available ammonium sulfide solution, then oxidizing by bubbling pure oxygen through it for about 30–45 min. This solution is then diluted with water, 20 drops in 15 ml \( \text{H}_2\text{O} \), and heated with intermittent stirring to 50–60°C with previously etched InP in it; Ref. (Iyer, R., 1991a,b)

\((\text{NH}_4)_2\text{S}_x \)-treated InP; study of surface S atoms; most S atoms on InP (0 0 1) form In–S–In bridge bonds in the first layer; Ref. (Sugiyama, M., 1996)
(NH₄)₂Sₓ (3.5 ml supersaturated solution: 45 ml H₂O); InP passivation; 15 min at 50°C under illumination of a 250 W tungsten lamp; reduction in dark current of MSM photodetectors; good stability; Ref. (Schade, U., 1994)

(NH₄)₂Sₓ InP surface cleaning for MOVPE regrowth; followed by hydrogen gas anneal at 450°C; Ref. (Miyamoto, Y., 1991)

(NH₄)₂Sₓ sulfidation of GaAs and InP; study of surface roughness and oxygen content; Ref. (Choy, W.H., 1999)

**GaAs**

(NH₄)₂S; surface passivation of GaAs; chemical structure study; Ref. (Lu, Z.H., 1993)

(NH₄)₂Sₓ:H₂O (1:1); Application: GaAs sulfide passivation; 20 min at 40°C; Ref. (Jeong, Y.-H., 1994)

(NH₄)Sₓ (10 ml solution with added 1 g sulfur and 2 g phosphorus pentasulfide); GaAs surface passivation, followed by deposition of SiNₓ overlayer; Ref. (Kapila, A., 1995)

(NH₄)₂S alcohol solutions; Na₂S alcohol solutions; Study of passivation efficiency; Ref. (Bessolov, V.N., 1997a)

Study of GaAs barrier height shift with surface sulfidization using:
- (NH₄)₂S (20%):ethanol (1:9)
- (NH₄)₂S (20%):isopropanol (1:9)
- (NH₄)₂S (20%):tert-butanol (1:9); Ref. (Bessolov, V.N., 1997b)

Sulfide passivation study on GaAs; dependence on sulfur activity and solvent dielectric constant
- (NH₄)₂S (20%)
- Na₂S: H₂O (60%)
- S₂Cl₂:CCl₄ (1:10)
- (NH₄)₂S:i-C₃H₇OH (20 v/o in isopropanol)
- (NH₄)₂S:t-C₄H₉OH (10 v/o in tert-butanol)
- Na₂S:i-C₃H₇OH
- Na₂S:t-C₄H₉OH; Ref. (Bessolov, V.N., 1998)

(HN₄)₂S; GaAs surface passivation; Ref. (Eftekhari, G.Rh., 1996)

(NH₄)₂Sₓ; GaAs surface treatment for MBE regrowth; Ref. (Furuhata, N., 1998)

(NH₄)₂Sₓ sulfidation of GaAs XPS study; Ref. (Kang, M.-G., 1999)

(NH₄)₂Sₓ solution; sulfur passivation of GaAs; 10 min at 60°C; XPS study of surface bonding states; Ref. (Kang, M.-G., 1997)

(NH₄)₂Sₓ sulfidation of GaAs for contact metalization; Ref. (Shoji, D., 1999)
(NH₄)₂S solution GaAs sulfidization; Ref. (Shun, J., 1991)

(NH₄)₂Sₓ solution; GaAs surface treatment to reduce carbon and oxide contamination prior to CBE regrowth, 40°C for 30 min; Ref. (Sik, H., 1996)

(NH₄)₂Sₓ sulfur passivation of GaAs structures; study of dependence on S concentration in the solution; Ref. (Sik, H., 1994)

P₂S₅:(NH₄)₂S:Sₓ solution; Application: sulfur passivation of GaAs; Ref. (Wu, D., 1997)

(NH₄)₂Sₓ + 6% S solution; Application: sulfur passivation of GaAs; Ref. (Wu, D., 1997)

(NH₄)₂Sₓ solution; GaAs passivation by dipping in solution and annealing at 400°C; Ref. (Yamaguchi, K., 1996)

**InSb**

(NH₄)₂Sₓ sulfidation study of InSb surfaces; Ref. (Ichikawa, S., 1999)

**GaSb**

(NH₄)₂S:H₂O (1:4) and (1:45); sulfur passivation of GaSb; Ref. (Lin, C.L., 1998)

**InAs**

(NH₄)₂Sₓ; InAs; study of surface structure; S replaces outer most As atoms; all S desorbs above 500°C; Ref. (Katayama, M., 1991)

(NH₄)₂Sₓ passivation of InAs/InAsPSb photodetectors; Ref. (Gong, X.Y., 1998)

**AlGaAs(P)**

(NH₄)₂Sₓ solution; study of AlGaAs and InGaP surface passivation; Ref. (Seo, J.M., 1996)

(NH₄)₂Sₓ; Application: surface passivation of AlGaInP laser mirror facets; Ref. (Kamiyama, S., 1991)

**InGa(Al)As**

(NH₄)₂Sₓ (ammonium polysulfide); passivation of InP/InGaAlAs/InGaAs heterostructures for MOCVD regrowth; Ref. (Kollakowski, St., 1998)

(NH₄)₂Sₓ (Ammonium polysulfide); passivation of InP/InGaAlAs/InGaAs heterostructures for MOCVD regrowth; Ref. (Lemm, Ch., 1997)

Polysulfide solution (50 ml (NH₄)₂S, dissolving 5 g sulfur into the solution, then flowing oxygen through the solution, bubbling for 45 min); first step in passivation of InP/InGaAs MSM
photodetectors. \((\text{NH}_4)_2\text{S}\) (8.9% S); second step in passivation of InP/InGaAs MSM photodetectors; Ref. (Pang, Z., 1999)

**GaP**

\((\text{NH}_4)_2\text{S}_x\) solution surface treatment of GaP to remove oxide; Ref. (Wang, X.-L., 1993)

\((\text{NH}_4)_2\text{S}_x\); InGaP surface passivation; Ref. (Pearton, S.J., 1993e); (Pearton, S.J., 1994a)

**GaN**

\((\text{NH}_4)_2\text{S}_x\); 10 min treatment of p-type GaN surface for Pd low resistivity Ohmic contact; Ref. (Kim, J.K., 1999)

\((\text{NH}_4)_2\text{S}_2\text{O}_8:\text{H}_2\text{SO}_4:\text{H}_2\text{O}\)

\((\text{NH}_4)_2\text{S}_2\text{O}_8:\text{H}_2\text{SO}_4:\text{H}_2\text{O}\) (15:75:15); InP surface cleaning; 1 min at RT; followed by Br\(_2\)/methanol for optimum smooth, oxide free (1 0 0) and (1 1 1)P surfaces; Ref. (Kurth, E., 1988)

**NH\(_4\)OH:**\(\text{NaOH}:\text{H}_2\text{O}_2\) (see \(\text{NaOH}:\text{H}_2\text{O}_2:\text{NH}_4\text{OH}\))

**NiSO\(_4\)**

\(\text{NiSO}_4\) (0.8 M) with pH adjusted to 2–3 with \(\text{H}_2\text{SO}_4\), \(\text{H}_2\text{O}\) diluted; nanoscale photoelectrochemical etch of GaAs with STM; Ref. (Kaneshiro, C., 1997)

**NRL etch** (see \(\text{HCl}:\text{HF}:\text{H}_2\text{O}:\text{H}_2\text{O}_2\))

**Oxalic acid:**\(\text{H}_2\text{O}_2\)

Use of organic acids and AlAs etch stop layers for InGaAlAs/InP structures:

Organic acid solutions: OA = oxalic acid: \(\text{H}_2\text{O}\) (15 g:2 l), pH = 6.3 (by adding ammonia)

OCA = oxalic acid: \(\text{H}_2\text{O}:\text{citric acid}\) (25 g:2 l:100 g), pH = 6.3

Etchant solutions (for InGaAs selective etch from InAlAs and InAlAs selective etch from AlAs):

| \(\text{In}_{0.53}\text{Ga}_{0.47}\text{As}\) | 40 |
| \(\text{In}_{0.52}\text{Al}_{0.48}\text{As}\) | 20 |
| AlAs | 0.57 |

| OCA: \(\text{H}_2\text{O}_2\) (25:1) | Etch rate (nm/min) |
| \(\text{In}_{0.53}\text{Ga}_{0.47}\text{As}\) | 75 |
| \(\text{In}_{0.52}\text{Al}_{0.48}\text{As}\) | 5 |
| AlAs | 0.20 |

Ref. (Broekaert, T.P.E., 1992a,b)
Oxalic acid: H₂O₂; InP (1 0 0) etch rate \( \leq 8 \, \text{Å/min} \); Ref. (Clawson, A.R., 1978)

**Pear Etch** (see HCl:HNO₃:isopropanol)

**Photoresist developer**

Photoresist developer Microdeposit MF319 as etchant; GaSb and AlGaSb selective etch from InAs; Ref. (Yoh, K., 1991)

AZ-303 developer; photochemical etchant for n-InP laser-induced maskless grating etching; Ref. (Aoyagi, Y., 1985)

AZ400K developer solution (~10% KOH active ingredient); Selective etchant of In\(_x\)Al\(_{1-x}\)N with \( x \) as high as 75%; etch rates given over temperature range of 20–80°C; does not etch pure InN or GaN; Ref. (Lee, J.W., 1996)

AZ400K photolithographic developer (KOH active ingredient); AZ400K:H₂O (1:5); AlN selective etch from either GaN or Al₂O₃; little undercut at 65°C; significant undercut at 85°C; etching behavior is rate limited; Ref. (Mileham, J.R., 1995)

AZ400K photoresist developer; AlN; rate depends on crystal quality; Ref. (Pearlton, S.J., 1996a)

InGaAs/InP photodiode surface passivation:
   - First step: place device wafer in OCG OPD 4262 positive photoresist developer
   - Second step: mix 2-propanol: H₂SO₄ (1:1) (an exothermic reaction; color changes from clear to amber)
   - Third step: immediately ultrasonically agitate fresh mixture for 15 s and add to developer containing the wafer; agitate this fuming mixture for 1 min
   - Fourth step: decant the bath and spray rinse the wafer with 2-propanol; remove wafer and N₂ blow dry; Ref. (Porkolab, G.A., 1997)

AZ400K photolithographic developer (active ingredient KOH); etch study of AlN and InAlN between 20 and 80°C; Ref. (Vartuli, C.B., 1996d)

**Propane:tricarbolic acid**

InGaAs selective etch from InAlAs and InAlAs selective etch from AlAs; Ref. (Broekaert, T.P.E., 1992b)

**Propylene glycol:HCl** (see HCl:propylene glycol)

**Quinone:hydroquinone** (see C₆H₄O₂:C₄H₆O₂)

**RC etch** (see AgNO₃:HF:HNO₃:H₂O)

**RRE etch** (see HCl:HNO₃:Br₂)
**Secco etch** (see HF:K$_2$Cr$_2$O$_7$)

**SeS$_2$**

SeS$_2$ solution passivation of GaAs surfaces; study of bonding and electrical properties; Ref. (Sun, J., 1999)

**Sirtl etch** (see HF:CrO$_3$)

**Succinic acid:H$_2$O$_2$**

Succinic acid:H$_2$O$_2$ (6:1) pH = 5.5 by adding NH$_4$OH; InGaAs selective etch from InAlAs; Ref. (Bahl, S.R., 1992)

Use of organic acids and AlAs etch stop layers for InGaAlAs/InP structures:
- Organic acid solutions: SA = succinic acid:H$_2$O (200 g:1 l), pH = 4.2
- Etchant solutions (for InGaAs selective etch from InAlAs and InAlAs selective etch from AlAs)
  - SA:H$_2$O$_2$ (15:1):
    - Etch rate (nm/min)
      | Material        | Rate (nm/min) |
      |-----------------|---------------|
      | In$_{0.53}$Ga$_{0.47}$As | 120           |
      | In$_{0.52}$Al$_{0.48}$As | 60            |
      | AlAs            | 0.12          |
      | GaAs            | 180           |

Ref. (Broekaert, T.P.E., 1992a,b)

Succinic acid (C$_4$H$_6$O$_4$):H$_2$O$_2$:NH$_3$ (20:4:1); selective InGaAs from InAlAs; InGaAs etch rate = 5 Å/s; InAlAs etch rate = 0.07 Å/s; Ref. (Daumann, W., 1997)

Succinic acid:H$_2$O$_2$ (30:1); selective etch of InGaAs from InAlAs; selectivity is 1030 for layers lattice-matched to InP; Ref. (Fourre, H., 1996)

Succinic acid:H$_2$O$_2$ (15:2); selective etch of InGaAs from InAlAs; selectivity is 70 for strained layers on GaAs; Ref. (Fourre, H., 1996)

(Succinic acid:NH$_4$OH, pH adjusted over the range 4.9–5.3):H$_2$O$_2$ (15:1), (25:1) and (50:1). Al$_x$Ga$_{1-x}$As etch rate versus pH and $x$; Ref. (Merritt, S.A., 1993)

(Succinic acid:NH$_4$OH):H$_2$O$_2$ (15:1); Application: selective removal of GaAs from AlGaAs etch stop layer for micromachining; very slow lateral etch rate; Ref. (Ribas, R.P., 1998)

**Tartaric acid**

Tartaric acid (40 w/o solution):H$_2$O$_2$ (1:1); InP (1 0 0) etch rate = 6 Å/min; Ref. (Clawson, A.R., 1978)
Tartaric acid (40 w/o solution):H₂O₂ (3:1); InP (1 0 0) etch rate = 120 Å/min; Ref. (Clawson, A.R., 1978)

Tartaric acid (3%):propylene glycol (1:3) electrolyte for InP anodization; Ref. (Schmitt, F., 1983)

Tartaric acid (3%):propylene glycol (1:3), pH = 7.2 adjusted with NaOH; anodization; Application: InP for InGaAsP/InP stripe laser; Ref. (Sakai, S., 1979b)

Tartaric acid (3%) with pH adjusted to 7 by adding NH₄OH; Application: InGaAs anodization; Ref. (Shirafuji, J., 1982)

KOH:tartaric acid:ethylenediamine tetra-acetic acid:H₂O (70 g:4 g:8 g:78 g); mixed with H₂O₂ (5:2); InSb surface cleaning for AES studies; Ref. (Auret, F.D., 1982)

Tartaric acid (40%):H₂O₂ (30%) (3:1); InP; rate = ~2000 Å/h; used as Schottky contact for C/V carrier concentration profiling; Ref. (Lile, D.L., 1978)

Tartaric acid (3 w/o) buffered with NH₄OH: ethylene glycol (1:2); electrolyte for GaN photoassisted anodic etch; rate dependence on current and pH; Ref. (Lu, H., 1997)

**Tartaric acid:HNO₃**

HNO₃:tartaric acid (1:3); GaSb; (0 0 1) orientation determination; Ref. (Faust, J.W., 1960)

HNO₃:tartaric acid (3:1); GaAs; (0 0 1) orientation determination; Ref. (Faust, J.W., 1960)

**Tartaric acid:HNO₃:H₂O₂**

HNO₃:H₂O₂:tartaric acid (1:1:6); InAs; (0 0 1) orientation determination; (1 1 1)A planes etch faster than (1 1 1)B planes; Ref. (Faust, J.W., 1960)

**Tartaric acid:H₂O₂**

Tartaric acid:H₂O₂ (1:1); InGaAs selective etch from InP; InGaAs etch rate = 3000 Å/min; InP etch rate = 6 Å/min; Ref. (Elder, D.I., 1983, 1984)

Tartaric acid:H₂O₂:H₂O (1:1:10); InGaAs etch rate = 1000 Å/min; InGaAs selective etch from InP; Ref. (Elder, D.I., 1983, 1984)

Tartaric acid:H₂O₂:H₂O (1:1:20); InGaAs etch rate = 600 Å/min; InGaAs selective etch from InP; Ref. (Elder, D.I., 1983, 1984)

Tartaric acid:H₂O₂:H₂O (1:1:10); selective etch of InGaAs from 75 Å InP etch stop layer; InGaAs etch rate (room temperature) = 750 Å/min; a bluish surface appears with the final removal of InGaAs then disappears as etching terminates at the InP stop layer; Ref. (Mullin, D.P., 1994)
Tetraethylammonium hydroxide

TEAH (tetraethylammonium hydroxide) (40%):H₂O; transverse (i.e. sidewall) etch for GaN; no etch in the (0 0 0 1) direction

Tiron

Tiron; (4,5-dihydroxy-1,3-benzenedisulfonic acid); Photoelectrochemical etching of n-GaAs; dependence on orientation and doping concentration; 0.5 M Tiron electrolyte (4,5-dihydroxy-1,3-benzenedisulfonic acid); shows cross-sectional profiles; Ref. (Carrabba, M.M., 1986, 1987)

Electrochemical C–V profiling; GaAs carrier concentration and electron mobility using Tiron electrolyte (1,2 dihydroxybenzene-3,5 disulphonic acid, disodium salt, aqueous solution); Ref. (Ambridge, T., 1979a)

Tiron (0.5 M); electrolyte for photoelectrochemical enhancement of defect structure on GaAs surfaces; Ref. (Faktor, M.M., 1978)

Tiron electrolyte for C–V profiling of InP and GaAs materials; Ref. (Faur, M., 1994c)

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H₂SO₄:H₂O₂:H₂O (3:1:1); Application: InGaAsP selective etch from InP for laser fabrication

HCl:H₂O (4:1); InP selective etch from InP for laser fabrication

ECR plasma etch; CH₄/H₂; Cl₂/H₂; CCl₂F₂/Ar; InN, presence of H₂ or F₂ is necessary for equi-rate removal of group III and nitrogen etch products


H₂O:AgNO₃:CrO₃:HF (2 ml:8 mg:1 g:1 ml) {A–B etch}; GaAs dislocation etch pit delineation A–B etch; two part mix for indefinite storage Ref. (Olsen et al., 1974):
\[ \text{A solution: } H_2O:AgNO_3:HF (40 ml:0.3 g:40 ml) \]
\[ \text{B solution: } CrO_3:H_2O (40 g:40 ml) \]
Mix A + B (1:1) for fresh etchant

Surface cleaning effects on GaAs light emission from Schottky contacts; assessment of etching on electronic surface behavior for:
\[
\begin{align*}
&\text{NH}_4\text{OH} \\
&\text{HCl}:\text{H}_2\text{O} \ (1:1) \\
&\text{HCl}:\text{H}_2\text{O}_2\cdot\text{H}_2\text{O} \ (1:20:50) \\
&\text{NH}_4\text{OH}:\text{H}_2\text{O} \ (1:1) \\
&\text{H}_2\text{SO}_4\cdot\text{H}_2\text{O}_2\cdot\text{H}_2\text{O} \ (20:1:1) \\
&\text{H}_2\text{SO}_4\cdot\text{H}_2\text{O}_2\cdot\text{H}_2\text{O} \ (1:1:250) \\
&\text{NaOH}:\text{H}_2\text{O} \ (1:2) \\
&\text{NaOH}:\text{H}_2\text{O}_2\cdot\text{H}_2\text{O} \ (1:3:30) \\
&\text{NaOH}:\text{H}_2\text{O}_2\cdot\text{H}_2\text{O} \ (1:3:150) \\
&\text{H}_3\text{PO}_4\cdot\text{H}_2\text{O}_2 \ (10:1) \\
&\text{H}_3\text{PO}_4\cdot\text{H}_2\text{O}_2\cdot\text{H}_2\text{O} \ (10:1:1)
\end{align*}
\]

\[ \text{HBr:CH}_3\text{COOH}:K_2\text{Cr}_2\text{O}_7 \ (1:1:1); \text{InP} \ (1 \ 0 \ 0) \text{ etch rate } = 3 \ \mu m/min \text{ non-stirring; } = 25 \ \mu m/min \text{ with stirring} \]
\[ \text{HBr:CH}_3\text{COOH}:K_2\text{Cr}_2\text{O}_7\ (1:2:1); \text{InP} \ (1 \ 0 \ 0) \text{ etch rate } = 1.5 \ \mu m/min, \text{ non-stirring; etch pit free surfaces; etch pits form at lower K}_2\text{Cr}_2\text{O}_7 \text{ concentrations; data is given on etch rate dependences on concentrations, surface quality, and photolithography etch profiles; nearly equal etch rates on InP and InGaAsP. HBr:CH}_3\text{PO}_4:K_2\text{Cr}_2\text{O}_7 \ (2:2:1); \text{InP and InGaAsP equal etch rate } = 1.5 \ \mu m/min; \text{ does not attack photoresist} \]

Review: InP etching overview; wet chemical and dry etching

Review: InP wet chemical etching; with: (1) defect or damage revealing etchant table, (2) polishing etchant table, and (3) pattern etchant table

InP photolithography: vee and dovetail groove cross-section etch profiles:
\[ \text{HCl; InP etch rate at } 25^\circ C \sim 12 \ \mu m/min \]
\[ \text{HCl:H}_2\text{O} \ (1:1); \text{InP etch rate at } 25^\circ C \sim 0.07 \ \mu m/min \]
\[ \text{HCl:H}_2\text{O}_2 \ (1:1); \text{InP etch rate at } 25^\circ C \sim 2.3 \ \mu m/min \]
HCl:CH₃COOH (1:1); InP etch rate at 25°C ~6.0 µm/min
HCl:H₃PO₄ (1:1); InP etch rate at 25°C ~4.0 µm/min
HCl:H₂O₂:H₂O (1:1:1); InP etch rate at 25°C ~0.1 µm/min
HCl:CH₃COOH:H₂O₂ (1:1:1); InP etch rate at 25°C ~4.0 µm/min
HCl:H₃PO₄:H₂O₂ (1:1:1); InP etch rate at 25°C ~2.0 µm/min
HCl:HNO₃ (1:1); InP etch rate at 25°C ~6.5 µm/min
HCl:HNO₃ (1:2); InP etch rate at 25°C ~7.0 µm/min
HCl:HNO₃ (2:1); InP etch rate at 25°C ~8.5 µm/min
HCl:HNO₃:H₂O₂ (1:1:2); InP etch rate at 25°C ~0.1 µm/min
HCl:HNO₃:CH₃COOH (1:1:2); InP etch rate at 25°C ~1.0 µm/min
HBr; InP etch rate at 25°C ~6.5 µm/min
HBr:H₂O₂ (1:1); InP etch rate at 25°C ~23 µm/min
HBr:CH₃COOH (1:1); InP etch rate at 25°C ~3.0 µm/min
H₃PO₄:HBr (1:1); InP etch rate at 25°C ~2.0 µm/min
HBr:HNO₃ (1:1); InP etch rate at 25°C ~11.0 µm/min
HBr:HNO₃:H₂O (1:1:5); InP etch rate at 25°C ~9.0 µm/min
H₂SO₄:H₂O₂ (1:1); InP etch rate at 60°C ~0.2 µm/min
H₂SO₄:H₂O₂:H₂O (1:1:1); InP etch rate at 60°C ~0.17 µm/min
H₂SO₄:H₂O₂:H₂O (3:1:1); InP etch rate at 60°C ~0.12 µm/min
K₂Cr₂O₇:H₂SO₄:HCl (3:1:1); InP etch rate at 60°C ~0.10 µm/min
Br/methanol (4%); InP etch rate at 25°C ~25 µm/min
Br/methanol (2%); InP etch rate at 25°C ~18 µm/min
Br/methanol (1%); InP etch rate at 25°C ~12 µm/min
Br/methanol (0.2%); InP etch rate at 25°C ~3.5 µm/min
Br/methanol (0.1%); InP etch rate at 25°C ~2.0 µm/min

Br/methanol; Application: InGaAsP/InP laser mirror etch
HCl:CH₃COOH:H₂O₂ (1:2:1) {KKI etch}; Application: InGaAsP/InP laser mirror etch
KI:I₂:H₂O; Application: photolithography etchant for Au/Zn contact layer from InP

Br₂/methanol; Application: InGaAsP/InP laser mirror etch

Br₂/methanol; Application: Photolithography: etch cross-section profiles; laser mirror etch; slight difference in etch rates between InGaAsP and InP

<table>
<thead>
<tr>
<th>Concentration</th>
<th>GaAs (1 0 0) etch rate (μm/min)</th>
<th>InP (1 0 0) etch rate (μm/min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(3:1:0) (60°C)</td>
<td>0.03</td>
<td>None</td>
</tr>
<tr>
<td>(3:1:1) (60°C)</td>
<td>12</td>
<td>0.25</td>
</tr>
<tr>
<td>(3:1:2) (25°C)</td>
<td>2.5</td>
<td>0.5</td>
</tr>
<tr>
<td>(3:1:2) (60°C)</td>
<td>20</td>
<td>1.5</td>
</tr>
<tr>
<td>(3:1:3) (60°C)</td>
<td>30</td>
<td>2.3</td>
</tr>
</tbody>
</table>

Gives GaAs and InP surface quality comparison for:
Br₂/methanol (0.3%); (attacks photoresists)
NaOH:H₂O₂:H₂O (12:1:10); (no erosion of photoresists)
1 M K₂Cr₂O₇:H₂SO₄:HCl (3:1:2)
H₂SO₄:H₂O₂:H₂O (3:1:1)
Gives GaAs and InP groove etch profiles for H₂SO₄:H₂O₂:H₂O (1:1:1) and all the above concentrations of 1 M K₂Cr₂O₇:H₂SO₄:HCl


InP photolithography; vee and dovetail groove cross-section etch profiles:
Br₂/methanol; InGaAsP and InP etch rates are similar for the concentration range from 0.1 to 4% HBr; InP selective etch from InGaAsP
HBr:HCl (2:1) to (1:2); InGaAsP and InP etch rates vary with proportions
HBr:H₂O₂ (1:1); InGaAsP and InP etch rates are similar
HBr:CH₃COOH (1:1); InP selective etch from InGaAsP
H₃PO₄:HBr (1:1); InP selective etch from InGaAsP
HCl: InP selective etch from InGaAsP
HCl:H₂O (1:1); InP selective etch from InGaAsP
HCl:H₂O₂ (1:1); InP selective etch from InGaAsP
HCl:CH₃COOH (1:1); InP selective etch from InGaAsP
HCl:CH₃COOH:H₂O₂ (1:1:1); InGaAsP and InP etch rates are similar
HCl:H₃PO₄:H₂O₂ (1:1:1); InGaAsP and InP etch rates are similar
HCl:HNO₃ (1:1); InGaAsP and InP etch rates are similar
HNO₃:HBr (1:1); InGaAsP and InP etch rates are similar
H₃PO₄:HCl (1:1); InP selective etch from InGaAsP
H₂SO₄:H₂O₂:H₂O (1:1:1); InGaAsP selective etch from InP
H₂SO₄:H₂O₂:H₂O (3:1:1); InGaAsP selective etch from InP
K₂Cr₂O₇:H₂O₂:HCl (3:1:2); InGaAsP selective etch from InP


HBr:CH₃COOH:K₂Cr₂O₇ (2:2:1); nearly equal etch rate ~ 2.5 μm/min for InGaAsP and InP
HBr:CH₃COOH:K₂Cr₂O₇ (1:1:1); Application: InGaAsP/InP laser; does not erode photoresist; provides very smooth and nearly vertical walls

HCl:CH₃COOH:H₂O₂ (1:1:1); masked pattern etch profiles on (0 0 1) GaAs
HCl:H₃PO₄:H₂O₂ (1:1:1)
HCl:CH₃COOH:(1N K₂Cr₂O₇) (1:1:1)
HCl:H₃PO₄:(1N K₂Cr₂O₇) (1:1:1)
HNO₃:H₂O₂ (1:1)
HNO₃:CH₃COOH: (1:1)
HNO₃:H₃PO₄ (1:1)
HNO₃:CH₃COOH:H₂O₂ (1:1:1)
HNO₃:H₃PO₄:H₂O₂ (1:1:1)
HBr:HNO₃ (1:1)
HBr:HNO₃:H₂O (1:1:1)
HBr:CH₃COOH:(1N K₂Cr₂O₇) (1:1:1)
HBr:H₃PO₄:(1N K₂Cr₂O₇) (1:1:1)
H₃PO₄:H₂O₂ (1:1:1)
H₃PO₄:CH₃OH:H₂O₂ (1:1:1)
H₂SO₄:H₂O₂:H₂O (1:1:1)
H₂SO₄:CH₃COOH:H₂O (1:1:1)
H₂SO₄:H₃PO₄:H₂O (1:1:1)
H₂SO₄:HCl:(1N K₂Cr₂O₇) (1:1:1)
HF:HNO₃:H₂O (1:1:1)
HF:HNO₃:H₂O₂ (1:1:1)
HF:HNO₃:CH₃COOH (1:1:1)
HF:HNO₃:H₃PO₄ (1:1:1)
HF:H₂SO₄:H₂O₂ (1:1:1)
Br₂:CH₃OH (4%)
Br₂:CH₃OH (1%); [Br₂:CH₃OH (1%)]:CH₃COOH (1:1)
[Br₂:CH₃OH (1%)]:H₃PO₄ (1:1)
NaOCl(aqueous solution)
NaOCl(aqueous solution):HCl (1:1)
1N NaOH:H₂O₂:H₂O (1:1:10)
1N NaOH:H₂O₂:NH₄OH (5:1:1)
NH₄OH:H₂O₂:H₂O (1:1:5)
1N KOH:H₂O₂:H₂O (1:1:10)
1N KOH:H₂O₂:NH₄OH (5:1:1)

Evaluation of GaAs surface oxides for various cleaning methods. Cleanest surface has ~8 Å film which grows due to air oxidation to ~30Å

Review of InGaAs selective etches:
Citric acid:H$_2$O$_2$ (1:1); InGaAs selective etch from InAlAs
NH$_4$OH:H$_2$O$_2$ (1:30)
H$_2$SO$_4$;H$_2$O$_2$;H$_2$O (1:1:10)
H$_3$PO$_4$;H$_2$O$_2$;H$_2$O (1:1:8)
HCl:H$_2$O (3:1)
Reactive ion etching: CH$_4$:H$_2$; CH$_3$:Br; HBr

Reactive ion etch; CH$_4$/H$_2$; CH$_4$/He; CH$_4$/Ar; Application: InP, InGaAs, InAlAs; InP etch rate $\approx 800$ Å/m; InGaAs etch rate $= 400$ Å/m

Reactive Ion Etch; SiCl$_4$:Ar (1:1) and SiCl$_4$:SiF$_4$ (1:1); GaN

Reactive ion etch; SiCl$_4$; SiCl$_4$:Ar (1:1); SiCl$_4$:SiF$_4$ (1:1); GaN; patterns masked with NiCr; profiles

CAIBE of GaN; Ar ion beam with HCl gas; lower etch rates than with Cl$_2$

Reactive ion etch, HBr; InGaAs selective etch from InAlAs followed by dilute HCl etch to remove surface residues

Reactive ion etch; assessment of damage in InAlAs/InGaAs heterostructures

Reactive Ion Etch; HBr; InGaAs selective etch from InAlAs; selectivity of 160

Reactive ion etch; HBr; selective etch of InGaAs from InAlAs
Inductively coupled plasma etch; BCl\textsubscript{3}/Cl\textsubscript{2}/Ar of GaAs/AlGaAs; high rate, low damage. Study of etch dependence on gas composition

Inductively coupled plasma etch; BCl\textsubscript{3}/Cl\textsubscript{2}; rate/profile study of GaAs/AlGaAs

Reactive ion etch; HBr; Application: InGaAs selective etch from InAlAs; selectivity > 150

Thermochemical HCl vapor etch for InP; low pressure OMVPE substrate etch at 650°C
HCl for InP prior InGaAs growth; etching condition: 152 Torr, 550–750°C; kinetic controlled etch rate increases with T from 550 to 750°C; InP:Fe etch rate is a little faster than InP:S although both have the same activation energy (0.6 eV); InP substrate etch rate is leveled off with $E_a = 0.25$ eV at high temperature; etch rate is independent of gas velocity for both low and high temperature; etched InP:S substrate morphology is better than InP:Fe; optimum etching conditions: low HCl pressure (used to prevent the buildup of InCl on surface), intermediate temperature and reduced chamber pressure

(NH\textsubscript{4})\textsubscript{2}S\textsubscript{x}; InP surface passivation, study of Schottky contact stability

A–B etch; Application: InGaAs dislocation etch pit delineation

Reactive ion etch of InGaAsP/InP lasers using CH\textsubscript{4}/H\textsubscript{2}
HBr:H\textsubscript{2}O\textsubscript{2}:H\textsubscript{2}O removal of RIE damage before MOCVD regrowth

Reactive Ion Etch; SiCl\textsubscript{4}/He/Ar; nanoscale columns in GaAs using gold islands as masks
H$_3$PO$_4$:H$_2$SO$_4$ (1:3); hot solution to clean sapphire substrates for MOVPE growth of GaN

H$_2$SO$_4$:H$_2$O$_2$:H$_2$O (7:1:1); Application: GaAs substrate cleaning for MBE, 1 min 3 M ammonium tartarate; GaAs, electrolyte for electrochemical $C$–$V$ profiling

HF:HNO$_3$; Application: InGaAsP/InP LPE layer cross-section delineation

HCl (36% aqueous solution):methanol (from 1:10 to 1:1000); protects GaAs surface from oxidation to improve photoluminescence intensity

Electron beam-induced HCl maskless pattern etching of GaAs

Electrochemical C–V profiling; InP n- and p-GaAs with HCl (36%) 1 vol.% in methanol electrolyte

Electron-beam-induced Cl$_2$ etching of GaAs patterns

Dimethylzinc; Application: thermochemical vapor etch of GaAs above 380°C in H₂ for OMVPE growth

Electrochemical C–V profiling; GaAs carrier concentration and electron mobility using Tiron electrolyte (1,2-dihydroxybenzene-3,5-disulphonic acid, disodium salt, aqueous solution)

Electrochemical C–V profiling; InP carrier concentration with HCl electrolyte

KOH; electrolyte for Schottky contact in ECV profiling

KOH; electrolyte for Schottky contact in ECV profiling

KOH; electrolyte for Schottky contact in ECV profiling

KOH; electrolyte for Schottky contact in ECV profiling

KOH; electrolyte for Schottky contact in ECV profiling

CAIBE of InP/GaInAsP in N₂/H₂/CH₄; damage study

KOH:K₃Fe(CN)₆·H₂O; Application: InGaAs/InP and p–n junction cleaved cross-section layer delineation
KOH, molten (400°C); GaAs \{100\}; dislocation etch pit delineation; 30 min

NH₄OH:H₂O₂:H₂O (1:3:16); Application: selective removal of GaAs from AlGaAs

H₂SO₄:H₂O₂:H₂O (1:8:1); Application: InGaAs selective etch from InP

I₂:KI:H₂O (1:10:89); photochemical etchant for n-GaAs laser-induced maskless grating etching
AZ-303 developer; photochemical etchant for n-InP laser-induced maskless grating etching

Br₂/methanol; Application: InGaAsP/InP non-selective mesa etch for laser fabrication. HCl:H₂O (4:1); InP selective etch from InGaAsP

NH₄OH:H₂O₂:H₂O (10:1:10) Application: GaAs \{100\} substrate cleaning for MBE. H₂SO₄:-H₂O₂:H₂O (10:2.8:10); GaAs \{100\} photolithography ridge and groove etch showing profiles

CH₃COOH:HCl:H₂O₂ (20:1:1); GaInP surface cleaning; 10 s; prior to photoluminescence measurements

CH₃COOH:HClO₃:HNO₃:HCl (1:1:5:1); Application: InP-n substrate preparation etch for ion implantation
Br₂/methanol (1%); InGaAsP/InP mesa etch

Br₂/methanol (3 vol.%): H₃PO₄ (1:1); Application: InP mesa etch at 45°C
HCl:HNO₃:CH₃COOH:HClO₄ (1:6:1:1); InP (1 0 0) jet thinning etch

Reactive ion etch, CH₄/H₂; InP and InGaAsP selective etch from InAlAs

Reactive ion etch; CH₄/H₂; InP and InGaAsP selective from InAlAs; fluorine free to use with SiO₂ masks

HCl:H₂O (5:1); InP substrate removal from InGaAs/InAlAs structure for transfer to glass substrate

citric acid:H₂O₂ (10:1); selective, anisotropic etch for shaping cantilevers in 2 μm GaAs layers with InGaP etch stop layer
HCl:H₃PO₄ (3:1) and (1:1); selective etch of InGaP from GaAs
H₃PO₄:H₂O₂:H₂O (2:1:10); anisotropic etch of GaAs substrate supporting cantalever stripes

Review; chlorine-based dry etching of III–V semiconductors; advantages of ECR/RIBE over conventional RIE

H₃PO₄:H₂SO₄ (1:3); Surface cleaning (hot) of Al₂O₃ (0001) substrates for GaN growth by MOVPE

Review: GaAs etching overview; wet and dry etching

Review: ion-assisted etching of GaAs; RIE, RIBE, IBAE, and RBIBE techniques; with tables of etchants, etch conditions, and etch rates

Review: ion-beam milling and sputter etching of GaAs; with table of etchants, etch conditions, and etch rates

Review: laser-assisted wet and dry etching of GaAs; with table of etchant, etch conditions, and etch rates

Photochemical dry etching of GaAs in plasma-decomposed HCl + He

Review: plasma etching of GaAs; with table of etchants, etch conditions, and etch rates

Review: wet and dry chemical etching of GaAs; classifies wet etchants as non-electrolyte (those with rates which are diffusion limited or chemical reaction limited) and electrolyte (those based on anodic oxidation followed by dissolution of products); gives tables of wet and dry etchants

ASPNES, D.E., (private communication), (1982a)
Br2/methanol; InGaAs surface treatment followed by H2O rinse and H2O:NH4OH (1:1) gives best contaminant-free interface
H2O2 (30%); InGaAs surface treatment leaves 8–10 Å of In2O3 and Ga2O3

H2SO4:H2O2:H2O (1:1:x) {10 < x < 100}; InGaAs surface study; behavior depends on solution pH

Ellipsometry measurements to assess cleanest and smoothest etched surfaces: NH4OH:H2O (1:1); III–V pre-etch surface oxide removal
Br2:methanol (0.05%), followed by H2O rinse gives most abrupt surface
HF (buffered)
HF (5% in methanol)


K$_3$Fe(CN)$_6$:KOH; Application: InP LPE layer interface delineation
HgCl$_2$:dimethylformamide (100 g:500 ml); In droplet removal from LPE InP surfaces; use ultrasonic agitation to free Hg reaction by-product from surface


InSb surface cleaning for AES studies:
Lactic acid:HNO$_3$ (10:1)
HF:H$_2$O$_2$:H$_2$O (1:1:4)
HF:HNO$_3$:CH$_3$COOH:Br (15:25:15:0.3)
HF:HNO$_3$:CH$_3$COOH (1:2:5)
Br$_2$/methanol (1%)
KOH:tartaric acid:ethylenediamine tetra-acetic acid:H$_2$O (70 g:4 g:8 g:78 g), mixed with H$_2$O$_2$ (5:2)
CH$_3$COOH:HNO$_3$:HF (15:30:15) {CP-4 etch}


NH$_4$OH:H$_2$O$_2$:H$_2$O (3:1:120); Application: GaAs surface cleaning, 1 min followed by H$_2$O rinse followed by: HCl:H$_2$O (1:1); 2 min oxide removal


Plasma passivation of GaAs; NH$_3$ and H$_2$; in situ monitoring of surface reactions with attenuated-total-reflection Fourier-transform-spectroscopy (ATR FTIR)


Plasma surface oxidation; GaAs; FTIR study of surface chemical reactions


KOH:H$_2$O (100 g:500 ml), boiling; Application; InP pre-etch surface cleaning
Br$_2$/methanol; InP thinning etch for measuring diffusion profile
Br$_2$/isopropanol; InP thinning etch for measuring diffusion profile
Br$_2$/methanol (0.5%) InP etch rate = 1.37 μm/min at −10°C
Br$_2$/methanol (1%) InP etch rate = 2.7 μm/min at −10°C
Br$_2$/methanol (1.5%) InP etch rate = 0.5 μm/min at $-10^\circ$C
Br$_2$/isopropanol (1.5%) InP etch rate = 0.5 μm/min at $-10^\circ$C
Br$_2$/isopropanol (2.5%) InP etch rate = 0.86 μm/min at $-10^\circ$C

HCl:HNO$_3$:CH$_3$COOH:HClO$_4$ (3:2:1:3); InP thinning etch; etch rate = 7 μm/min

H$_2$SO$_4$:H$_2$O$_2$:H$_2$O (1:10:220); Application: InGaAs/InAlAs mesa etch; selective from InP stop layer
H$_2$SO$_4$:H$_2$O$_2$:H$_2$O (3:1:1); followed by: Br$_2$/methanol (0.5%); InP substrate cleaning for MBE growth

H$_2$SO$_4$:H$_2$O$_2$:H$_2$O (1:10:220); Application: InAlAs/InGaAs selective etch from InP
Succinic acid:H$_2$O$_2$ (6:1) pH = 5.5 by adding NH$_4$OH; InGaAs selective etch from InAlAs

ECR plasma; Ar/Cl$_2$; Study and modeling of trench profile dependence in GaAs and Si on etch temperature
NH$_4$OH:H$_2$O (3%); native oxide removal from GaAs to demonstrate that plasma etch rates do not depend on initial presence of oxides

ECR etch; trench etching in GaAs; scaling of etch rates to pattern aspect ratio

HF:H$_2$O$_2$:H$_2$O (1:1:10); citric acid:H$_2$O:H$_2$O$_2$ (1:1:8); AlAs selective etch from InP as a sacrifice layer to lift-off InP epilayer from the substrate

Reactive ion etch; SiCl$_4$/SiF$_4$; selective removal of GaAs from AlGaAs; damage effects on MODFETs

Reactive ion etch; SiCl$_4$/SiF$_4$; Application: GaAs selective from AlGaAs for gate recess in MODFET fabrication

HF buffered: RIE SiO$_x$ residue removal


Thermochemical vapor etch; HCl + H$_2$; silicon


KOH solution + 0.02 M K$_2$S$_2$O$_8$; photoenhanced etching of GaN using a Pt mask

HCl:HNO$_3$:H$_2$O (7:1:8); Pt mask removal from GaN; 85°C for 4 min


Reactive ion etch; Cl$_2$; InP


Reactive ion etching of GaN and AlGaN using Cl$_2$/CH$_4$/Ar


HNO$_3$:HCl:H$_2$O (1:1:2); InP (1 0 0) etch rate = 5 μm/min

HCl (37%); InP (1 0 0) etch rate = 6.2 μm/min

H$_2$SO$_4$:H$_2$O:H$_2$O (3:1:1); InP (1 0 0) etch rate = 0.25 μm/min

HCl:HNO$_3$ (1:1); InP (1 0 0) etch rate = 40 μm/min

HCl:HNO$_3$:CH$_3$COOH (1:1:1); InP (1 0 0) etch rate = 5.5 μm/min

HCl:HNO$_3$:CH$_3$COOH (3:1:5); InP (1 0 0) etch rate = 4 μm/min

HCl:HNO$_3$:HClO$_4$:CH$_3$COOH (1:6:1:1); InP (1 0 0) etch rate = 2.5 μm/min

HCl:HNO$_3$:HClO$_4$:CH$_3$COOH (1:3:3:2); InP etch rate = 3.2 μm/min

Br$_2$/methanol (1%); InP (1 0 0) etch rate = 0.4 μm/min

H$_3$PO$_4$ (85%); InP (1 0 0) etch rate at 90°C = 0.15 μm/min


Cl$_2$ assisted Ar ion etching; Application: GaAs/AlGaAs laser facets

H$_3$PO$_4$: H$_2$O$_2$:H$_2$O (1:1:38); Application: InP mesa fabrication
HCl:CH$_3$COOH (1:1); Application: selective removal of InP from InGaAs/AlInGaAs structure

BERDINSKIKH, T., H.E. Ruda, X.Y. Mei, and M. Buchanan, “A kinetic study of structured surface relief patterning of GaP ($\bar{1},\bar{1},\bar{1}$),” J. Electron. Mater., 27(3), 114 (1998)
HCl:CH$_3$COOH:H$_2$O$_2$ (1:1:1); etch for GaP photolithographic patterning; polish on ($-1,-1,-1$); complex relief on (1 1 1) at room temperature. Fresh solution needed; shows time dependent etch rate; discusses etch mechanism. HCl:HNO$_3$ (3:1) (aqua regia); GaP polish on ($-1,-1,-1$); pitted on (1 1 1) for $T \approx 40^\circ$C, complex relief for $T = 65^\circ$C
HCl:HNO$_3$:H$_2$O (2:1:2); GaP polish on ($-1,-1,-1$); pitted on (1 1 1) for $T = 60^\circ$C

NH$_4$OH:H$_2$O$_2$:H$_2$O (3:1:130); mesa etch for AlGaAs/InGaAs; 3000 Å/min
citric acid:H$_2$O$_2$:H$_3$PO$_4$:H$_2$O (55:5:1:220); mesa etch for AlInAs/InGaAs; 480 Å/min
Inductively coupled plasma etch; Cl$_2$; grating etch in AlGaAs/InGaAs QW structures

Inductively coupled plasma etch of nanostructures in GaAs and via holes in InP using a Ni mask with pure Cl$_2$ at 0.1 mTorr

ECR etch damage, time dependence; GaAs

Cl$_2$ ICP plasma passivation of GaAs and InGaAs surface damage

Na$_2$S:H$_2$O (2 and 0.4 M); sulfide passivation of GaAs

Reactive ion etch, first step pattern etch in InP using CH$_4$:H$_2$. (for MOVPE regrowth)
saturated bromine water: HBr: H$_2$O; second step following RIE etch for patterns in InP
FeCN:KOH:H$_2$O; cleaved cross-section layer delineation stain for SEM study

GaAs and InP XPS surface study giving binding energies and Ga/As and In/P surface compositions after etching in: HCl conc.; Br₂/methanol; H₂SO₄

Anodic oxidation; InP; study of oxidation mechanism

Na₂S:isopropanol (1:9); surface passivation of GaAs; reduces surface recombination and increases photoluminescence efficiency; comparison to passivation with:
Na₂S:H₂O (1:9)
Na₂S:ethylene glycol (1:9)

Na₂S:H₂O (1:9); sulfide passivation of GaAs, InP, GaP

Na₂S solution passivation of GaAs surfaces; dependence on the solvent dielectric constant; comparison of water, ethylene glycol, ethanol, isopropanol, butanol and tert-butanol. Photoluminescence efficiency increases as surface oxygen is replaced with sulfur

(NH₄)₂S alcohol solutions
Na₂S alcohol solutions
Study of passivation efficiency

NaS₂:isopropanol (1:9); sulfidization to reduce optical degradation in InGaAs/AlGaAs laser mirrors

Study of GaAs barrier height shift with surface sulfidization using:
(NH₄)₂S(20%):ethanol (1:9)
(NH₄)₂S(20%):isopropanol (1:9)
(NH₄)₂S(20%):tert-butanol (1:9)
Sulfide passivation study on GaAs; dependence on sulfur activity and solvent dielectric constant
(NH4)2S (20%)
Na2S:H2O (60%)
S2Cl2:CCl4 (1:10)
(NH4)2S:i-C3H7OH (20 v/o in isopropanol)
(NH4)2S:t-C4H9OH (10 v/o in tert-butanol)
Na2S:i-C3H7OH Na2S:t-C4H9OH

CAIBE; I2/Ar+; GaAs and GaSb

Thermochemical vapor etch; HCl + H2 + AsH3; GaAs (1 0 0) and (1 1 1)B in cold wall reactor

H3PO4:HCl (3:1); Application: InP photolithography; faceted grooves

Thermochemical etch; AsH3, HCl; GaAs in situ etch for OMVPE

Thermochemical vapor etch; AsCl3 + H2; GaAs (1 0 0) and (1 1 1)B in cold wall reactor

H2SO4:H2O2:H2O (4:1:1); InP etch rate = 500 Å/min

Cl2/methanol; GaAs, InP, GaP, AlGaAs jet thinning of electron microscope specimens

Cl₂/methanol; GaAs, InP, GaP, AlGaAs jet thinning of electron microscope specimens


NaOCl:H₂O (1:5); GaAs jet etch thinning; etch gives a grainy structure

HCl:H₂O₂:H₂O (40:4:1); GaAs jet etch thinning; gives smooth, uniform etch


H₂SO₄:H₂O₂:H₂O (10:1:1); GaAs substrate cleaning for MOCVD

Lactic acid:HNO₃ (10:1); InSb substrate cleaning for MOCVD

HF:H₂O (1:1); InAs substrate cleaning for MOCVD


HF:CH₃COOH:KMnO₄ (1:1:1) (0.05 M); AlGaSb striation delineation etch


HF:CH₃COOH:KMnO₄ (0.05 M) (1:1:1); AlGaSb striation and defect delineation etch


HCl:HNO₃:H₂O (1:2:1); InP pattern etch for OMVPE regrowth; etch rate ~ 4 μm/min


Review: STM study of surface reconstruction and effect on etching behavior


HBr(37%); InP vee-groove etch using titanium mask, first step to form sharp vees with minimal undercutting; 20 s at 20°C

HBr:K₂Cr₂O₇ (3:1); InP vee-groove sidewall smoothing (step 2) using titanium mask

HF(40%):HNO₃(65%):H₂O (5:24:64); selective removal of titanium mask from InP; 10 s at 20°C


Reactive ion etch; Cl₂; InP masked with Ti. InP etch rate = 0.2 μm/min at <1 keV; wall sloped outward by 17° (overcut or negative undercut) with normal incident ion beam; etch rate is enhanced by introducing Ar and O₂; etch rate could go up to 0.75 μm/min
  Reactive ion etch of InP-based materials with CH4/H2; damage study

  Ar ion sputter etch of InP; LN2 cooled sample to improve surface morphology
  Ar+ ion beam etch; LN2 cooled sample holder reduces etch surface roughness; reducing substrate temperature improves surface smoothness; study: InP; etch rate = 6 Å/min at 1 keV, ion current density of 60 nA/cm2 and incident angle of 50°C; etch rate is higher when sample is cooled with LN2

  Ar ion sputter etch; Application: InP/InGaAsP BH Laser cavity etch
  Br2/methanol (0.5%); 2–3 s etch to remove ion damage

  Photoassisted dry etch; Cl2/He (1:3); GaAs monolayer by monolayer etch by surface chlorination followed by laser desorption of surface chlorides

  RIBE of InP-based materials with CH4/H2/Ar; etch is non-corrosive

  HCl:H2O (1:20); Application: InP n-type photoelectrochemical etch with the sample biased to form a surface depletion layer; forms deep narrow grooves

  Br thermochemical etch of GaAs; STM study of etch mechanism dependence on Br concentration at 700°K

  Br2/Methanol (0.2%); InP/InGaAsP; with SiOx masked patterns etch etch rate is enhanced by Br diffusion from masked areas; at low Br concentrations etch rate is diffusion limited and is independent of concentration, temperature and crystallographic orientation
   UV photochemical etching of GaAs in CF\textsubscript{3}Br or CH\textsubscript{3}Br

   Photochemical dry etching of GaAs in HBr

   Photochemical dry etch of GaAs in HBr

   \( \text{H}_3\text{PO}_4:\text{H}_2\text{O}_2:\text{H}_2\text{O} \) (1:1:10); InGaAs and InAlAs surface cleaning prior to etch studies
   {Use of organic acids and AlAs etch stop layers for InGaAlAs/InP structures.}
   Organic acid solutions:
   OA = oxalic acid:H\textsubscript{2}O (15 g; 2 l), pH = 6.3 (by adding ammonia)
   OCA = oxalic acid:H\textsubscript{2}O:citric acid (25 g;2 l:100 g), pH = 6.3
   MA = malonic acid:H\textsubscript{2}O (75 g;1 l), \( p\text{H} = 6.1 \)
   SA = succinic acid:H\textsubscript{2}O (200 g;1 l), pH = 4.2
   Etchant solutions (for InGaAs selective etch from InAlAs and InAlAs selective etch from AlAs):

<table>
<thead>
<tr>
<th>Etchant</th>
<th>In\textsubscript{0.53}Ga\textsubscript{0.47}As (nm/min)</th>
<th>In\textsubscript{0.52}Al\textsubscript{0.48}As (nm/min)</th>
<th>AlAs (nm/min)</th>
<th>GaAs (nm/min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>OA:H\textsubscript{2}O (20:1)</td>
<td>40</td>
<td>20</td>
<td>0.57</td>
<td>–</td>
</tr>
<tr>
<td>OCA:H\textsubscript{2}O (25:1)</td>
<td>75</td>
<td>5</td>
<td>0.20</td>
<td>–</td>
</tr>
<tr>
<td>MA:H\textsubscript{2}O (25:1)</td>
<td>100</td>
<td>6</td>
<td>1.23</td>
<td>–</td>
</tr>
<tr>
<td>SA:H\textsubscript{2}O (15:1)</td>
<td>120</td>
<td>60</td>
<td>0.12</td>
<td>180</td>
</tr>
</tbody>
</table>

BROEKAERT, T.P.E., and C.G. Fonstad, “Novel, Organic Acid-Based Etchants for InGaAlAs/InP Heterostructure Devices with AlAs Etch-stop Layers,”
   Same data as for (Broekaert, 1992a) with data for additional organic acids:
   Adipic
   Methylsuccinic
   Dimethylsuccinic
   Fumaric
   Maleic
   Citric
   Propane
   Tricarboxlic
   Butane
   Tetracarboxlic
   Acetic
BROWN, A., N. Hunt, A.M. Patterson, J.C. Vickerman, and J.O. Williams, “SIMS Analysis of the Surface Preparation of InAs (1 0 0),” Chemtronics, 1, 11–14 (1986)

InAs surface contaminant studies:
(A) Br₂/methanol (2%); InAs surface cleaning 5 min first step followed by: HF conc.; InAs surface cleaning 5 min second step; followed by DI water rinse; leaves residual Br₂, F; demonstrates need for high purity water rinse to reduce ionic contaminants
(B) HCl:H₂O₂:H₂O (150:1:100); InAs surface cleaning 5 min; leaves surface pitting and chloride contamination


H₂SO₄:H₂O₂:H₂O (1:8:80); Application: InAs/AlSb mesa etch


HBr:H₃PO₄ (1:2) {Huber etch}; InP, delineation of pits, ridges, and striations, 1–2 min at 20°C
CrO₃:AgNO₃:H₂O:HF (1 g:8 mg:2 ml:1 ml) {A–B etch}; InP, delineation of pits, ridges, and striations, 30–90 min at 60°C


H₃PO₄:H₂O₂:H₂O (1:1:10); selective etch of GaAs from InGaP. HCl; selective etch of InGaP from GaAs


0.5 M citric acid + 0.5 M potassium citrate (buffer solution)
buffer:H₂O₂ (5:1); GaAs selective etch from AlGaAs or AlAs. Used for reproducible fabrication of integrated circuit GaAs FETs with etch stop layer of 25 Å Al₀.₃₅Ga₀.₆₅As or 8 Å AlAs. The buffered solution is insensitive to dilution or contamination. GaAs etch rate = 45 Å/s


Lactic acid:HNO₃:HF (50:8:2); Safety caution: This etchant evolves heat and gas when stored which can explosively burst capped containers


H₃PO₄:HCl (3:1); Application: InP (1 0 0) photolithography; rectangular cross-section rib etch

Citric acid (3 g in 100 ml H₂O):ethyleneglycol (1:2), with pH adjusted to 6 using ammonia; electrolyte for anodizing AlₓGa₁₋ₓAs. HCl:H₂O (1:10); anodic oxide removal from AlₓGa₁₋ₓAs (to thin AlₓGa₁₋ₓAs by repeated discrete incremental steps)


Surface cleaning of GaAs in hydrogen radicals for MBE epilayer regrowth


Plasma etch; CCl₃F/O₂; GaAs and InP


Plasma etching kinetics of InP, GaAs, and GaP at 300°C in combinations of O₂ with either Cl₂ or CCl₄


Plasma etch; CCl₄/O₂; Application: InGaAsP/InP separation of LEDs


H₂SO₄:H₂O₂:H₂O (3:1:1); study of sulfur contamination of GaAs from etchant

HCl:H₂O; removal of sulfur contamination from GaAs following etch in H₂SO₄:H₂O₂:H₂O


Electrochemical C–V profiling:

InP with 0.5 M HCl electrolyte

p–n AlGaAs with 1 M NaOH electrolyte (gives poor results)

p–n GaAs with 0.1 M EDTA/0.2 M NaOH electrolyte (gives good results)


Reactive ion etch; Cl₂ and SiCl₄; GaAs; study of characteristics for etching via holes

Reactive ion etch, CCl$_2$F$_2$; Application: GaAs selective etch with AlGaAs etch stop; GaAs:Al$_{0.3}$Ga$_{0.7}$As selectivity > 4000:1


Reactive ion etch; CCl$_2$F$_2$; Application: GaAs selective etch from Al$_{0.3}$Ga$_{0.7}$As stop etch layer; selectivity > 4000; gas residence time dependent


Thermochemical vapor etch; HCl + H$_2$ + PH$_3$; InP etch through SiO$_2$ masks for OMVPE


Br$_2$/methanol; Application: InGaAsP/InP non-selective mesa etch. buffered HF (i.e. NH$_4$F:HF (10:1)); InGaAsP oxide removal


H$_2$SO$_4$:H$_2$O$_2$:H$_2$O (1:8:80); Application: Al$_{0.1}$Ga$_{0.9}$As contact layer removal for waveguide fabrication


H$_3$PO$_4$:HBr (2:1) [Huber etch]; InP first step etch pit delineation; 1–2 min at 20°C gives symmetrical etch pits

H$_2$SO$_4$:H$_2$O$_2$:H$_2$O (1:1:1); InP second step free etch of 30 µm for elongated etch pit delineation for (1 0 0) orientation determination; 5 min at 85°C

HCl:H$_2$O$_2$:H$_2$O (1:1:1); GaAs first step surface roughening etch. 10 min

H$_2$SO$_4$:H$_2$O$_2$:H$_2$O (1:8:8); GaAs second step free etch of 50 µm for elongated etch pit delineation for (1 0 0) orientation determination; 3 min at 55°C


RIBE of InP using trimethylamine/Ar; damage study

Reactive ion beam etch and chemically assisted ion beam etch using N₂/CH₄/H₂ and Ar/CH₄/H₂ of InP. CAIBE produces less polymer by-product

RIE etch; CH₄/H₂; Al₀.₄₈In₀.₅₂As etch optimization

Photoelectrochemical etching of n-GaAs; dependence on orientation and doping concentration; 0.5 M Tiron electrolyte (4,5-dihydroxy-1,3-benzenedisulfonic acid); shows cross-sectional profiles

Photoelectrochemical etch of GaAs using electrolytes of either 1 M KCl or 0.5 M Tiron (4,5-dihydroxy-1,3-benzenedisulfonic acid, disodium salt); pH = 7, non-corrosive, compatible with photoresists; Application: sawtooth grating fabrication

Plasma etching; CH₄/H₂; GaAs and InP etch characteristics dependence on temperature; gives favorable surface roughness compared with Cl-based etchants

citric acid:H₂O₂ (m:1, with 1 < m < 9); GaAs substrate removal using AlAs or AlGaAs etch stop layers; problems with etch stop layer oxidation
NH₄OH:H₂O₂; GaAs substrate removal using AlAs or AlGaAs etch stop layers
NH₄OH:H₂O (1:10); GaAs surface oxide removal prior to other etching

Reactive ion etch; Ar + Cl₂; Application: InGaAsP/InP formation of vertical wall ridge structures. Br₂/methanol (0.2%); 30 s etch prior to MOVPE regrowth of InP

Br etch mechanism study of GaAs by STM
  Monolayer etching of GaAs in Br₂ vapor; study of etch kinetics

  Citric acid:H₂O₂ (24:1); Application: InGaAs FET flat bottom gate recess etch

  Citric acid:H₂O₂ (24:1); Application: In₀.₅₃Ga₀.₄₇As FET gates; uses undercutting of photolithography mask to achieve submicron widths

  ECR plasma; CH₃I, C₂H₅I, and C₃H₇I with Ar and H₂; Study: etch rates, surface morphology, damage, etch anisotropy for InP, InAs, InSb, GaAs, AlGaAs, GaSb, InAlAs, InGaAs, and InAlP

  Plasma etch; CH₄ + H₂ + Ar; InP; sidewall roughness is related to roughness of mask edge

  ECR etch; HBr/H₂/Ar and HI/H₂/Ar; InP, GaAs, AlGaAs; effect of substrate temperature

  Reactive ion etch; CH₄/H₂ of p-InGaP and p-GaAs; etch rate study

  Real-time etch rate monitoring by optical interferometry of AlGaAs/GaAs and InGaAsP/InP structures
  NH₄OH:H₂O₂:H₂O (3:1:50); AlGaAs/GaAs thinning etch

  Reactive ion etch; SiCl₄/CH₄/Ar; AllInGaP and GaAs

Thermochemical vapor etch; ethylene dibromide (EDB); InP; low temperatures to avoid InP thermal degradation are achieved by use of a separate high temperature decomposition of the EDB

Plasma etch; hydrogen etching of GaAs, GaSb, InP and their oxides. InP etching preferentially removes phosphorus and leaves In to accumulate on the surface

Reactive ion etch; CCl$_2$F$_2$/Ar; GaAs

Cl$_2$/methanol; GaP jet thinning for TEM samples

Cl$_2$/methanol; GaP jet thinning for TEM samples

Thermochemical etch; Cl$_2$; in situ etch of InGaAs for regrowth of AlInAs by MBE

Ar ion etch damage of GaAs; study of Schottky diodes and DLTS

Reactive ion etch; CF$_4$–O$_2$; GaAs pattern etch with TaSix contact mask for self-aligned MESFETs

Reactive ion etch damage; mechanism modeling; results with GaAs/AlGaAs

Reactive ion etching of AlGaN/GaN using Cl$_2$; Application to FET gate recessing

Ar ion etch damage study; GaAs and InP; enhanced defect diffusion with illumination energies above bandgap


KOH (1 M); selective photoetch of n-GaAs from stop layer of low-temperature MBE grown GaAs:As


KOH (1 M); selective photoetch of n-GaAs from stop layer of low-temperature MBE grown GaAs:As


HCl:H2O (4:1); Application: InP selective etch from InGaAsP at 15°C for laser fabrication


CrO3:HF:H2O (1:2:3); GaAs defect delineation; ultrasonic aided; etch rate at 40°C 0.5 μm/min; etch depth 0.5–2 μm to produce etch pits


Br2/methanol; Application: InP substrate cleaning. H2SO4:H2O2:H2O (3:1:1); InGaAsP selective etch from InP. HCl; InP selective etch from InGaAsP


KOH: K3Fe(CN)6:H2O; or H2SO4:H2O2:H2O (3:1:1); InGaAsP selective etch from InP for laser fabrication. HCl:H2O (1.5:1); InP selective etch from InGaAsP


HCl:H2O (4:1); Application: InP selective substrate removal from InGaAs etch stop layer to allow backside SIMS measurements of metal contact diffusion profiles in InGaAs/InP structures


Ion beam etch; Ar/O2; CF4, C2F6 and Ar ion milling of InGaAs, InP, GaAs, Si and Ge; gives etch rate comparison of reactive and non-reactive ion beam etching; reports different etching rates between photoresist and semiconductor


H3PO4:H2O2:H2O (1:1:38); Application: InGaAs FET channel recess

Cl₂ chemically assisted Ar ion beam etching of GaAs to form 3D interlinked mesh structures


Resonance-radio frequency (ECR) plasma and RIE etching of GaAs; comparison of surface damage

CHEUNG, R., W. Patrick, I. Pfund, and G. Hähner, “Reactive ion etch-induced effects on 0.2 μm T-gate In₀.₅₂Al₀.₄₈As/In₀.₅₃Ga₀.₄₇As/InP high electron mobility transistors,” J. Vac. Sci. Technol., B, 14(6), 3679 (1996)

reactive ion etch; CH₄/H₂; transistor gate recess etch; selective etch of InAlAs from InGaAs

H₃PO₄:H₂O₂:H₂O (1:1:150); non-selective InAlAs/InGaAs etch at 22°C. isopropanol:H₂O (1:5); wetting agent post etch rinse


Reactive ion etch of GaN patterns using SF₆ and Ar; damage study


Reactive ion etch; SiCl₄; GaAs and Al₀.₃Ga₀.₇As-induced damage study


Br₂:HBr:H₂O (1:17:1000); Application: InP FET channel etch preparation for Schottky contact


Thermochemical vapor etch; PCl₃ + H₂; Application InP VPE growth


Ion milling; iodine, Ar, Xe; InP

III–V semiconductor mask patterning by ion implantation damage used with photoelectrochemical etching of the non-damaged semiconductor

HF:KOH (2 M:0.5 M); electrolyte for InP etching

H₂SO₄:methanol (3 ml:250 ml); electrolyte for InGaAs

H₂SO₄ (2 M); electrolyte for InGaAsP and InP


Br₂/methanol; InP, polishing techniques for (1 0 0) substrates


Br₂/methanol; InP (1 0 0) polishing; dependence on Br₂ concentration


Thermochemical etch; PCl₃; InP in situ CBE chamber etch at 550°C. Thermochemical etch; AsCl₃; GaAs at 600°C


Inductively coupled plasma etch of GaN, InN and AlN with BI₃, BBr₃, ICl and IBr


Inductively coupled plasma etch, selective removal of InN and InGaN from GaN using BI₃ and BBr₃


ICP of GaN, InN, AlN, InAlN and InGaN in Cl₂ and CH₄/H₂ plasmas


Inductively coupled plasma etch; Cl₂/Ar, Cl₂/N₂, Cl₂/H₂ of InN, InGaN, GaN, InAlN and AlN; dependences on Cl₂ percent and pressure

H₃PO₄:H₂O₂:H₂O (1:1:10); Application: non-selective etch of AlGaAs/GaAs and InAlGaAs/InAlAs. Etch depth monitoring with laser reflectometry


Citric acid (1 wt.% anhydrous to 1 wt.% water): H₂O₂:H₂O (5:1:75)
GaAs/Al₀.₃Ga₀.₇As non-selective etch; GaAs rate = 15.3 nm/min
AlGaAs rate = 17.6 nm/min Real time monitoring control of etch depth using spectroscopic ellipsometry


ECR plasma etch, H₂; GaAs and AlGaAs surface oxide removal for MBE growth


ECR plasma; hydrogen surface cleaning of GaAs in situ for MBE


H₂ plasma oxide removal; AlGaAs cleaning for MBE overgrowth


Reactive ion Etch; SiCl₄; GaAs, smooth surfaces with H₂ plasma pretreatment to remove oxides


ECR plasma etch; SiCl₄; Study: GaAs etch rates, etch profiles and uniformity


(NH₄)₂S sulfidation of GaAs and InP; study of surface roughness and oxygen content.
H₂S + polysulfide gas exposure (N₂ through a liquid bubbler of pH-adjusted polysulfide solution) sulfidation of GaAs and InP; study of surface roughness and oxygen content

HCl:H2O:H2O2 (10 ml:10 ml:40 ml:5 drops) \{NRL etch\}; Application: GaAs surface cleaning for deposition of metal Schottky contacts

H3PO4:HBF4:H2O (2:1:10); Al contact removal from GaAs


HF:H2O (1:3); Application: Si-removal of thermal oxide as a step in Si substrate cleaning for GaAs MBE growth, followed by:

NH4OH:H2O (1:10) for 30 s, followed by:

HCl:H2O (1:10) for 30 s, followed by:

HF dip, followed by DI water rinse and \( \mathrm{N}_2 \) blow dry


HNO3:HBr (1:3); InP dislocation delineation on \( (1 \ 1 \ 1) \) and \( (1 \ 0 \ 0) \)


NaOH:H2O (1:1); GaN etch at 5–90°C


Ga\(^{+}\) ion micromachining of laser gratings in GaN


KOH:K\(_3\)Fe(CN)\(_6\):H\(_2\)O (6 g:4 g:50 ml); Application: InP cleaved cross-section layer delineation; \( \sim 5 \) min at 20°C; selectively etches InGaAsP on InP


KOH:K\(_3\)Fe(CN)\(_6\):H\(_2\)O (6 g:4 g:50 ml); Application: InP cleaved cross-section layer delineation; \( \sim 5 \) min at 20°C

HNO3:HCl:Br\(_2\) (20:10:0.25); InP and GaP dislocation delineation; 5 s for \( (1 \ 1 \ 1) \); 60 s for \( (1 \ 0 \ 0) \)


Thermochemical vapor etch; ethylene dibromide + \( \mathrm{H}_2 + \mathrm{PH}_3 \); InP \( (1 \ 0 \ 0) \) in situ etch for OMVPE


Thermochemical vapor etch; ethylene dibromide + \( \mathrm{H}_2 + \mathrm{PH}_3 \); InP \( (1 \ 0 \ 0) \) in situ etch for OMVPE

{All data are at room temperature.}

KOH 45% solution; Used for InP native oxide removal prior to acid etch; does not attack InP

Br₂/methanol (1 vol.%); InP (0 0 0) etch rate = 3000 Å/min

Br₂/methanol (0.5 vol.%); InP (0 0 0) etch rate = 2000 Å/min

HBr; InP (0 0 0) etch rate = 4–8 μm/min, highly pitted surface

HBr:H₂O (1:10); InP (0 0 0) etch rate = 167 Å/min

HBr:H₂O (1:5); InP (0 0 0) etch rate = 250 Å/min

H₃PO₄:H₂O₂ (1:1); InP (0 0 0) etch rate = 100 Å/min

H₂O:AgNO₃:CrO₃:HF (10 ml:40 mg:5 g:8 ml) {A – B etch}; InP (0 0 0) etch rate = 600 Å/min at 20°C

Citric acid:H₂O₂ (3:1); InP (0 0 0) etch rate = 10 Å/min

Tartaric acid (40 wt.% solution):H₂O₂ (1:1); InP (0 0 0) etch rate = 6 Å/min

Tartaric acid (40 wt.% solution):H₂O₂ (3:1); InP (0 0 0) etch rate = 120 Å/min

Iodic acid (5 wt.% solution); InP (0 0 0) etch rate = 67 Å/min; smooth, uniform surfaces; thinning etch

Iodic acid (10 wt.% solution); InP (0 0 0) etch rate = 350 Å/min; does not attack photoresists; leaves a black residue on InAs and InGaAs

Iodic acid (20 wt.% solution); InP (0 0 0) etch rate = 750 Å/min. Lactic acid:HNO₃ (10:1); InP (0 0 0) etch rate < 8 Å/min

Oxalic acid:H₂O₂; InP (0 0 0) etch rate ≤ 8 Å/min


Thermal etching (degradation) of InP in H₂; PH₃ surface stabilization


Review of plasma etching and reactive ion etching principles; Si


KOH:K₃Fe(CN)₆:H₂O (12 g:9 g:70 ml); Application: GaAlAs/GaAs cleaved cross-section layer delineation

H₂SO₄:H₂O₂:H₂O (1:8:40); GaAs dovetail mesa etch


H₂SO₄:H₂O₂:H₂O (1:8:40); Application: GaAs (0 0 0) mesa etch
Reactive ion etch; Cl\(_2 + O_2\); Application: InGaAsP/InP deep groove etch for laser fabrication; Ti mask

Reactive ion etch; Cl\(_2/Ar/O_2\); Application: followed by HCl etch for vertical sidewall laser mirror. HCl conc.; InP vertical wall groove etch (following reactive ion etch formation of the groove)

Reactive ion etch; Cl\(_2/Ar/O_2\); Application: followed by HCl etch for vertical sidewall laser mirror. HCl conc.; InP vertical wall groove etch (following reactive ion etch formation of the groove)

KOH:K\(_3\)Fe(CN)\(_6\):H\(_2\)O (6 g:4 g:50 ml); selectively etches InGaAsP on InP
Br\(_2\)/methanol; InGaAsP/InP non-selective mesa etch
HCl:HNO\(_3\) (1:3); InGaAsP/InP non-selective mesa etch; data is given on etch wall profiles
HCl:CH\(_3\)COOH:H\(_2\)O\(_2\) (1:2:1) \{KKI etch\}; InGaAsP/InP (1 0 0) groove and mesa etch
Reactive ion etch; Cl\(_2/Ar/O_2\) followed by HCl etch for vertical sidewall laser mirror. HCl conc.; InP vertical wall groove etch (following reactive ion etch formation of the groove)

Reactive ion etching; Cl\(_2/O_2\); Application: InGaAsP/InP grooves and laser facets with vertical sidewalls and no undercutting

Reactive ion etching, Cl\(_2/O_2\); Application: InGaAsP/InP grooves and laser facets

Reactive ion etch; Cl\(_2\), Cl\(_2/O_2\) (4:1); InP photolithography

HF:HNO\(_3\):H\(_2\)O (50:1:50) + 5 mg K(FeCN)\(_6\); Application: InGaAs/InP cleaved cross-section later delineation

HCl:HNO₃:H₂O (2:3:6); InP etch rate = 1 μm/min; non-preferential
HCl:HNO₃:H₂O (2:2:1); InP etch rate = 2 μm/min; non-preferential
HCl:H₃PO₄ (2:3); InP bulk etch rate = 2.5 μm/min; no measurable InGaAsP or InGaAs etching after 30 min
HCl:H₃PO₄ (2:3); InP bulk etch rate = 2.5 μm/min; no measurable InGaAsP or InGaAs etching after 30 min; Ref. (Colliver, D.J. 1976)

Br₂:HBr:H₂O (1:17:35); InP etch rate = 2 μm/min
H₂SO₄:H₂O₂:H₂O (3:1:1); GaAs etch rate = 3.1 μm/min
H₂SO₄:H₂O₂:H₂O (18:1:1); GaAs etch rate = 2.1 μm/min
H₂SO₄:H₂O₂:H₂O (8:1:1); GaAs etch rate = 2.8 μm/min
H₂SO₄:H₂O₂:H₂O (9:9:2); GaAs etch rate = 8.7 μm/min
H₂SO₄:H₂O₂ (1:1); GaAs etch rate = 5.0 μm/min
NH₄OH:H₂O₂:H₂O (1:4:20) GaAs etch rate = 1.8 μm/min
HNO₃:HF (1:3); GaAs layer delineation
HNO₃:HF:H₂O (1:3:4); GaAs layer delineation
HNO₃:HF:H₂O (3:1:5); GaAs layer delineation
KOH:K₃Fe(CN)₆ ((120 g KOH + 500 ml H₂O):(80 g K₃Fe(CN)₆ + 500 ml H₂O)); GaAs layer delineation
H₂O:AgNO₃:CrO₃:HF (2 ml:8 mg:1 g:1 ml) {A–B etch}; GaAs etch rate = 4 μm/min at 65°C


Reactive ion etch; CH₄ + H₂; GaAs n-type; electrical damage due to hydrogen passivation of donors


H₂SO₄:H₂O₂:H₂O (1:8:80); Application: vee-groove etch of GaAs, quasi (1 1 1)A sidewalls; with Si₃N₄ mask


ECR etch; Cl₂/CH₄/H₂; InP at 150°C for laser mesa fabrication


ECR etch; non-selective for GaAs AlGaAs; BCl₃/Cl₂/N₂/Ar; where BCl₃ reduces oxidation effects for AlGaAs and N₂ protects from sidewall polymer deposition when using photoresist masks


Reactive ion etch; BCl₃:Cl₂; GaAs, AlGaAs, InP; etch rate is temperature dependent
Thermochemical vapor etch; HCl; InP and GaAs in situ surface cleaning for MBE growth

HCl:H3PO4 (1:1); InP selective etch from InGaAsP; etch rate = 4.0 μm/min for bulk InP; etch rate = 6.5 μm/min for LPE InP layers
HCl:H3PO4 (2:3); InP bulk etch rate = 2.5 μm/min; no measurable InGaAsP or InGaAs etching after 30 min
KOH:K3Fe(CN)6:H2O (24 g:16 g:140 ml); InGaAsP selective etch from InP; etch rate = 4.1 μm/min; InP etch rate < 0.05 μm/min; (Fresh solution mixed daily)

Reactive ion etching, SiCl4 + Cl2; Application: via holes in GaAs

Reactive ion etch; SiF6/SiCl4; AlGaAs/GaAs with use of etch stop layers of AlGaAs and InGaAs

Defect delineation in GaSb:
CP-4 40% diluted in H2O; etch pit delineation only on (1 1 1)A
Br2/methanol (3%); etch pit delineation only on (1 1 1)A
HCl:HNO3:H2O (6:1:6); unreproducible etch pit delineation
HCl:H2O2 (2:1); unreproducible etch pit delineation
H2SO4:H2O2 (5:1); etch pit delineation on (1 1 1)A, (1 1 1)B, (1 0 0), (1 1 0), striations on (1 1 1)A and (1 1 1)B; precipitates on (1 1 1)A, (1 0 0), (1 1 0)
CrO3 (5 M aq. sol.):HF (5:1); etch pit delineation on (1 1 1)A, (1 1 1)B, (1 0 0), (1 1 0), striations on (1 1 1)A and (1 1 1)B; precipitates on (1 1 1)A, (1 1 1)B, (1 0 0), (1 1 0)
KMnO4 (sat.):HF:CH3COOH (1:1:1); growth striations on (1 1 0) in n-type GaSb
Ce(SO4)2(0.1 M):HNO3:CH3COOH (1:2:2); Growth striations on (1 1 0) in Te-doped GaSb

Reactive ion etch; CH4/H2; Application: InP and InGaAsP grating with titanium layer mask

III–V semiconductor mask patterning by focused Ga ion beam damage; using photoelectrochemical etching of non-damaged areas on n-type GaAs, InP, InGaAs, InGaAsP

$\text{H}_2\text{SO}_4$ (2 M); Photoelectrochemical etch electrolyte


Chemically assisted ion beam etch; Cl$_2$/BCl$_3$/IBr in a cryo-pumped vacuum system; GaAs and InP


Chemically assisted ion beam etching; BCl$_3$/Ar of InGaAsP/InP and AlInGaAsP/InP; control of the sidewall slope by tilting the sample


CAIBE damage of AlGaAs/GaAs using BCl$_3$/Cl$_2$; post-etch damage removal by Cl$_2$ flow at 120°C without plasma


$\text{H}_2\text{SO}_4$:$\text{H}_2\text{O}_2$:$\text{H}_2\text{O}$ (1:1:20); Application: InGaAs slow etch, etch rate = 0.25 µm/min at 20°C; photolithography gives positively tapered sidewalls for both (0 1 1) and (0 1 1)

$\text{H}_3\text{PO}_4$:$\text{HCl}$ (3:1); InP selective etch from InGaAs


HCl:ethanol; InP; etch rate concentration and temperature dependence; mesa sidewall profiles


Plasma etched via holes in GaAs with 6% Cl$_2$ + 94% BCl$_3$


$\text{H}_2\text{SO}_4$:$\text{H}_2\text{O}_2$:$\text{H}_2\text{O}$ (1:1:40); selective InAlAs/InGaAs HFET mesa etch from InP. succinic acid ($\text{C}_4\text{H}_6\text{O}_4$):$\text{H}_2\text{O}_2$:$\text{NH}_3$ (20:4:1); selective InGaAs from InAlAs; InGaAs etch rate = 5 Å/s; InAlAs etch rate = 0.07 Å/s

H$_2$SO$_4$:H$_2$O$_2$:H$_2$O (7:1:1); Application: InP substrate cleaning for MBE; oxidizing etch shows little or no carbon contamination (C < 1% monolayer); oxide is removed in MBE by heating above 500°C in As flux

RIE damage study of n-GaAs in CH$_4$/H$_2$ and H$_2$ plasmas

H$_2$ plasma damage study; GaAs; X-ray photoelectron spectroscopy analysis


(NH$_4$)$_2$S; Application: InGaAsP laser facet passivation

NH$_4$OH:H$_2$O (1:10); oxide removal from InAlAs; 20 s; prior to deposition of silicon nitride passivation layer

H$_3$PO$_4$:H$_2$O$_2$:H$_2$O (1:1:100); Application: GaAs slow recess etch; showing etch profiles with little anisotropy
H$_2$O:AgNO$_3$:CrO$_3$:HF (10 ml:40 mg:5 g:8 ml) {A–B etch}; GaAs/AlGaAs layer cross-section interface delineation: {1 1 1} facets along {0 1 1}; {2 2 1} facets along {0 1 1}
H$_2$SO$_4$:H$_2$O$_2$:H$_2$O (1:8:11) and (1:8:40); GaAs (1 0 0) photolithography substrate patterning etch profiles

Ar ion beam assisted Cl$_2$ dry etching of InP; temperatures above 150°C are required to remove reaction products

H$_2$O$_2$ (30%); oxidation of GaAs followed by
HCl:H$_2$O (1:1); oxide removal agent from GaAs
Citric acid (1 M); oxide removal agent from GaAs
H$_3$PO$_4$:H$_2$O (1:4); oxide removal agent from GaAs
H$_2$SO$_4$:H$_2$O (1:10); oxide removal agent from GaAs
HF:NH$_4$F (1:7); oxide removal agent from GaAs
NH$_4$OH:H$_2$O (1:1); oxide removal agent from GaAs

DESALVO, G.C., W.F. Tseng, and J. Comas, “Etch Rates and Selectivities of Citric Acid/H$_2$O$_2$ on GaAs, Al$_{0.3}$Ga$_{0.7}$As, In$_{0.2}$Ga$_{0.8}$As, InGa$_{0.53}$Ga$_{0.47}$As, In$_{0.52}$Ga$_{0.48}$As and InP,” J. Electrochem. Soc., 139(3), 831–35 (1992)

Citric acid:H$_2$O$_2$ range (0.5:1) to (50:1); GaAs, InP, AlGaAs, InGaAs, InAlAs etch rates (selectivities are tabulated in the reference)

<table>
<thead>
<tr>
<th>Volume ratio of citric acid/H$_2$O$_2$</th>
<th>Etch rates of layers on GaAs substrate (Å/min)</th>
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<td>GaAs</td>
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<table>
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<tr>
<th>Volume ratio of citric acid/H$_2$O$_2$</th>
<th>Etch rates of layers on InP substrate (Å/min)</th>
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<td>In$<em>{0.53}$Ga$</em>{0.47}$As</td>
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</table>

Si₃N₄ surface passivation of GaAs by plasma nitridation of a Si layer


Thermochemical vapor etch using AsCl₃/He; GaAs in situ substrate etch for CVD


H₂SO₄:H₂O₂:H₂O (2:1:1); Application: rapid GaAs substrate thinning, 300 µm under continuous swirling at 60°C for < 15 s

citric acid:H₂O₂ (2:1); Application: selective removal of GaAs from Al₀.26Ga₀.74As; selectivity of 70:1


CHF₃ and NH₃ additives for reactive ion etching of GaAs using CCl₂F₂ and SiCl₄


Reactive ion etch; CCl₂F₂; GaAs pattern etching of deep features comparing metal, Si₃N₄ and photoresist masks


Thermochemical vapor etch; Cl₂; InP, Ar laser-induced etching


HF:HNO₃:CH₃COOH (2:18:40); GaSb first step prior to defect delineation etch

Br₂/methanol (2%); GaSb(1 1 1)A etch pit defect delineation etch

HCl:H₂O₂; GaSb etch pit defect delineation etch for all other orientations


Plasma etch; CCl₄, CHCl₃, CF₂Cl₂, BCl₃; InP and GaAs review


Plasma etch; Cl₂; InP and GaAs; non-volatile reaction by-product InCl₃ limits low temperature etching. InP activation energy = 34.5 ± 2.8 kcal/mol; GaAs activation energy = 10.5 ± 0.7 kcal/
mol; InP absolute etch rate = 7 μm/m at 250°C; multilayers of InCl₃ deposit on InP and submonolayer of InCl₃ on GaAs; etched surface texture depends strongly on etch temperature; InP etching is anisotropic while GaAs is partially anisotropic; InP etch rate is controlled by volatilization of InCl₃ layer from surface; GaAs etch rate is limited by slow chemical reaction

   Ar ion etch; reactive ion etch using iodine; InP

   Review; dry etching of InP; Ar ion milling, reactive ion etching and ion beam assisted I₂ and Cl₂ etching; gives comparison of results. Reactive ion etch; SiCl₄:Ar(2:1) at 23 mTorr for InP with etch rate of 70 nm/min and etched walls are smooth but not vertical; Ni/Cr mask; CF₃ and CH₃I give rough surface due to CH₃I polymers on substrate; smooth surface is obtained from 25% O₂ in CH₃I with Ti mask; Cl₂ ion beam etching for GaAs requires high temperature, above 150°C; smooth etched surface also obtained from I₂:Ar at 0.1 mTorr with high Ar + beam of 300–500 V and high flow rate of I₂; vertical walls are obtained by 15° titled substrate to beam

   HCl:H₂O₂:H₂O (40:4:1); field emitter tip formation on GaAs by etching through square mask patterns
   HF:H₂O₂:H₂O (1:10:21.2); field emitter tip formation on GaAs by etching through square mask patterns
   HF:HNO₃:H₂O (1:1:2); field emitter tip formation on GaAs by etching through square mask patterns
   HF:H₂O₂:H₂O (1:20:100); field emitter tip formation on GaAs by etching through square mask patterns
   NH₄OH:H₂O₂:H₂O (1:1:8); field emitter tip formation on GaAs by etching through square mask patterns
   H₃PO₄:H₂O₂:H₂O (3:1:50); sharpening of dry etched field emitter tips. Reactive ion etch of GaAs field emitter tips using Ar + SiCl₄

   HCl:H₂O₂:H₂O (40:4:1); tip formation on GaAs by etching through square mask patterns
   HF:HNO₃:H₂O (1:1:2); tip formation on GaAs by etching through square mask patterns

   HCl; Application: Al₀.₅Ga₀.₅As selective etch from GaAs
  KOH:methanol (2.5 g:200 ml); InP surface cleaning study for Schottky contacts

  H3PO4:HCl (3:1); Application: InP selective etch from InGaAs. H2SO4:H2O2:H2O (3:1:1); InGaAs selective etch from InP

  Reactive ion etch; CH4/H2 for gate recess in InGaAs/InAlAs HEMTs; AFM surface study

  HF (4%) (in isopropanol:H2O (1:5) as wetting agent); 5 s native oxide removal from InGaAs
  Reactive ion etch using CH4(8.3%) of InGaAs/InAlAs/InP for gate recess in HEMTs
  H3PO4:H2O2:H2O (1:1:150); gate recess etch in InGaAs/InAlAs/InP HEMTs

  Laser-induced dry etch of InP using UV photolysis of CH3I; direct write patterning contrast is enhanced by presence of surface oxide. Photochemical etching using CH3I in H2 with laser assisted beam to clean InP and InGaAs; InGaAs etch rate is higher than InP etch rate

  NH4OH:H2O2 (1:700); GaAs chemi-mechanical polishing solution. Br2/methanol; GaAs chemi-
  mechanical polishing solution

  Chemically assisted ion beam etch; Ar/Cl2; Application: InGaAsP/InP laser facets

  CAIBE of GaN and GaAs using Cl2–Ar; vertical, smooth sidewalls for laser facets

$\text{H}_2\text{SO}_4:\text{H}_2\text{O}_2:\text{H}_2\text{O}$ (5:1:1); Application: InP(Zn) thinning etch for two step MOVPE regrowth in InGaAs/InP pin-FET


ECR plasma etch; Cl$_2$/Ar; GaAs; surface damage study


ECR plasma etching, CH$_4$/H$_2$/Ar for compound semiconductor; study of gas species versus process conditions


HF Buffered, (5N H$_3$F:1 HF) is used to etch windows in SiO$_2$ mask on InP; HCl (conc.) is preferential vee-grooved etchant for InP (1 0 0) but shows damage on vee-groove walls due to high etch rate (7.33 $\mu$m/min at 22°C)

H$_3$PO$_4$:HCl (1:1) is preferred vee-grooved etchant for InP with smaller etch rate (0.1 $\mu$m/min at 22°C). Optimum etching conditions: 50 s in H$_3$PO$_4$:HCl at 22°C produces narrow, straight sided vee-groove with minimal wall damage; no undercut; adhesion is improved with 1000 Å SiO$_2$ and 1.8 $\mu$m photoresist mask giving an angle of 35°


Surface treatment of GaN, AlN, and AlGaN to remove air-exposure overlayers; studied by spectroscopic ellipsometry


(HN$_4$)$_2$S; GaAs surface passivation


$\text{H}_2\text{SO}_4:\text{H}_2\text{O}_2:\text{H}_2\text{O}$ (5:1:1); Application: InP surface cleaning prior to oxidation; 4 min HNO$_3$; 50 Å anodic oxide growth on InP

Vapor etch; GaAs and InP by ultra-violet photodecomposition of methyl-halides; etch rate $> 10^4$ X the dark reactions


CAIBE for InP optoelectronic devices using Cl$_2$, CH$_3$I and IBr$_3$


Thermochemical vapor etch; AsCl$_3$ + H$_2$; GaAs in situ etch for OMVPE. H$_2$SO$_4$:H$_2$O$_2$:H$_2$O (5:1:1); GaAs substrate cleaning for 20 s at 20°C


Thermochemical vapor etch; AsCl$_3$ + H$_2$; GaAs in situ etch for OMVPE

ELDER, D.I., “Etching In$_{0.53}$Ga$_{0.47}$As epilayers grown on indium phosphide,” NOSC Progress Report (1983)

- Tartaric acid:H$_2$O$_2$:H$_2$O (1:1:10); InGaAs etch rate = 1000 Å/min
- Tartaric acid:H$_2$O$_2$:H$_2$O (1:1:20); InGaAs etch rate = 700 Å/min
- Tartaric acid:H$_2$O$_2$:H$_2$O (1:1:20); InGaAs etch rate = 2900 Å/min
- HF:H$_2$O$_2$:H$_2$O (1:1:10); InGaAs etch rate = 6300 Å/min
- HF:H$_2$O$_2$:H$_2$O (1:1:20); InGaAs etch rate = 2750 Å/min
- H$_2$SO$_4$:H$_2$O$_2$:H$_2$O (1:1:10); InGaAs etch rate = 9500 Å/min
- H$_2$SO$_4$:H$_2$O$_2$:H$_2$O (1:1:20); InGaAs etch rate = 4500 Å/min
- H$_2$SO$_4$:H$_2$O$_2$:H$_2$O (1:1:60); InGaAs etch rate = 700 Å/min
- Citric acid:H$_2$O$_2$ (25:1); InGaAs etch rate = 1200 Å/min
- Citric acid:H$_2$O$_2$ (25:1); p-InGaAs etch rate = 450 Å/min
- Citric acid:H$_2$O$_2$:H$_2$O (1:1:10); InGaAs etch rate = 700 Å/min
- Lactic acid:H$_2$O$_2$:HF (50:8:2); InGaAs etch rate = 7200 Å/min


Buffered HF, [NH$_4$F:HF (10:1)]; InP etch rate after 60 min at 20°C is negligible


InGaAs selective etches from InP:
- Tartaric acid:H$_2$O$_2$ (1:1); InGaAs rate = 3000 Å/min; InP etch rate = 6 Å/min; Ref. (Clawson, 1978)
- Tartaric acid:H$_2$O$_2$:H$_2$O (1:1:10); InGaAs etch rate = 1000 Å/min
- Tartaric acid:H$_2$O$_2$:H$_2$O (1:1:20); InGaAs etch rate = 600 Å/min
- H$_2$SO$_4$:H$_2$O$_2$:H$_2$O (1:1:10); InGaAs etch rate = 9000 Å/min

H₃PO₄:H₂O₂:H₂O (1:1:8); Selective etch of InGaAs mask patterns on InP; at 25°C in light, 120 nm InGaAs etched through in ~25 s

H₃PO₄:H₂O₂:H₂O (1:1:32); Selective etch of InGaAs mask patterns on InP; at 25°C in light, 120 nm InGaAs etches through in ~60 s

HCl:H₃PO₄ (0.5:1); at 25°C in light InP rate is 21 nm/s

HCl:H₃PO₄ (5:1); at 25°C in light InP rate is 151 nm/s; for 20 μm high mesas smooth, (2 1 1)A side surfaces, but deep pit features on the (1 0 0) bottom

HCl:H₃PO₄:lactic acid (x:y:z); gives etch rate dependence on composition; incorporation of lactic acid reduces size and number of etch pits on bottom (1 0 0) plane; higher lactic acid increases roughness of (2 1 1)A and (1 0 0) surfaces

Requires final 2% Br₂/methanol polish to reduce roughness. Br₂/methanol (2%); final polish of 40 μm mesas etched in HCl:H₃PO₄:lactic acid to reduce surface roughness


KOH molten; Application: GaAs (1 0 0) dislocation etch pit delineation. Sirtl etch, modified; GaAs (1 1 1) dislocation etch pit delineation


Anodization: InP; defect delineation


EDTA:NH₄OH (0.2 M ethylene diamine tetraacetic acid disodium salt with ammonium hydroxide for pH control); electrolyte for photoelectrochemical etching of GaAs and GaSb


HCl (1.2 M); electrolyte (pH = 0) for study of anodic dissolution of InP


Inductively coupled plasma etch using CH₄/H₂/O₂ of InGaAs/InP HBTs; conditions for InGaAs selectivity of 30
Inductively coupled plasma etch of GaAs and InP for HBTs using SiCl₄

Study on InP of etch damage dependence on ion energy using CH₄/H₂/O₂; comparing inductively-coupled plasma etch to reactive ion etch

Inductively coupled plasma etch; CH₄/H₂ of InP; study of pattern etching and etch damage

Tiron (0.5 M); electrolyte for photoelectrochemical enhancement of defect structure on GaAs surfaces
Sodium dihydrogen orthophosphate (0.3 M); electrolyte for photoelectrochemical enhancement of defect structure on GaAs surfaces

Reactive ion etch of Si₃N₄ masked InP mesas, followed by wet etch for controlled undercutting of mask in preparation for MOVPE regrowth
H₃PO₄:H₂O:saturated bromine water (1:15:2); undercut-mesa etch of InP for MOVPE regrowth following RIE etch
HNO₃:HBr:H₂O (1:1:10); undercut-mesa etch of InP for MOVPE regrowth following RIE etch
H₃PO₄:H₂O:saturated bromine water (5:5:2); undercut-mesa etch of InP for MOVPE regrowth following RIE etch
H₃PO₄:H₂O:saturated bromine water (10:10:1); undercut-mesa etch of InP for MOVPE regrowth following RIE etch

HF:H₂O (1:20) or (1:40); Selective etch of sacrificial AlSb layer to lift-off an InAs layer from a GaAs substrate
HF:H₂O₂:H₂O (2:1:20); Selective etch of GaSb from InAs stop layer

ECV profiling; InP; unidentified electrolyte compared with HCl
  o-H$_3$PO$_4$:HNO$_3$:H$_2$O (5:30:1); Application: chemical growth of native oxide on InP for use as solar cell surface coating

  NH$_3$F$_2$-H$_3$PO$_4$ (UNIEL); Electrolyte for EC-V profiling InP and GaAs

  Comparison of electrolyte for C–V profiling of InP and GaAs materials:
  - HCl
  - Tiron
  - pear etch
  - EDTA
  - Ammonium tartarate
  - FAP

  0.3 M $N$-$n$-butylpyridinium Chloride (C$_{14}$H$_{23}$ClN):1 M NH$_3$F$_2$ (1:4); electrolyte for Electrochemical C–V profiling; does not destroy calomel electrodes (in BIORAD/Polaron proflers); useful on InP, GaAs, InGaAs, AlGaAs, AlGaP, GaP, InGaAsP, Si and Ge

  o-H$_3$PO$_4$:HNO$_3$:H$_2$O$_2$:H$_2$O; InP thinning etch; with concentration dependent etch rates from 5 to 110 nm/min

  HF:CH$_3$COOH:H$_2$O$_2$
  H$_3$PO$_4$:HF (1:1); electrolytes for photoelectrochemical defect etch pit delineation; compared with chemical defect etchant results from: HNO$_3$:HBr (1:3)
  H$_3$PO$_4$:HBr (1:2) (Huber etch)

III–V semiconductor etchant review; gives pre-1962 data tables for chemical etchants of InSb, GaSb, AlSb, InAs, GaAs, InP, GaP

Review: general discussion of etch pit dislocation and hillock formation

(0 0 1)orientation determination; (1 1 1)A planes etch faster than (1 1 1)B planes:
HF:H2O2:H2O (1:1:4); InSb, InAs, GaAs
HF:HNO3:H2O (1:1:4); InSb
HF:HNO3 (1:1); InSb
HCl conc.; InAs
HNO3:H2O2:tartaric acid (1:1:6); InAs
HNO3:HF:CH3COOH:Br2 (75:15:15:0.06); InAs
HCl:H2O2:H2O (1:1:2); GaSb
HNO3:tartaric acid (1:3); GaSb
HNO3:tartaric acid (3:1); GaAs
HF:HNO3:H2O (1:1:1); GaSb
HCl:HNO3:H2O 1:1:1); GaAs
H2O2:NaOH (3:1); GaAs

Reactive ion etching; HBr for gate recess in InGaAs/InAlAs FETs; surface analysis

Reactive ion etch; BCl3/N2 of GaN; nitrogen decreases etch rate of sapphire substrates

Br2/methanol; Application: InGaAsP thinning for X-ray lattice parameter profile

HCl conc.; InP (1 0 0) etch rate = 5.4 μm/min; InP selective etch from InGaAsP. H2SO4:H2O2:H2O (1:1:10); InP (1 1 1)B etch rate = 30 Å/min; InP (1 0 0) etch rate is negligible
H2SO4:H2O2:H2O (1:1:10); In0.73Ga0.27As0.63P0.37 etch rate = 1000 Å/min
H2SO4:H2O2:H2O (1:1:10); In0.33Ga0.17As0.39P0.61 etch rate = 420 Å/min
H2SO4:H2O2:H2O (1:1:10); In0.90Ga0.10As0.04P0.96 etch rate = 75 Å/min
  Reactive ion etch; CH$_4$/H$_2$; InP; study of etch mechanism

  Plasma etching of InP in CH$_4$–H$_2$ mixtures; study of etch mechanism

  Reactive ion etch; CH$_4$/H$_2$; InP; study of surface damage with X-ray photoelectron spectroscopy

  HCl:H$_2$O (2:1); InP (1 0 0) etch rate = 5 μm/min; acts as dislocation delineation etch with increased dilution
  HCl:HClO$_4$ (1:1); InP selective etch from InGaAsP; etch rate = 6 μm/min
  Glycerine:HCl:HClO$_4$ (1:2:2); InP selective etch from InGaAsP; etch rate = 2 μm/min at 20°C; similar rates on n- and Si-InP; with smooth mesa surfaces. Glycerine:HCl:HClO$_4$ (2:1:4); InP etch rate = 0.6 μm/min

<table>
<thead>
<tr>
<th>H$_2$SO$_4$:H$_2$O$_2$:H$_2$O:</th>
<th>InGaAsP etch rate (μm/min)</th>
<th>InP etch rate (μm/min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(3:1:1) 20°C</td>
<td>0.7</td>
<td>0.014</td>
</tr>
<tr>
<td>(3:1:1) 30°C</td>
<td>1.6</td>
<td>0.035</td>
</tr>
<tr>
<td>(3:1:1) 20°C</td>
<td>0.6</td>
<td>0.012</td>
</tr>
<tr>
<td>(3:1:1) 30°C</td>
<td>–</td>
<td>0.030</td>
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<table>
<thead>
<tr>
<th>HCl:H$_3$PO$_4$</th>
<th>InP etch rate (selective from InGaAsP) (μm/min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1:1) 60°C</td>
<td>27</td>
</tr>
<tr>
<td>(1:4) 60°C</td>
<td>4.8</td>
</tr>
<tr>
<td>(1:6) 60°C</td>
<td>3.0</td>
</tr>
<tr>
<td>(1:1) 20°C</td>
<td>2</td>
</tr>
</tbody>
</table>

  HNO$_3$:H$_2$O (1:10–100); GaAs and AlGaAs non-selective etch under illumination
  HNO$_3$:H$_2$O (1:200); GaAs selective etch from AlGaAs under illumination. HNO$_3$:H$_2$O (1:300–1000); weak etching for both GaAs and AlGaAs with trench at boundary between illuminated and dark regions

HNO₃:H₂O (1:20); GaAs n-type photoelectrochemical etch; no measurable etch without illumination; similar etch rates for AlGaAs; applied bias shows a current minimum as a GaAs/AlGaAs interface is crossed during etching; surface roughness limits assessment of MQWs


Plasma etch environmental concerns


HCl:CH₃COOH:H₂O₂ (1:20:x); 0 < x < 5; etch rates for GaAs, InP and InGaP
HCl:CH₃COOH:H₂O₂ (1:y:1); y > 20 gives slow etch rates and smooth surfaces
HCl:CH₃COOH:H₂O₂ (1:40:1); etch rate dependence on the age of the solution


Reactive ion etch; CH₄/H₂ and SiCl₄
Ar and Ne ion beam etching
ECR plasma etching in CCl₂F₂/He; GaAs surface conductance measurement assessment of etch damage


Review: dry etching processes; classification of dry etching as: physical, chemical, chemical-physical, and photochemical; tabulates the approaches and their characteristics


HBr:HNO₃ (3:1); Application: InP (1 1 1) dislocation etch pit delineation; for 7 s


KF (0.75N):HF (0.75N); Application: InGaAs/InP photochemical etch; n-substrate wafer is biased to deplete the surface; incident light generates holes which assist oxidation to promote etching; 175 μm in 4 h; etch depth stops at p-InGaAs; diameter continues to widen


Laser-induced projected pattern etching of GaAs in Cl₂
Thermochemical, laser-induced dry etch of GaAs in Cl₂

Thermochemical Cl₂ etching of GaAs; pulsed laser heating to desorb etch products; photomask pattern etching of vias and recesses

succinic acid:H₂O₂ (30:1); selective etch of InGaAs from InAlAs; selectivity is 1030 for layers lattice-matched to InP
succinic acid:H₂O₂ (15:2); selective etch of InGaAs from InAlAs; selectivity is 70 for strained layers on GaAs

Capacitance coupled plasma; BCl₃/Cl₂ of GaAs; rate enhancement by adding Lewis acid gas (BCl₃)

Reactive ion etch; BCl₃/(Ar, He); study of AlGaAs etching

Reactive ion etch and ECR etch; BCl₃/Cl₂/CH₄/H₂/Ar of GaN and GaAs; radially uniform etching

Reactive ion etch; BCl₃ + He; AlGaAs/GaAs; very small etch rate dependence on Al content

H₂SO₄:H₂O₂:H₂O (5:1:1); InGaAs surface cleaning for OMVPE InP regrowth
H₂SO₄:H₂O₂:H₂O (1:8:100); InGaAs/InP mesa p–n junction surface treatment to reduce excess surface recombination
HBr:CH₃COOH:K₂Cr₂O₇ (1:1:1); InP and InGaAs mesa etch, equal rates for both

NH₄OH:H₂O₂ (1:170); Application:? selective etch from?
H₃PO₄:H₂O₂:CH₃OH (28:16:84); Application: AlGaAs mesa etch
NH₄OH:H₂O₂:H₂O (2:0.7:100); Application: Al₀.₄₂Ga₀.₅₈As selective etch from GaAs

HF:CrO₃:H₂O; diluted Sirtl-like (DSL) photoetching; GaAs; identification of etch features with transmission electron microscopy

CrO₃:HF:H₂O (DSL, diluted Sirtl-like with light photoetch); defect delineation in GaAs; comparison to EBIC images

HF:CrO₃ (1:5) diluted with H₂O (1:1) {DSL; diluted Sirtl-like etch with light}; GaAs photoetch, 30 s for etch pit delineation of dislocations

CrO₃:HF:H₂O; diluted Sirtl-like (DSL) photoetching; Application: GaAs defect delineation

H₃PO₄:HCl (1:1); Application: InP selective etch from InGaAsP
H₂SO₄:H₂O₂:H₂O (3:1:1); InGaAsP selective etch from InP

NaOCl; GaAs etch-polish to remove surface polish damage
H₂SO₄:H₂O₂:H₂O (3:1:1); Application: GaAs substrate cleaning for MBE; at 48°C for 1 min followed by heating in air at 250–300°C for 3–5 min to form a protective stable oxide as protection against contamination

Thermochemical etch of AlGaAs with HCl; in situ MOVPE

H$_2$SO$_4$:H$_2$O$_2$:H$_2$O (10:1:1); GaAs striation pattern delineation in semi-insulating LEC material; 20–30 min at 10°C under illumination.


Br$_2$/methanol; GaAs and GaP
I$_2$/methanol; InSb
Cl$_2$/methanol


ECR plasma etch; CH$_4$/H$_2$/Ar; Application to self-aligned InAlAs/InGaAs HBT


Reactive ion etch; CF$_6$, SF$_6$; selective removal of tungsten from III–V semiconductors using a titanium etch mask


Thermochemical vapor etch; Cl$_2$; GaAs and InP in situ vacuum technique for MBE substrate cleaning


Thermochemical vapor etch; Cl$_2$; GaAs under high vacuum conditions; temperature range: 100–700°C; surface and profile characteristics of SiO$_2$-masked patterns


(NH$_4$)$_2$S$_x$; GaAs surface treatment for MBE regrowth


HCl:HNO$_3$ (1:2); equal etch rate on InP and InGaAsP = 0.16 μm/s


Plasma anodic oxidation; InP

$\text{H}_3\text{PO}_4: \text{H}_2\text{O}_2: \text{H}_2\text{O}$ (1:1:8); Application: InGaAs notch etch for FET; etch rate $= 0.47 \mu \text{m/min}$


$\text{NH}_4\text{OH}: \text{H}_2\text{O}_2: \text{H}_2\text{O}$ (20:7:973); GaAs (1 1 1)B etch rate $= 0.2 \mu \text{m/min}$; GaAs (1 0 0) etch rate $= 0.12 \mu \text{m/min}$; GaAs (1 1 1)A etch rate $= 0.037 \mu \text{m/min}$; shows much less SiO$_2$ mask undercutting than with NaOH: H$_2$O$_2$ etchant


S passivation of InP in $\text{S}_2\text{Cl}_2$, $(\text{NH}_4)_2\text{S}$, and sulfide-containing Br$_2$:methanol solutions


$\text{H}_2\text{O}_2$: [HF + H$_2$O + 0.4% butylthiobutane] (1:1); InSb {1 1 1}Sb dislocation delineation


InSb {1 1 1}; dislocation etch pit delineation

GATOS, H.C., and M.C. Lavine, “Etching Behavior of the {1 1 0} and {1 0 0} Surfaces of InSb,” J. Electrochem. Soc., 107(5), 433–36 (1960b)

InSb {1 1 0} and {1 0 0}; dislocation etch pit delineation


Reactive ion etch; CCl$_2$F$_2$, SiCl$_4$, BCl$_3$, CF$_4$ and mixtures with Ar; GaAs via hole fabrication characteristics


Relationship of semiconductor etching to the Fermi level for electrochemical and photochemical techniques; GaP, GaAs


Review of electrochemical behavior of semiconductor electrodes

Treatise on photochemical behavior of semiconductors; discusses thermodynamics and kinetics of photodecomposition and function of electrolyte junction solar cells


Ar ion milling; energy dependence and damage depth distribution; GaAs/AlGaAs; uses degradation of a single quantum well to assess damage depth


Ion milling etch; Ar + O₂; InGaAs/InP quantum well structure profiling by photoluminescence at different depths


Ion beam etch; Ar + O₂; InGaAs/InP; induced damage is assessed from photoluminescence of a single quantum well

Reactive ion etch; Ar:O₂ (9:1) from 175 to 1200 eV with constant current density of 0.12 mA/cm²; Application: InGaAs/InP heterostructures; etch rate for InP = 4.5 nm/m at 175 eV and 27.8 nm/min at 1200 eV; Ar + O₂ mixture causes damage to InP barrier layer


NH₄OH:H₂O₂:H₂O (5:3:80); Application: GaAs/AlGaAs for 6 s; photolithography isolation of Hall bars


NH₄OH:H₂O₂:H₂O; Application: selective removal of GaAs from InGaP

HBr:Br₂:H₂O (5:0.1:100); Application: non-selective mesa etch for InGaP/GaAs; etch rate 0.6 μm/min for both materials


Ceric sulfate (saturated solution):HNO₃ (9:1); chromium etchant from semiconductor surface; etch rate ~800 Å/min
I2:KI:H2O (100 g:400 g:400 ml); gold etchant from semiconductor surface. NaOH (20%); Al etchant; 60–90°C

Ar ion sputtering; GaAs etch rate = 650 Å/s; etch profiles

HCl conc.:CuCl (1.0 N); GaSb surface etching to determine crystal orientation

Review; electrochemistry of III–V semiconductors

(NH4)2Sx passivation of InAs/InAsPSb photodetectors

Plasma etch; CCl4; InP and GaAs; time dependent etch rates indicate inhibition of etching above 250°C by a chlorocarbon deposit. kinetic study with spectroscopy; diffusion model; etch rate depends on temperature and power; etch rate is enhanced at lower flow rate of CCl4

GOTTSCHALCH, V., “Structural Etching of {0 0 1} and {1 1 0} faces of various AIII BV Compounds,” Kristall. und Technik., 14(8), 939–47 (1979a)
Photochemical dislocation etch pit delineation and cleaved cross-section layer delineation:
H2PO4:H2O2 (1:1); GaP (1 0 0), 15 min under illumination
H2PO4:H2O2 (1:1); GaAs0.2P0.8 (1 0 0) 10 min under illumination
H2PO4:H2O2 (10:1); GaAs0.6P0.4 (1 0 0) 15 min under illumination
H2PO4:H2O2 (10:1); GaAs (1 0 0) 3 min under illumination
H2PO4:H2O2 (10:1); Ga0.98In0.02As (1 0 0) 3 min under illumination
A–B etch; with A = 40 ml H2O: 40 g CrO3; B = 40 ml H2O: 0.3 g AgNO3; A:B (3:1); GaP 15 min at boiling; etch pits show 1-to-1 correlation with H2PO4:H2O2 photoetch

GOTTSCHALCH, V., W. Heinig, E. Butter, H. Rosin, and G. Freydank, “H3PO4 Etching of (0 0 1)-faces of InP, GaInP, GaP and GaAsP,” Kristall. und Technik., 14, 563 (1979b)
H3PO4; (1 0 0): InP, GaInP, GaP, GaAsP
H$_3$PO$_4$:H$_2$O$_2$ (1:1); InP and InGaAs lattice defect delineation with preferential photoetching
H$_2$O$_2$ (30%); InGaAs treatment leaves 8–10 Å In$_2$O$_3$ and Ga$_2$O$_3$

HCl:HNO$_3$:H$_2$O (1:3:x); InP photoetching through thin electrolyte layer; etch rate is dependent on x

Ar ion beam etch, surface damage study using characteristics of a GaAs/AlGaAs superlattice quantum well structure

Reactive ion etch surface damage assessment from cathodo- and photo-luminescence of buried quantum wells as damaged surface is incrementally thinned by oxidation/stripping steps
HCl:H$_2$O (1:3); oxide removal; from AlGaAs/GaAs

NH$_4$OH:H$_2$O electrochemical etch with pH = 10.6–13.4; GaAs delineation of striations, dislocations and twins

Electrochemical C–V profiling; InP; best results with HCl(37%):HNO$_3$(70%):isopropanol (36:24:1000) electrolyte (Pear Etch); low free chemical etch rate = 0.66 µm/h; requires low constant flow of electrolyte over sample (note: do not store longer than 1 week)

H$_2$SO$_4$:H$_2$O$_2$:H$_2$O (1:10:220); selective etch of InGaAs layer with InP etch-stop layer for HFET

Ferric sulfate(non-ahydrate):EDTA(disodium salt of ethylenediaminetetracetic acid):H$_2$O (5 g:3 g:100 ml); GaAs photoelectrochemical p–n junction delineation

H₂O₂ buffered with NH₄OH (pH ≈ 7); Application; GaAs selective etch from InGaAs; at 21°C the GaAs etch rate = 740 Å/min; the In₀.₁₈Ga₀.₈₂As etch rate = 67 Å/min


ECR etch, rate monitoring with laser reflectance; GaAs, AlAs, AlGaAs in situ measurement


Citric acid:H₂O₂ (3:1); GaAs selective etch from AlAs stop etch layer

HCl dilute; AlAs etch stop layer removal from GaAs


InN wet chemical etching study; no etch in acid:H₂O₂ solutions; KOH:H₂O (33 wt.% solution); InN etch rate at 50°C = 220 Å/min. NaOH:H₂O (33 wt.% solution); InN etch rate at 50°C = 65 Å/min

GUYAUX, J.L., J.-M. Ortion, Y. Cordier, M. Kappers, E. Chirlias, and J.-Ch. Garcia, “Kinetics of AsCl₃ chemical beam etching of GaAs(0 0 1, (1 1 1)A and (1 1 1)B surfaces,” J. Cryst. Growth, 201/202, 614 (1999)

Thermochemical etching of SiO₂-patterned GaAs using AsCl₃ in a CBE reactor
Photochemical etch in HBr gas; selective etch of InGaAs from InAlAs; selectivity of \( \sim 1.0 \) results from non-volatile oxide formation on InAlAs

HABIBI, S., M. Totsuka, J. Tanaka, and S. Matsumoto, “Dry sequential process of photochemical etching and surface passivation of In\(_{0.52}\)Al\(_{0.48}\)As using HBr and H\(_2\)S,” J. Vac. Sci. Technol., B, 13(4), 1466 (1995b)  
HBr photochemical dry etch; selectively removes InGaAs from InAlAs. H\(_2\)S:N\(_2\) (1:9) photochemical gas sulfidization of In\(_{0.52}\)Al\(_{0.48}\)As

Ion beam etch, chemically assisted; Cl\(_2\); GaAs vertical facets

ICl thermochemical vapor etch; GaAs etch rate study in 100–300°C temperature range

Inductively coupled plasma etching; Cl\(_2\)/Xe, Cl\(_2\)/Ar, and Cl\(_2\)/He of InN, GaN, and AlN; study of etch characteristics

RIE inductively coupled plasma etch of GaAs, GaP, AlGaAs, GaSb in Cl\(_2\)–Ar mixtures

Photoetching of n-GaAs in KCl, KOH, and HCl electrolytes

H\(_{3}\)NO\(_3\):HCl:H\(_2\)SO\(_4\):H\(_2\)O (1:2:2:2); GaP \{1 1 1\}B, 5 min to remove mechanical polish damage. etch rate is dependent on carrier concentration

Na\(_2\)S:isopropanol (saturated solution); sulfur passivation of InGaAsP/InP laser diodes; reduced surface recombination
KOH: K$_2$Fe(CN)$_6$:H$_2$O (6 g:4 g:50 ml); Application: InP cleaved cross-section layer delineation; ~5 min at 20°C

KCN (20%) solution; Application: GaAs, Si, Ge; cleaning of metallic ions from surface prior diffusion

HCl (1 M); electrolyte for photo-anodic etching and pulsed avalanche etching of InP (0 0 1); formation of pore arrays

KI:I$_2$:H$_2$O; Application: removal Au implantation mask from InGaP; etch rate = 150 Å/s

Layer by layer etch of GaAs (1 1 0) by Cl$_2$ exposure followed by laser photodesorption

Sulfur passivation of InP; anodization in (NH$_4$)$_2$S$_x$ solution; study of surface stability

Dry etch optical emission spectroscopy monitoring of etch products to determine etch endpoint for removing InAlAs emitter layers without removing InGaAs base layers in HBT structures; development of modeling algorithm

H$_2$SO$_4$:H$_2$O$_2$:H$_2$O (1:8:200); Application: selective etch of GaAs from InGaP
HCl:H$_3$PO$_4$ (1:3); Application: selective etch of InGaP from GaAs

Nitridization of GaAs in plasmas of N$_2$ + O$_2$ with pretreatment in O$_2$ + Ar plasma
Ar ion etching; Cl2 assisted; Application: InP substrate patterning by etch of a Ga ion beam direct-write damage pattern

H2SO4 (0.2 M); electrolyte for photo-selective etch of n-InAs
HCl (0.2 M); electrolyte for photoelectrochemical etch of InAs

H3PO4:H2O2:H2O (3:1:50); Application: GaAs MESFET mesas

ICP and ECR etching of InP submicron pillars using SiCl4/Ar

Reactive ion etch; CH4 + H2; InP and InGaAsP; near-surface properties are modified. phosphorous depletion rate depends on CH4/H2 ratio; morphology and electrical damage (Ohmic contacts) caused by etching; layer of damage ~150 Å; great H2 passivation near Zn-acceptor for p-InP but not for p-InGaAsP

Reactive ion etch; CH4/H2; InP etch kinetics

Br2:KBr:H2O (1:10:89); n-GaAs photoetchant for maskless laser-induced patterning
I2:KI:H2O (0.1:10:90); n-GaAs photoetchant for maskless laser-induced patterning

Plasma etch; CF4; InP surface damage study by photoreflectance
HCl:H$_3$PO$_4$:CH$_3$COOH (1:1:2); InP selective etch from InAlAs; selectivity > 85; InP etch rate = 3000 Å/min
HCl:H$_3$PO$_4$:CH$_3$COOH (1:1:1); InP selective etch from InAlAs; selectivity > 34 with improved photolithographic pattern definition; InP etch rate = 10,000 Å/min; InAlAs etch rate = 300 Å/min

Review: silicon defect etch pit delineation

HCl conc.; InP photolithography; gives HCl etch orientation dependence of sidewall profiles and InGaAsP mask undercutting following an initial reactive ion dry etch in Cl$_2$/O$_2$ which leaves the pattern with an initial 75° wall angle

Reactive ion etch; CH$_4$ + Ar + H$_2$; InP, GaAs, InGaAs, AlGaAs and InGaAsP; Si$_3$N$_4$ mask is used; Ar reduces deposited hydrocarbon polymers and improves surface morphology at 1 W/cm$^2$ RF power current density, almost vertical walls are achieved; InP, InGaAs, GaAs, and AlGaAs etch rates are 70, 50, 30 and 10 nm/min, respectively; better control of etching rate could be obtained at lower power (0.3 W/cm$^2$ with SiO$_2$ mask instead with Si$_3$N$_4$); Application: InGaAs junction FET; Al$_{0.3}$Ga$_{0.7}$As etch rate is less than other III–V compounds etch rate

HCl:HNO$_3$:HF (5:3:4); InP grain boundary delineation; no effect on first-order twins

Reactive ion etch; CCl$_4$/He; Application: AlGaAs selective etch from GaAs with selectivity > 1000

Adipic acid:NH$_4$OH:H$_2$O$_2$ (1 g adipic acid in 5 ml H$_2$O; NH$_4$OH to adjust pH over the range 5.3–7.0; H$_2$O$_2$ added in the range of volume ratios of 0.013–0.12); InGaAs removal from InAlAs; selectivity up to 250

Reactive ion etch; CCl₂F₂ + He; GaAs selective etch from Ga₀.₇Al₀.₃As; gives etch rate selectivity dependence on gas pressures and concentrations


H₂O₂:NH₄OH (250:1), pH = 7.3; GaAs selective etch from InGaAs, selectivity > 50; attacks photoresists; SiO₂ photolithographic mask defined by buffered HF etch

K₃Fe(CN)₆:K₄Fe(CN)₆·3H₂O (14.8 g:19.0 g:200 ml H₂O:buffered with 3 ml HCl:H₂O {1:1000} to pH = 6.7); GaAs and Al₀.₃Ga₀.₇As selective etch from In₀.₁Ga₀.₉As; selectivity > 8

H₃PO₄:H₂O (1:4); GaAs oxide removal prior to etching and InGaAs oxide removal following the above etch


Reactive ion etch, CCl₂F₂; Application: via hole formation in GaAs


Reactive ion etch; CCl₂F₂; Application: via holes in GaAs


H₃PO₄:HBr (2:1) (Huber etch); Application: InP defect delineation etch; 2 min at room temperature

CrO₃:AgNO₃:H₂O:HF (1 g:8 mg:2 ml:1 ml) (A–B etch); Application: InP defect delineation etch; 60 min at 60°C


Br₂/methanol; Application: InGaAsP stripe etch for BH laser fabrication


Br₂/methanol; Application: InGaAsP stripe etch for BH laser fabrication


Reactive ion etch; CCl₄:O₂; Application: InP laser gratings. highest etch rate at 5E–4 Torr = 850 Å/m; etch rate ratio of InP to AZ-1350 photoresist is 3.5 at 1E–3 Torr; InP etch rate linearly increases with O₂ concentration up to 50% but then decreases when O₂ is higher than 50% while etch rate for photoresist increases with O₂ concentration; in CCl₄ + O₂, O₂ reacts with carbon to produce CO₂ which enhances InP etch rate; InP etch rate rapidly decreases at
pressure above 2E–2 Torr; etch rate for InP and photoresist linearly increase with RF power density


NH₄OH:H₂O₂:H₂O (1:1:20); Application: GaAs; for removal of surface damage after annealing, prior to Schottky contact


H₂O; GaAs (0 0 1) surfaces treated with ultrasonic running deionized water show complete removal of arsenic and gallium oxides following etch in H₂SO₄ or NH₄OH


NH₄OH:H₂O₂:H₂O (1:1:20); GaAs surface treatment to remove damage, 2 min at room temperature

H₂O (deoxygenated, deionized); GaAs treatment for oxide-free surface


H₂O; dissolution of oxides from GaAs


H₂SO₄:H₂O₂:H₂O (1:1:10); Application: InGaAs/AlGaAs MQW laser using 30 Å InGaP etch stop layer


HF:H₂O (1:10); Si photoetch, rate increase of 1000X under illumination; Si etch rate = 26 Å/s


1 M KOH aqueous solution; GaAs n-type voltage-controlled photoetching at 26°C; self-limiting to thickness of the depletion layer for FETs


Iodic acid:H₂O (10% wt. solution); InP surface preparation AES study for Schottky contacts


Electrochemical etch study on GaAs; redox processes and photoeffects on III–V etchant selectivity

XPS study of InP surface oxides following chemical treatment:

- NaOH:H₂O₂ (1 M:0 > 8 M)
- Br₂:HBr:H₂O (1:17:35)
- HNO₃

Wet chemical etch; Br₂:CH₃OH and HF are used for InP surface treatment before oxidation study; chemicals for oxidation study include: NaOH:H₂O₂ (1 M:0.8 M) for 20 min at 80°C; Br₂:HBr:H₂O (1:17:35) for 30 s and HNO₃ (40%) under strong illumination


Anodization: InP; study of surface passivation


- H₂SO₄:H₂O₂:H₂O (1:8:80); Application: selective removal of GaAs from InAlP stop layer; 1 min
- HCl:H₂O (1:1); Application: selective removal of InAlP layer form GaAs; 20 s


- NH₄OH:H₂O₂ (1:1); Application: InAs and InSb substrate cleaning; used boiling to remove organic residues
- Lactic acid:HNO₃:HF (50:8:2); InSb surface cleaning for LPE; no carbon contamination


- NaClO (5% solution); AlGaAs/GaAs stained, chemi-mechanical beveled cross-section quantum well layer delineation


- ECR hydrogen plasma surface oxide removal from InP


- ECR etch; CCl₂F₂/Ar; AlGaInP/GaInP low damage

Inductively coupled plasma (ICP) etch of InGaAlP using $\text{BI}_3$ and $\text{BBr}_3$ with or without $\text{Ar}$; AlInP acts as etch stop for InGaP and AlGaP

Inductively coupled plasma etching in $\text{Cl}_2$ and $\text{BCl}_3$ of InGaP, InAlP and AlGaP; study of etch behavior

ECR etch; ICl and IBr; comparison for etching InGaAlP

ECR plasma etch; $\text{Cl}_2$/Ar, $\text{BCl}_3$/Ar, $\text{BCl}_3$/N$_2$, ICl/Ar, and IBr/Ar; study of etch rates for InGaP and AlGaP

ICP etch study of InGaP, AlInP and AlGaP using CH$_4$/H$_2$/Ar and Cl$_2$/Ar

ECR etch; $\text{Cl}_2$/Ar; high etch rate conditions for InGaP and AlInP

ECR plasma etch; $\text{BCl}_3$/Ar; of InGaP, AlInP and AlGaP; comparison to RIE

ECR etch; $\text{H}_2$; GaAs surface cleaning followed by:
$\text{Cl}_2$ thermochemical etch: 1–2 min at 350–400°C

$\text{Cl}_2$ etch of AlGaAs; in situ high vacuum; surface reconstruction and anneal
HF:HNO₃:H₂O (15:10:300) {p-etch (Si)}; Application: SiO₂ selective etch of electron beam irradiated pattern mask on Si; irradiated area etch rate is 3 × non-irradiated area
KOH:H₂O (5 g:20 ml); Si anisotropic etch at 65°C, stops at {1 1 1} planes

Laser-induced photoetching of Si in Cl₂ and NF₃ gases

Inductively coupled plasma etch; BCl₃/Cl₂; etched mirrors for ridge lasers

Br₂/methanol (1%); InGaAsP/InP mesa etch; temperature dependence of etch rate; for T < −58°C there is no undercutting of SiO₂ masks

KOH:Fe(CN)₆:H₂O (6 g:4 g:50 ml); Application: p–n junction photochemical delineation for Zn diffusion assessment in InGaAsP/InP structures

Sulfur passivation of GaAs surface using a sulfur glow discharge plasma

Reactive ion etch of InP in CH₄/H₂; reaction modeling

H₃PO₄:HCl (4:6); Application: InP selective etch from InGaAs
H₂SO₄:H₂O₂:H₂O (3:5:50) InGaAs selective etch from InP

CAIBE; Ar/Cl₂ of AlGaAs/GaAs in ultrahigh vacuum to eliminate aluminum oxide problems

HCl: photochemical; InAs and GaP etch characteristics under illumination; reaction kinetics dependence on semiconductor band structure


HNO3: GaP oxidation/etching under illumination; chemical kinetics


KOH: K2Fe(CN)6·H2O; Application: InGaAsP/InP cleaved cross-section layer delineation; ∼5 s at 20°C


Reactive ion etching; modeling of ion-induced damage in III–V semiconductors


1. Etch damage using low energy ions on semiconductors


Review; plasma etching of III–Vs


Reactive ion etch; CCl2F2/Ar/O2; InP and GaAs


Reactive ion etch of InP using CH4/H2/Ar; damage study

Thermochemical etch of InP using Cl; damage study

Cl-assisted RIE of InP; damage study


HNO3:HCl:H2O (1:4:50); GaAs photoinduced etching to taper the thickness by varying pattern of the UV intensity
ECR plasma oxidation study of InP

ECR plasma oxidation; InP surface passivation
HF:methanol (1:10); Application: InP native oxide removal; 2 min ultrasonic

HBr:HNO₃:H₂O; Application: InP mesa stripe using an InGaAsP interface layer to control the sidewall shape for reproducible height and width

H₃PO₄:HBr (2:1) {Huber etch}; InP dislocation etch pit delineation
A–B etch; InP dislocation etch pit delineation
HCl:HNO₃:H₂O (1:3:6)
HCl:HNO₃:Br₂ (10:20:0.25); comparison

Citric acid:H₂O₂:NH₄OH; study of concentration and pH for selective etch of GaAs from Al₀.₂₂Ga₀.₇₈As; selectivity of 200 at 20°C and 500 at 0°C; GaAs rate = 1000 Å/min
H₂SO₄:H₂O (1:8); GaAs deoxidation for 1 min

Thermochemical nitridization of GaAs in NH₃; synchrotron photoemission spectroscopy study

HCl:H₃PO₄ (5:1); InP; vee-groove etchant with photoresist mask; undercut rate is modified by heating substrate

HBr:H₂O₂:HCl:H₂O (20:2:20:20); InP (1 1 1) and (1 0 0) dislocation etch pit delineation; etch pit shape and formation depend on H₂O₂ and water concentration; shelf time of this etchant is about 12 h
HCl:H3PO4 (3:1); InP vee-groove etchant at room temperature with photoresist mask; depth etch rate = 0.083 μm/s; undercut etch rate = 0.042 μm/s; shelf time is about 20 h; undercut may be reduced by heating substrate

InP (1 0 0) photoresist undercut study; etch profiles:
H3PO4:HCl:H2O2 (1:5:0.1–1)
H3PO4:HCl:HF (1:5:0.1–1); (HF causes bad undercut)
H3PO4:HCl:HBr (1:5:0.1–1)
H3PO4:HCl (1:5)

HBr:H2O2:H2O:HCl (20:2:20:20); InP (1 0 0) photolithography vertical sidewalls; control of (1 1 1)A versus (1 1 1) B anisotropy; shows effects of changing HBr and HCl concentrations

HCl:H3PO4 (5:1); InP vee-groove etch ⟨1 1 0⟩ direction; no undercut
HBr:H3PO4:1N K2Cr2O7 (2:1:1); InP vee-groove etch for ⟨1 1 0⟩ direction; attacks photoresist; undercut

HCl:H3PO4 (5:1); InP vee-groove etchant with photoresist mask; undercut is minimized with oxide removal in 48°C HF bath before etch; undercut etch rate = 0.042 μm/s

HUO, D.T.C., M.F. Yan, and J.D. Wynn, “New Chemical Solutions for the Etching of (0 0 1) Oriented V-Grooves in InP (0 0 1) for CSBH Laser Diodes,” J. Materials Research, 4, 857 (1989d)
HP3O4:HCl:H2O (1:1:1); InP (1 0 0) vee-groove etch; does not erode photoresist
HP3O4:HCl:HBr (1:1:1); InP (1 0 0) vee-groove etch; does not erode photoresist

Br2/methanol (1%); InGaAsP/InP; study of etch temperature on profile geometry and undercutting; Application: InGaAsP/InP double heterostructure laser; zero mask undercutting when etch at or below −58°C
KOH:K3Fe(CN)6:H2O (6 g:4 g:50 g): InGaAsP/InP layer delineation
Reactive ion etching; Cl₂/BCl₃/Ar and BCl₃/Ar; Application: GaAs free standing airbridge contacts

Reactive ion etch; Cl₂/HBr/BCl₃/Ar; InP via holes

Reactive ion etch; Cl₂:HBr:BCl₃:Ar; Application: using lift-off carbon masks for etching deep features on InP

Br₂/methanol; Application: InGaAsP/InP non-selective mesa etch

H₂SO₄:H₂O₂:H₂O (1:8:1); Application: GaAs etch

KOH:K₃Fe(CN)₆:H₂O (6 g:4g:50 ml); Application: InGaAs/InP cleaved cross-section layer delineation; etches InGaAs selectively; etch rate ~2 μm/min. This works best for multilayer delineation where the top layer is InP; etch rate is too fast to use on InGaAs layer directly
H₂SO₄:H₂O₂:H₂O (4:1:1); InP surface cleaning
Br₂:HBr:H₂O (1:17:300); InP surface treatment following H₂SO₄:H₂O₂:H₂O (4:1:1) for 2–4 min; etch rate = 0.8 μm/min

Plasma etch; Cl₂ and Br₂; GaAs (1 0 0); development of {1 1 1}, {1 0 0}, and {1 1 1}A facets

Reactive ion beam etch; N₂/O₂ of InP; characterization of surface damage

(NH₄)₂Sₓ sulfidation study of InSb surfaces

HCl:CH₃COOH:H₂O₂ (1:2:1) {KKI etch}; Application: InGaAsP/InP (1 0 0) non-selective etch; shows etch profiles


HCl:CH₃COOH:H₂O₂ (1:2:1) {KKI etch}; Application: InGaAsP/InP (1 0 0) non-selective mesa etch


HCl:CH₃COOH:H₂O₂ (1:2:1) {KKI etch}; Application: InGaAsP/InP (1 0 0) non-selective mesa etch

H₂SO₄:H₂O₂:H₂O (3:1:1); InP substrate cleaning for LPE


HCl:CH₃COOH:H₂O₂ (1:2:1) {KKI etch}; Application: InGaASP/InP non-selective groove etch at 15°C for laser mirror


HCl:CH₃COOH:H₂O₂ (1:2:1) {KKI etch}; Application: InGaASP/InP non-selective groove etch at 15°C for laser mirror

Buffered HF [NH₄F:HF (10:1)]; InGaAsP oxide removal


HCl:CH₃COOH:H₂O₂ (1:2:1) {KKI etch}; Application: InGaAsP/InP non-selective groove etch at 15°C for laser mirror


HCl:CH₃COOH:H₂O₂ (1:2:1) {KKI etch}; Application: InGaASP/InP non-selective groove etch for laser mirror

HCl:H₂O (4:1); InP (1 0 0) orientation determination


GaAs (1 0 0); study of etch rate dependence on temperature; etch rates and surface morphologies at 0°C are given as a ternary diagram:

H₂SO₄:H₂O₂:H₂O (1:4:0); GaAs (1 0 0) etch rate = 10 µm/min at 20°C
H$_2$SO$_4$:H$_2$O$_2$:H$_2$O (1:1:1); GaAs (1 0 0) etch rate = 8.8 µm/min at 20°C
H$_2$SO$_4$:H$_2$O$_2$:H$_2$O (5:1:1); GaAs (1 0 0) etch rate = 1.4 µm/min at 20°C
H$_2$SO$_4$:H$_2$O$_2$:H$_2$O (5:1:20); GaAs (1 0 0) etch rate = 0.60 µm/min at 20°C
H$_2$SO$_4$:H$_2$O$_2$:H$_2$O (40:1:1); GaAs (1 0 0) etch rate = 0.37 µm/min at 20°C

Orientation dependence of etch rate and etch profiles are given for:
H$_2$SO$_4$:H$_2$O$_2$:H$_2$O (1:8:1); GaAs (1 0 0) etch rate = 8.8 µm/min at 20°C
H$_2$SO$_4$:H$_2$O$_2$:H$_2$O (8:1:1); GaAs (1 0 0) etch rate = 1.3 µm/min at 20°C

H$_2$O:AgNO$_3$:CrO$_3$:HF (10 ml:40 mg:5 g:8 ml) {A–B etch}; GaP defect delineation; 50 min at 75°C
H$_2$O:AgNO$_3$:HNO$_3$:HF (8 ml:10 mg:6 ml:4 ml) {RC etch}; GaP defect delineation; 3 min at 60°C

Lactic acid (CH$_3$CHOHCOOH):Iodic acid (HIO$_3$):H$_2$O (1.5:1:2); InP etch rate of 2 A/s; specular surfaces; diffusion limited, isotropic etch
HCl:H$_3$PO$_4$:CH$_3$COOH (1:1:x, with 0 < x < 6); study of InP etch rate, surface finish and photoresist undercut
HCl:H$_3$PO$_4$:lactic acid (1:1:x, with 0 < x < 6); study of InP etch rate, surface finish and photoresist undercut. Smoother InP surfaces

HBr:HNO$_3$:H$_2$O (1:1:4); Application: InP/InGaAs pattern etch with Au mask for quantum wires; etch rate 100–200 Å/min at 33°C
KI:I$_2$:H$_2$O; Au mask removal from InP

HCl:H$_3$PO$_4$ (1:1); Application: InGaAsP ($\lambda = 0.997$ µm) stripe etch
H$_2$SO$_4$:H$_2$O$_2$:H$_2$O (3:1:1); InGaAsP ($\lambda = 1.52$ µm) stripe etch

HCl:HNO$_3$; Application: InGaAsP/InP photolithography groove etch profiles for vee-groove laser
HCl:H$_3$PO$_4$
Br$_2$/methanol

Application of reactive-ion-beam etching to recessed-gate GaAs metal–semiconductor field-effect transistors

HF:H2O (1:1); InP etch rate enhanced by Mg ion bombardment damage for maskless patterning

HBr:H3PO4:H2O (1:1:8); InGaAs etch at 0°C to define a lithography pattern for the purpose of using the thin InGaAs as an etch mask for underlying InP; eliminates mask undercutting
HCl:H3PO4:H2O (3:1:1); InP etch at 0°C, material selective from InGaAs; shows sidewall deformation for nanometer geometries. HCl:CH3COOH (1:4); InP material selective etch from InGaAs; gives near vertical sidewalls for nanometer geometries

HBr:H3PO4:H2O (1:1:8); InGaAs etch at 0°C to define a lithography pattern for the purpose of using the thin InGaAs as an etch mask for underlying InP; eliminates mask undercutting
HCl:H3PO4:H2O (3:1:1); InP etch at 0°C, material selective from InGaAs; shows sidewall deformation for nanometer geometries
HCl:CH3COOH (1:4); InP material selective etch from InGaAs; gives near vertical sidewalls for nanometer geometries

HCl:propylene glycol (1:2); Application: InP selective etch from InGaAs mask layer
H2SO4:H2O2:H2O (4:1:1); InGaAs selective etch from InP

HCl:H3PO4 (3:1); Application: InP vee-groove etch for laser fabrication

HCl:H3PO4 (3:1); Application: InP vee-groove etch for laser fabrication

Br2/methanol (0.05%) and H2SO4:H2O2:H2O (3:1:1); Application: InGaAsP/GaAs etched mirror lasers

K₂Cr₂O₇:HBr:CH₃COOH (3:1:1); Application: InGaAsP tilted laser facet etch
Saturated Br₂ water:HBr:H₂O; InGaAsP/InP laser surface grating etch


KOH:K₃Fe(CN)₆:H₂O; Application: InGaAsP/InP cleaved cross-section layer delineation


Br₂/methanol (0.1%); Application: InGaAsP stripe etch with SiO₂ mask for BH laser


HCl:H₂O (m:1, with 0.6 < m < 1.5); rate dependence for In₀.₅Ga₀.₅P, InGaAsP and GaAs
HCl:H₂SO₄:H₂O₂:H₂O (m:1:10:2000, with 0.6 < m < 1.5); rate dependence and selectivity for In₀.₅Ga₀.₅P, InGaAsP and GaAs


Anodization; InGaAsP/InP anodize/strip thinning of InP


NaOH:H₂O₂:NH₄OH (5:1:1); Application: GaAs/AlGaAs laser mirror etch
H₂SO₄:H₂O₂:H₂O; comparison profiles


H₂O; photochemical reaction on GaAs to unpin the Fermi level

(NH₄)₂S₇; sulfidization of InP surfaces; ammonium polysulfide solution prepared by dissolving about 2–2.5 g free sulfur into 25 ml of commercially available ammonium sulfide solution, then oxidizing by bubbling pure oxygen through it for about 30–45 min. This solution is then diluted with water, 20 drops in 15 ml H₂O, and heated with intermittent stirring to 50–60°C with previously etched InP in it

Low temperature thermochemical etching of InP, GaAs and InSb using remote plasma decomposition of ethylene dibromide. Plasma activated etching; ethylene dibromide, C_2H_4Br_2; InP, GaAs, InSb; InP etch rate = 4500 Å/min at 160°C, 25 W power without any damage; InP activation energy ~1.1 kcal/mol at <240°C; this low activation energy is due to low vaporization.

(NH_4)_2S_x; sulfidization of InP surfaces; ammonium polysulfide solution prepared by dissolving about 2–2.5 g free sulfur into 25 ml of commercially available ammonium sulfide solution, then oxidizing by bubbling pure oxygen through it for about 30–45 min. This solution is then diluted with water, 20 drops in 15 ml H_2O, and heated with intermittent stirring to 50–60°C with previously etched InP in it.

Electrochemical C–V profiling; III–V semiconductor carrier concentrations

Reactive ion etch of InP using CH_4/H_2; uniformity study

HCl conc.; InP; Application: low angle groove etch to reduce optical reflection in solar cells

NH_4OH:H_2O (1:15); Application: GaAs native oxide removal, 15 s
(NH_4)_2S_x:H_2O (1:1); Application: GaAs sulfide passivation; 20 min at 40°C

Electron cyclotron resonance ion stream etching of GaAs with SF_6–CF_4–SiF_4–O_2 for WSiN-gate FETs

H_2SO_4:H_2O (1:80); GaAs surface cleaning for MOCVD regrowth
H_2SO_4:H_2O_2:H_2O (1:8:80); selective removal of InGaAs from InGaP in MQW laser fabrication
Sulfur passivation of GaAs from H$_2$S; study of reaction behavior

Reactive ion etch; CF$_4$/O$_2$; InGaAs, study of surface treatment on photoluminescence behavior

Juang, C., K.J. Kuhn, and R.B. Darling, “Selective Etching of GaAs and Al$_{0.3}$Ga$_{0.7}$As with Citric Acid/Hydrogen Peroxide Solutions,” J. Vac. Sci. Technol., B, 8(5), 1122–24 (1990)
Citric acid:H$_2$O$_2$ (10:1); GaAs selective etch from Al$_{0.3}$Ga$_{0.7}$As, selectivity = 90; GaAs etch rate = 0.21 μm/min at 18°C; Al$_{0.3}$Ga$_{0.7}$As etch rate = 0.022 μm/min at 18°C

Reactive ion etch; comparison of Cl$_2$/BCl$_3$/Ar and CCl$_2$F$_2$/BCl$_3$/Ar for III–V compounds
NH$_4$OH:H$_2$O$_2$:H$_2$O (1:1:50); GaAs substrate cleaning prior to RIE

RIE using BCl$_3$/Ar from GaAs, GaInP, AlGaInP, and AlInP; selective removal of GaAs from InGaP; selective removal of InGaP from AlInP

Thermochemical etch; HCl in situ GaAs etch for MBE AlGaAs overgrowth

Monoethanolamine solution with NH$_4$OH:H$_2$O (1:5); treatment of GaAs prior to Ohmic contact metallization
H$_2$SO$_4$ (10%); oxide removal from GaAs
Atomic hydrogen; in situ cleaning of GaAs prior to Ohmic contact metallization

ECR etch; Cl$_2$/Ar; GaAs; in situ mass spectrometry monitoring of volatile by-products to assess etch efficiency

Kalburge, A., A. Konkar, T.R. Ramachandran, P. Chen, and A. Madhukar, “Focused ion beam assisted chemically etched mesas on GaAs(0 0 1) and the nature of subsequent molecular beam epitaxial growth,” J. Appl. Phys., 82(2), 859 (1997)
Focused ion beam chemical etch; Ga$^+$ ion beam assisted Cl$_2$ etching of GaAs for in situ patterning and MBE overgrowth

HF conc.; removal of Ti from InGaAs
C$_4$H$_6$O$_6$:H$_2$O:H$_2$O$_2$ (5:5:1); selective etch of InGaAs layer from InP; 8 min for 3000 Å
CH$_3$COOH:HCl (1:1); selective InP removal from InGaAsP; etch rate $\sim$1 μm/min
For fresh solution; rate decreases after 30 min
Etch mask, transparent low melting point was (Gatan Inc., USA)

K$_2$[Fe(CN)$_6$] (10 g): KOH (15 g): H$_2$O (270 ml); photochemical dopant selective n-InP from p-InP; smooth surfaces

H$_3$PO$_4$:H$_2$O$_2$:H$_2$O (3:1:50); InGaAs thinning, etch rate = 10 Å/s at 20°C; for differential Hall measurements
H$_2$SO$_4$:H$_2$O$_2$:H$_2$O (5:1:1); InP substrate cleaning prior to OMVPE growth; 3 min at 60°C

HCl:CH$_3$COOH:H$_2$O$_2$ (1:2:1) [KKI-121 etch]; InP (1 0 0) etch rate = 1.4 μm/min at 25°C; very smooth, flat etched surfaces
HCl:CH$_3$COOH:H$_2$O$_2$ (1:1:1) [KKI-111 etch]; InP etch rate = 1.1 μm/min at 25°C H$_3$PO$_4$:HCl:H$_2$O$_2$; and
HNO$_3$:HCl:H$_2$O$_2$; comparison of surface smoothness
HCl:H$_2$O (4:1); InP (1 0 0) orientation determination

HCl:H$_3$PO$_4$; Application: InP selective etch from InGaAsP stop layer for laser fabrication

Br$_2$/methanol (5%); GaP etch rate at 20°C = 0.8 μm/min
Br$_2$/methanol (1%); GaP etch rate at 20°C = 0.3 μm/min
Br$_2$/methanol (0.5%); GaP etch rate at 20°C = 0.2 μm/min
KOH:K$_3$Fe(CN)$_6$ (1:5); GaP etch rate at 21°C = 0.2 μm/min
KOH:K$_3$Fe(CN)$_6$ (2:1); GaP etch rate at 21°C = 0.3 μm/min
KOH:K$_3$Fe(CN)$_6$:H$_2$O (3:1:60); GaP etch rate at 21°C = 0.03 μm/min
HCl:HNO₃ (3:1); GaP etch rate at 30°C = 2 μm/min
HCl:HNO₃ (3:1); GaP etch rate at boiling = 6 μm/min
HCl:HNO₃:H₂O (2:1:2); GaP etch rate at 60°C = 1 μm/min
HCl:HNO₃:H₂O (1:1:2); GaP etch rate at 60°C = 0.45 μm/min
HCl:HNO₃:CH₃COOH (3:1:5); GaP etch rate at 21°C = 1.15 μm/min
HCl:HNO₃:CH₃COOH (1:1:1); GaP etch rate at 21°C = 1.2 μm/min fresh solution
HCl:HNO₃:CH₃COOH:HClO₄ (1:3:2:3); GaP etch rate at 21°C = 0.25 μm/min, 30 min stabilized solution
HCl:HNO₃:CH₃COOH:HClO₄ (1:3:2:3); GaP etch rate at 21°C = 6 μm/min from fresh solution
HCl:HNO₃:CH₃COOH:HClO₄ (1:3:2:3); GaP etch rate at 21°C = 0.6 μm/min from 30 min stabilized solution
HCl:HNO₃:CH₃COOH:HClO₄ (1:6:1:1); GaP etch rate at 21°C = 1.8 μm/min
HCl:HNO₃:H₂SO₄:H₂O (2:1:2:2); GaP etch rate at 30°C = 1.2 μm/min
HCl:HNO₃:H₂SO₄:H₂O (2:1:2:2); GaP etch rate at 50°C = 3.2 μm/min

H₂SO₄:H₂O₂:H₂O (5:5:1); Application: GaAs 5 min surface cleaning for ion implantation. InP and InGaAs 2 min surface cleaning followed by 5 min 1% Br₂/methanol
Anodization of InP for successive anodization/stripping thickness profile van der Pauw measurements using N-methylacetamide electrolyte

(NH₄)₂Sₓ; Application: surface passivation of AlGaInP laser mirror facets

H₂SO₄:H₂O₂:H₂O (10:1:1); Application: InGaAs mesa etch for photodiode fabrication
Br₂/methanol; InP mesa etch

KANBE, H., Y. Yamaguchi, and N. Susa, “Vapor-Phase Epitaxial InGaAs on (1 0 0), (1 1 1)A and (1 1 1)B InP Substrates,” Appl. Phys. Lett., 35, 603 (1979)
Br₂/methanol (5%); Application: InP substrate cleaning for VPE

H₂SO₄:H₂O₂:H₂O (5:1:1); GaAs native oxide removal, 2 min
NiSO₄ (0.8 M) with pH adjusted to 2–3 with H₂SO₄, H₂O diluted; nanoscale photoelectrochemical etch of GaAs with STM

HCl dilute (pH = 1.0); electrolyte for electrochemical etching of InP; study of reaction using voltammetry, XPS and STM

(NH₄)₂Sₓ sulfidation of GaAs XPS study

(NH₄)₂Sₓ solution; sulfur passivation of GaAs; 10 min at 60°C; XPS study of surface bonding states

(NH₄)₂Sₓ sulfidation of GaAs XPS study

In–As metal solution; Application: LPE melt back in situ cleaning of mesa stripe prior to regrowth of InP encapsulant layers
Br₂/methanol; InGaAsP/InP stripe etch

In–As metal solution; Application: LPE melt back in situ cleaning of mesa stripe prior to regrowth of InP encapsulant layers
Br₂/methanol; InGaAsP/InP stripe etch

KAO, H.-C., L.-S. Lai, and Y.-J. Chan, “Reactive ion etching of CHF₃ + BCl₃ for ternary InₓAl₁₋ₓAs and InₓGa₁₋ₓAs (x = 0.18, 0.3, 0.52) compounds using various In contents,” J. Vac. Sci. Technol., B, 16(1), 253 (1998)
Reactive ion etch; CHF₃ + BCl₃; rate dependence on ternary composition for InAlAs and InGaAs

(NH₄)Sₓ (10 ml solution with added 1 g sulfur and 2 g phosphorus pentasulfide); GaAs surface passivation, followed by deposition of SiNx overlay

H₂SO₄:H₂O₂:H₂O (1:8:40); Application; GaAs (1 0 0) photolithography [0 1 1] channel etch
H₂SO₄:H₂O₂:H₂O (4:1:1); GaAs patterned substrate cleaning for MBE

KAPPELT, M., and D. Bimberg, “Wet chemical etching of high quality vee-grooves with {1 1 1}A sidewalls on (0 0 1) InP,” J. Electrochem. Soc., 143(10), 3271 (1996)
Br₂/methanol (0.1%); InP vee-groove etch, first step; exposes {1 1 1}A sidewalls but leaves surface defects
H₂SO₄:H₂O₂:H₂O (3:1:1); second step of InP vee-groove etch; removes defects from exposed {1 1 1}A surfaces; broadens the radius of the vee
Br₂/methanol (0.1%); third step of InP vee-groove etch; reduces the radius of the vee after H₂SO₄:H₂O₂:H₂O etch

Reactive ion etch; Cl₂; Application: InGaAsP/InP buried crescent laser; photoresist mask; etched width is smaller than with wet chemical etch


(NH₄)₂Sₓ; InAs; study of surface structure; S replaces outermost As atoms; all S desorbs above 500°C


H₂SO₄:H₂O₂:H₂O (7:1:1); InP surface preparation etch for flat, damage-free surface


Reactive ion etch; N₂, N₂/O₂; InP and InGaAsP etch profiles


Ion beam milling; Ar + O₂; InP


HCl; InP selective etch from GaInAsP

H₂SO₄:H₂O₂:H₂O; InGaAsP first-order grating etch for laser


Reactive ion etch; BCl₃; selective removal of GaAs from AlGaAs or InGaAs


HBr (9n); Application: InP photolithography grating at −15°C; (1 1 1)A facets

HCl:H₂O₂ (1:1); InP (1 0 0) orientation determination


Review of III–V etching; describes mechanisms for 1.] anodic (electrochemical) etching; 2.] electroless etching (redox potential driven and illumination driven); 3.] chemical etching; gives data on: K₃Fe(CN)₆ at pH = 14; p+ GaAs(10²⁰ cm⁻³) selective etch from p-GaAs(10⁻¹⁸ cm⁻³)
HCl conc.; InP selective etch from InGaAsP
Ce⁺⁺⁺⁺:H₂SO₄ solution; InGaAsP selective etch from InP
Br₂: KBr solution; GaAs groove etch profile dependence on temperature

Ion beam etching, CO; Use of hafnium mask for GaAs and InP patterning

H₂O₂ with NH₄OH added to adjust pH from 7.2 to 8.6; GaAs selective etch from Al₀.₁₆Ga₀.₈₄As with selectivity > 30 at pH ≈ 8.4

KERN, W., “Chemical Etching of Silicon, Germanium, Gallium Arsenide and Gallium Phosphide,” RCA Review, 39, 278 (1978a)
Review of Si and Ge etching; GaAs etching, GaAs electrochemical etching, GaAs thermochemical etching; GaP etching

Review; chemical etching of insulators, semiconductors, and conductors; describes etching principles and techniques; provides tables of etchants for: GaAs, GaP, AlN, BN, BP, AISb, GaN, GaSb, InAs, InP, InSb

HF:0.15 M K₂Cr₂O₇ (2:1) {Secco etch}; Application: Si wafer defect delineation

Reactive ion etch; SiCl₄ + SiF₄; Application: GaAs selective etch from AlGaAs for MODFET processing

CAIBE of GaN and GaAs using Cl₂–Ar; vertical, smooth sidewalls for laser facets

KHARA, R., J. Brown, M. Hu, D. Piersoon, M. Melendes, and C. Constantine, “CH₄/H₂/Ar/Cl₂ ECR plasma etch; CH₄/H₂/Ar/Cl₂; InP via holes

ECR plasma etch; CH₄/H₂/Ar/Cl₂; InP via holes

HCl:HNO₃:H₂O (4:1:50); GaAs photoelectrochemical electrolyte for high aspect ratio features


HCl:H₂O (1:20); GaAs n-type selective photoetch from GaAs p-type, selectivity > 15,000

GaAs n-type selective etch from GaAs semi-insulating, selectivity ~30


HCl:H₂O (1:20); electrolyte for photoelectrochemical etching of GaAs and InP; etch rates and profiles for via hole fabrication are given


Photoelectrochemical dopant selective and bandgap selective etch; HCl:H₂O (1:20) electrolyte; GaAs/AlGaAs structures; dependence on band structure


NaOCl:H₂O; GaAs chemomechanical polishing


Thermochemical vapor etch; CCl₄; InP in situ etch for OMVPE


Br₂/methanol; Br₂/ethylene glycol H₃PO₄:H₂O₂:H₂O; Application: first step stairstep groove etchant for AlAs/GaAs multilayer structures for quantum wire MOCVD growth. citric acid:H₂O₂; Application: second step stairstep groove etchant for shaping grooves in AlAs/GaAs multilayer structures for quantum wire MOCVD growth


Inductively coupled plasma etch; Cl₂/H₂; GaN etch characteristics; effect of surface stoichiometry on Ohmic contact

Inductively couple plasma etch of GaN using \( \text{Cl}_2/\text{BCl}_3 \)


\( \text{H}_2\text{SO}_4:\text{H}_3\text{PO}_4 \) (3:1); sapphire substrate cleaning: 140°C for 10 min

\( \text{H}_2 \) thermal cleaning of sapphire substrate, in situ MOVPE; 1070°C


\( \text{HCl}:\text{HNO}_3 \) (3:1); 10 min in boiling aqua regia to remove surface oxide from p-type GaN prior to \( (\text{NH}_4)_2\text{S}_x \) surface treatment for Pd low resistivity Ohmic contact

\( (\text{NH}_4)_2\text{S}_x \); 10 min treatment of p-type GaN surface for Pd low resistivity Ohmic contact


citric acid: \( \text{H}_2\text{O}_2 \) (4:1); selective removal of GaAs from AlAs (and of low Al content AlGaAs from high Al content AlGaAs); shows dependence of etch rates (selectivity) on volume ratio

\( \text{H}_2\text{O}: \) buffered HF (40:1) where buffered HF is \( \text{NH}_4\text{F} \) (36%):HF(6.4%) (7:1); selective removal of AlAs from GaAs (and of high Al content AlGaAs from low Al content AlGaAs); shows dependence of etch rates (selectivity) on volume ratio


\( \text{H}_3\text{PO}_4: \text{H}_2\text{O}_2 \) (5:1); Application: InGaAs selective etch from InP; pattern for OMVPE overgrowth

\( \text{H}_2\text{SO}_4: \text{H}_2\text{O} \) (1:5); InP surface cleaning for photoresist ash removal following \( \text{O}_2 \) plasma prior to InP regrowth

\( \text{KOH}: \text{K}_3\text{Fe(CN)}_6: \text{H}_2\text{O} \); InP cleaved cross-section layer delineation

laser-induced thermochemical, maskless etch using \( \text{CHClF}_2 \) and \( \text{C}_2\text{H}_2\text{F}_4 \) on GaAs


\( \text{H}_2\text{SO}_4: \text{H}_2\text{O}_2: \text{H}_2\text{O} \) (1:8:40); Application: GaAs vee-groove etch; 90 min for 1.2 \( \mu \text{m} \) wide stripe with (111)A sidewalls

H₃PO₄:HBr (2:1) (Huber etch); Application: InP dislocation etch pit delineation


Wet chemical cleaning; study for AlN and GaN
HF(buffered, 7 NH₄F:1 HF): H₂O (10:1); surface oxide removal from AlN and GaN
HCl:H₂O (1:1); surface oxide removal from AlN and GaN
Thermal desorption of oxygen and carbon from AlN and GaN surfaces in UHV


HCl:H₂O (4:1); Application: InP mesa etch for BH laser


citric acid:NH₄OH:H₂O₂ (citric acid pH adjusted to 6.5 with NH₄OH; citric acid:H₂O₂ ratio = 100); selective etch of GaAs from Al₀.₁₅Ga₀.₈₅As and Al₀.₃Ga₀.₇As; shows etch rate dependence on concentration and pH


Thermochemical etch, HCl + AsH₃; GaAs/AlGaAs in situ etch at 750°C prior to MOVPE regrowth of GaAs


Thermochemical vapor etch; HCl; in situ etch for GaAs MOCVD regrowth on AlGaAs; optimization of AsH₃ flow rate to minimize dislocation density in regrowth


HCl gas thermochemical etch; In situ etch of GaAs/AlGaAs for MOVPE regrowth of GaAs; two steps: 350°C for 60 min surface cleaning (etch rate 2 Å/min) then 750°C GaAs etch (800 Å/min)


Reactive ion etch; CCl₂F₂ and CCl₂F₂/Ar; GaAs
KLINGER, R.E., and J.E. Greene, “Reactive Ion Etching of GaAs in CCl$_4$–xF$_x$ ($x = 0, 2, 4$) and Mixed CCl$_4$–xF$_x$/Ar Discharges,” J. Appl. Phys., 54(3), 1595–1604 (1983)

KLOCKENBRINK, R., E. Peiner, H.-H. Wehmann, and A. Schlachetski, “Wet Chemical Etching of Alignment V-Grooves in (1 0 0) InP through Titanium or In$_{0.53}$Ga$_{0.47}$As Masks,” J. Electrochem. Soc., 141(6), 1594–99 (1994)


KO, K.K., K. Kamath, O. Zia, E. Berg, S.W. Pang, and P. Bhattacharya, “Fabrication of dry etched mirrors for In$_{0.20}$Ga$_{0.80}$As/GaAs waveguides using an electron cyclotron resonance source,” J. Vac. Sci. Technol., B, 13(6), 2709 (1995a)


ECR etch surface damage study; GaAs


citric acid (100 g in 100 ml H2O):H2O2 (30%) (3:1); surface cleaning of ZnSe (1 0 0) substrates; etch rate 400 Å/min
CS2; rinse of ZnSe surface to remove residual Se


H3PO4:H2O2:H2O (3:1:50); Application: selective etch of GaAs from InGaP
HCl:H2O (3:2); Application: selective etch of InGaP from GaAs


HF:HNO3:CH3COOH (8:2:1); Application: Si substrate cleaning for GaAs MBE growth


HBr:HNO3:H2O (1:1:30); Application: InGaAsP selective etch from InP
HCl conc.; InP selective etch from InGaAsP mask and stop layer

KODAMA, M., “Improvement of reverse leakage current characteristics of GaSb and Al0.3Ga0.7As/ GaSb diodes grown by MBE,” Solid-State Electron., 37(8), 1567 (1994)

CH3COOH:HNO3:HF (40:18:2); GaSb mesa etch; room temperature for 40 s
Br2:methanol (2%); GaSb mesa etch; room temperature 1 min

CH3COOH:HNO3:HF (40:18:2), followed by HCl:HNO3 (30:1) at 5°C for 10 s; GaSb mesa etch for oxygen-free, low p–n junction leakage


Photochemical etching review; p–n dopant selectivity; surface relief etching; InGaAsP/InP and GaAs

KOHL, P.A., C. Wolowodiuk, and F.W. Ostermayer, “The Photoelectrochemical Oxidation of (1 0 0), (1 1 1), and (1 1 1) n-InP and n-GaAs,” J. Electrochem. Soc., 130(11), 2288–93 (1983)

Anodization; InP and GaAs


Cl2 reactive ion beam etch; AlGaAs/GaAs in situ etch prior to AlGaAs regrowth by MBE

ECR etch; Cl₂; Oxide mask with e-beam patterning; GaAs


GaAs etch rate study shows proportional dependence on H₂O₂ concentration; low etch rates are surface reaction limited and show flat bottomed profiles; high etch rates are H₂O₂-diffusion limited and show enhanced etching at mask edges: NaOH:H₂O₂:H₂O (2:x:100), 1 < x < 10; NH₄OH:H₂O₂:H₂O (1:1:x), 16 < x < 50; H₂SO₄:H₂O₂:H₂O (x:1:1), 10 < x < 250; citric acid:H₂O₂:H₂O (50:x:50); 1 < x < 10; H₃PO₄:H₂O₂:H₂O (1:1:x), 18 < x < 50


Reactive ion etch; CH₄/H₂/Ar of InP/InGaAlAs/InGaAs heterostructure detectors. Reactive ion etch; CHF₃/O₂; removal of SiNx mask from InP

C₆H₈O₇(citric acid):H₂O₂:H₂O; 5 s wet etch following reactive ion etch of InP/InGaAlAs/InGaAs heterostructure detectors; removes about 150 Å InGaAs, 70 Å InAlGaAs and <20 Å InP

H₂SO₄; 1 min cleaning step for InP/InGaAlAs/InGaAs heterostructure detectors prior to sulfide passivation in preparation for MOCVD regrowth step

(NH₄)₂S (Ammonium polysulfide); passivation of InP/InGaAlAs/InGaAs heterostructures for MOCVD regrowth; Ref. (Iyer, R., 1991)

HF; InGaAlAs/InP surface cleaning for MOCVD regrowth

HF:2-propanol; InGaAlAs/InP surface cleaning for MOCVD regrowth


HF; Ga₀.₃Al₀.₇As selective etch from GaAs; Application: removal of GaAs solar cell layers from the substrate


ECR plasma etch, H₂; AlGaAs substrate in situ cleaning for GaAs MBE growth


Focused Ga+ ion beam patterning of InP; followed by HF (ultrasonic bath at 80°C) selective etch of the Ga implanted area to form a grating

H₂SO₄:H₂O₂:H₂O (8:1:40); Application: mesa etch for {1 1 1}A sidewalls on GaAs [1,−1,0] stripe patterns
H₂F₆:H₂O₂:H₂O (1:9:5); Application: mesa etch for concave sidewalls of ~70° near mesa top on GaAs ⟨1 0 0⟩ stripe patterns

ECR plasma etch of InGaAs/InP; comparison of CH₄/H₂/Ar and BCl₃/N₂

ECR etching of InGaAs/InP using BCl₃ + N₂; end point monitoring using optical emission spectroscopy

Laser-induced etching of GaAs in Cl₂ and O₃ gases

Focused Ga ion beam etching of GaAs in Cl₂; Auger surface study

Br₂:methanol: GaAs etching anisotropy is dependent on concentration; shows {1 1 1} plane terminated features for Br₂ < 1%; shows {3 3 2} plane terminated features for Br₂ > 1%; Application of negative bias increases etch rate and eliminates etch anisotropy

HF:HBr (5:1) and (10:1); InP dislocation etch pit delineation study. A–B etch comparison

KOH molten; GaN dislocation etch pit delineation; 10 min at 360°C

Surface treatment scanning photoluminescence study: HF: InP oxide removal
H₂O₂: InP surface oxidation
NH₄OH: InP oxide removal
HNO₃: InP surface oxidation

- H$_2$SO$_4$:H$_2$O$_2$:HF (3:2:2); heats spontaneously to 90°C
- H$_2$SO$_4$:H$_2$O$_2$:HF (1:4:1); H$_2$SO$_4$:H$_2$O$_2$:HF (1:1:2); best shape pits for crystal orientation

For GaP etch pit delineation use at 60–90°C for 3–15 min; for GaAs room temperature etch rate ~6 µm/min


- H$_2$SO$_4$:H$_2$O$_2$:H$_2$O (3:1:1); GaAs selective n- from p-photoetching


- Modeling of masked pattern etching


- Modeling of profiles for photolithographic etching using diffusion limited etchants


- Reactive ion etch; BCl$_3$/Ar of GaInP/InGaAs/GaInP; surface damage in HEMTs


- Reactive ion etch; BCl$_3$ + Ar(6:4); selective etch of GaAs from InGaP for gate recess of FETs


- HCl:H$_2$O (1:10); Application: In$_{0.5}$Al$_{0.5}$P selective etch from GaAs


- Photochemical dry etch; CH$_3$Br with a low pressure mercury lamp; InGaAs selective etch from InAlAs; selectivity of 25


- XPS surface study of different etch treatments:
  1.1. residual oxide
  1.2. residual Br dependence on methanol rinse time following Br$_2$/methanol etch
  1.3. time dependence of oxide growth on surfaces for different etch treatments
H₂SO₄:H₂O₂:H₂O; discusses time dependence of secondary reaction products after initial mixing of the etchant

Optimum polishing treatment to obtain optical smooth and oxide free (0 0 1) and (1 1 1) InP:
1/rinse with trichlorethylene, acetone and methanol
2/pre-etch with (NH₄)₃S₂O₈:H₂SO₄:H₂O (15:73:15) at RT for 1 min
3/rinse with methanol
4/Br₂:methanol polishing etch (1% at RT for 1 min)
5/rinse with methanol for 90 min; 6/etch with HCl:methanol (1:10) at RT for 10 s 7/rinse with methanol

HCl:CH₃COOH:H₂O (6:4:1); Application: InGaAs/InP mesa etch at 8°C
H₃PO₄:H₂O₂:H₂O (1:1:40); Application: InGaAs selective etch from InP for HEMT gate recess at 20°C

HF:H₂O (1:30); InP surface oxide cleaning in N₂ dry box
gas phase polysulfide in N₂ from a bubbler; analysis of S on the InP surface

Glancing-angle Ar ion beam, low damage sputtering to clean GaAs surfaces for MBE growth

Reactive ion etch of InAlAs/InGaAs using mixtures CHF₃ + BCl₃ and CF₄/BCl₃; selective removal of InGaAs from AlGaAs

CAIBE etch of InP using Cl₂/Ar; roughness from InClₓ clusters

ECR nitridization of GaAs using N₂ plasma; formation of As–N bonds for SiNx deposition
KI:I₂:H₂O (27.8 g:16.25 g:25 ml) with pH adjusted by adding an equal amount of H₂SO₄(diluted with H₂O to pH = 0.9); selective etch of Al₀.₃Ga₀.₇As from GaAs; selectivity of 137 at 20°C and 330 at 38°C

Ar ion sputter etching of InP; surface study

Reactive ion etch; CH₄/H₂; Application: InGaAs selective etch from InAlAs stop layer

Anodization; InGaAsP in 0.1 M ammonium phosphate dibasic solution electrolyte

ECR plasma etch; CH₄ + H₂ + Ar; GaAs

RF plasma etch, CH₄ in He, Ne and Ar; GaAs

Reactive ion etch; ClCH₃ with H₂, He, O₂, Ne or Ar; GaAs and InP; GaAs and InP etch selectivity depend on gas combinations

RF plasma etch C₃H₈ + H₂; GaAs; greater etch rates than with CH₄ + H₂

Reactive ion etch; CH₄ + H₂; Application: GaAs selective etch from AlGaAs

RF plasma etch; CH₄ + H₂; GaAs; etch rate dependence on temperature and CH₄ concentration

300 kHz Pulse Plasma Etching of GaAs Using a Mixture of ClCH\textsubscript{3} and H\textsubscript{2}


Reactive ion etch; CH\textsubscript{4}/H\textsubscript{2}/Ar; Application: InGaAs FET gate etch


Reactive ion etch; CH\textsubscript{4}/H\textsubscript{2}, SiO\textsubscript{2} mask erosion and sidewall residues; InGaAsP/InP


Reactive ion etch of InP using CH\textsubscript{4}/H\textsubscript{2}; investigation of oxide residues
HF, dilute; removal of oxide residues from RIE etched InP prior to regrowth


Reactive ion etch of InP mesas using CH\textsubscript{4}/H\textsubscript{2}; characterization of mesa sidewall deposits


Maskless laser-induced etching of GaAs in KOH


Thermochemical etch; Cl\textsubscript{2}; GaAs and AlGaAs in situ MBE; at 350°C; etched surfaces suitable for layer regrowth


RIE plasma etch of patterned GaN; CHF\textsubscript{3}/Ar, C\textsubscript{2}ClF\textsubscript{3}/Ar, C\textsubscript{2}ClF\textsubscript{5}/Ar/O\textsubscript{2}, SiCl\textsubscript{4}
CHCl\textsubscript{3}; sputtered iron nitride (Fe–8% N) mask is resistant to Cl-based ion etch and easily removed
H\textsubscript{2}SO\textsubscript{4}:H\textsubscript{2}O\textsubscript{2}:H\textsubscript{2}O (1:1:10); removal of iron nitride pattern mask from GaN


RIE etch; CHF\textsubscript{3}/Ar and C\textsubscript{2}ClF\textsubscript{3}/Ar; GaN


Reactive ion etching of GaN films; CHF\textsubscript{3}/Ar and C\textsubscript{2}ClF\textsubscript{3}/Ar; study

citric acid:H_{2}O_{2} (4:1); etches GaAs selectivity from Al_{x}Ga_{1-x}As; selectivity ~110


Inductively couple plasma etch (ICP); Ar; of GaAs and InP; etch damage comparison to ECR etch


ECR plasma etch; CH_{4}/H_{2}/Ar; comparison of masking materials(SiN_{x}, W, photoresist) for pattern etching of GaAs


ICP etch using Ar, damage of AlGaAs


ECR plasma etch; Cl_{2}/Ar, Cl_{2}/N_{2}, Cl_{2}/H_{2} of GaAs, Al_{0.3}Ga_{0.7}As, and GaP


ECR plasma etch; ICl/Ar and IBr/Ar; InP, InGaAs, InSb, GaAs, GaSb, AlGaAs; study of etch rates and morphologies


ECR plasma etch; IBr/Ar; room temperature processing of GaAs, AlGaAs, GaSb, InP, InGaAs, InSb. Requires hard mask (photoresist degrades). Chemistry is H_{2}-free, thus avoiding p-dopant passivation and polymer deposition


ECR plasma etch; ICl/Ar; etch study on GaAs, GaSb, InP, and InSb


ECR plasma etch of AlGaAs and InGaP in Ar and SF_{6}; study of surface damage
ECR high power plasma etch; CH₄/H₂/Ar; of InGaP, AlInP, and AlGaP

AZ400K developer solution (~10% KOH active ingredient)
Selective etchant of InₓAl₁₋ₓN with x as high as 75%; etch rates given over temperature range of 20–80°C; does not etch pure InN or GaN
ECR plasma etch of InN and GaN using ICl

NH₄OH:H₂O₂:H₂O (2:1:12); Application: GaAs substrate cleaning for OMVPE growth, 1 min

AgNO₃:HF:HNO₃:H₂O (40 mg:16 ml:24 ml:32 ml) {RC etch}; Application: InP (1 1 1)B dislocation delineation; etch time a few hours

Br₂/methanol (1%); Application: InGaAs mesa etch

CAIBE of GaN with Cl₂ in Ar beam; etch profile dependence on tilt angle

Reactive ion etch; C₂F₆; Application: SiNₓ/SiO₂ deposited mask pattern etching
ECR plasma etch; Cl₂/Ar; InGaAs and GaAs etch
ECR plasma etch; Cl₂/Ne/Ar; GaAs selective etch from AlGaAs
ECR plasma etch; NF₃; Ti/W metal removal from mesa sidewalls

Inductively coupled plasma etch; Cl₂/Ar and Cl₂/BCl₃ of GaN
Lateral oxidation of InAlAs and AlAsSb layers on InP by heating in water saturated N₂; study of properties

Br₂/methanol; Application: InGaAs mesa etch

Reactive ion etch; CH₄/H₂/Ar of InP/InGaAlAs/InGaAs heterostructure detectors
C₆H₇O₇(citric acid):H₂O₂:H₂O; 5 s wet etch following reactive ion etch of InP/InGaAlAs/InGaAs heterostructure detectors; removes about 150 Å InGaAs, 70 Å InAlGaAs and <20 Å InP
H₂SO₄; 1 min cleaning step for InP/InGaAlAs/InGaAs heterostructure detectors prior to sulfide passivation in preparation for MOCVD regrowth step
(NH₄)₂S, (Ammonium polysulfide); passivation of InP/InGaAlAs/InGaAs heterostructures for MOCVD regrowth; Ref. (Iyer, R., 1991)

High density plasma etching of GaAs in Cl₂/Ar; study of surface chemistry and damage

NH₄OH:H₂O₂ (1:60); GaAs selective removal from AlGaAs by jet thinning; GaAs etch rate at 0°C = 60 μm/h with selectivity of 60

KOH:NaOH (50 mol%:50 mol%): GaAs defect delineation etch; used at 170°C eutectic melting temperature; keeps surfaces smooth compared to molten KOH; shows defects in nominally zero-dislocation GaAs

H₂PO₃:H₂O₂:H₂O (1:1:25); Application: GaAs mesa etch
Ar ion beam etch; GaAs damage effects on surface depletion

KOH:K₃Fe(CN)₆:H₂O (6 g:4 g:50 ml); selectively etches InGaAsP on InP

Photoelectrochemical etch; KCl electrolyte; GaAs; Application: sawtooth gratings using photoresist mask


Thermochemical etch; tris-dimethylaminoarsenic in situ etch of GaAs for MBE regrowth of AlGaAs


Cl₂ assisted Ar ion etch, AlGaAs/GaAs sidewall facets using SiO₂ mask

Reactive ion etch; CF₄; transfer of photoresist pattern to SiO₂ mask


H₃PO₄:H₂O₂:H₂O (38:1:1)? (or (1:1:38)?); Application: InGaAs FET gate channel etch


buffered HF (i.e., HF:NH₄F, 1:6):H₂O (1:4); Ti removal from InP; 30 s at room temperature removes ~200 Å


KOH:K₃Fe(CN)₆:H₂O (10 g:0.2 g:50 ml); Application: InGaAsP strip mesa etch for DH lasers; selective etch from InP

HCl conc.; InP selective etch from InGaAsP


Tartaric acid(40%):H₂O₂(30%) (3:1); InP; rate =~ 2000 Å/h; used as Schottky contact for C/V carrier concentration profiling


High resolution photoelectrochemical etch of GaAs with scanning tunneling microscope


HCl:H₂O (3:7); GaSb surface treatment to provide Sb surface termination prior to sulfidation (NH₄)₂S:H₂O (1:4) and (1:45); sulfur passivation of GaSb

NH$_4$OH:H$_2$O (1:1) deoxidation of GaAs, GaSb and InAs surfaces, 10 min, N$_2$ dried

Photoetching (193 nm excimer laser) in low pressure Cl$_2$ at 140 K of GaAs, GaSb, InAs, InSb


Reactive ion etching; BCl$_3$ of GaN etch study


Br$_2$/methanol (1%); Application: InP (1 1 1)B etch rate = 2.5 µm/min for LPE substrate preparation

Br$_2$/methanol (3%); InP (1 1 1)B etch rate = 6 µm/min


H$_2$SO$_4$:H$_2$O etched InP; study of surface oxides by glancing angle X-ray diffraction

H$_2$SO$_4$:H$_2$O$_2$:H$_2$O etched InP; study of surface oxides by glancing angle X-ray diffraction; H$_2$O$_2$ plays no significant role in etch of InP


Inductively coupled plasma (ICP) etch of InP using HBr/BCl$_3$/CH$_4$/H$_2$/Ar for Gunn diode mesa fabrication


NH$_4$OH:H$_2$O$_2$ (1:225) {pH = 7.04}; Application: GaAs selective removal from Al$_{0.25}$Ga$_{0.75}$As; GaAs etch rate = 6 µm/h with selectivity of 10. K$_3$Fe(CN)$_6$:K$_4$Fe(CN)$_6$ (with NaOH or HCl to buffer pH); GaAs selective etch from AlGaAs for pH > 9; AlGaAs selective etch from GaAs for pH between 5 and 9


Anodization; GaAs using H$_2$O$_2$ electrolyte with pH adjusted by H$_3$PO$_4$ or NH$_4$OH


KOH molten at 450°C; Application: GaAs defect etch pit delineation

$\text{H}_2\text{SO}_4$:$\text{H}_2\text{O}_2$:$\text{H}_2\text{O}$ (8:1:1); InP surface cleaning; room temperature for 5 min to remove native oxide overlayer; longer times does not improve oxide removal but causes contamination and roughening.

Hydrogen remote plasma cleaning of InP surface, in situ in MOCVD reactor at 270°C provides an oxide-free surface superior to wet etching.

LOTHIAN, J.R., J.M. Kuo, F. Ren, and S.J. Pearton, “Plasma and Wet Chemical Etching of In$_{0.5}$Ga$_{0.5}$P,” J. Electron. Mater., 21(4), 441–45 (1992a)

$\text{H}_3\text{PO}_4$:$\text{HCl}$:$\text{H}_2\text{O}$ (1:1:1); In$_{0.5}$Ga$_{0.5}$P selective etch from GaAs; InGaP etch rate $= 900$ Å/min at 25°C; data show rate dependence on etch composition.

Plasma etch; PCl$_3$/Ar and CCl$_2$F$_2$/Ar; InGaP selective etch from GaAs.


$\text{H}_3\text{PO}_4$:$\text{HCl}$:$\text{H}_2\text{O}$ (1:1:1); InGaP selectively etched from GaAs; rate is reaction limited at the surface; rate increases with HCl content.

Plasma etch of InGaP and GaAs in PCl$_3$/Ar, CCl$_2$F$_2$/Ar, CH$_4$/H$_2$/Ar; Conditions for selective etch of GaAs from InGaP are determined.

LOTHIAN, J.R., J.M. Kuo, W.S. Hobson, E. Lane, F. Ren, and S.J. Pearton, “Wet and Dry Etching of Al$_{0.5}$In$_{0.5}$P,” J. Vac. Sci. Technol., B, 10(3), 1061–65 (1992c)

HCl:$\text{H}_2\text{O}$ (1:30); Al$_{0.5}$In$_{0.5}$P etch rate $= 600$ Å/min at 25°C.

HCl:$\text{H}_2\text{O}$ (1:5); Al$_{0.5}$In$_{0.5}$P etch rate $= 600$ Å/min at 25°C; Al$_{0.5}$In$_{0.5}$P selective etch from GaAs.

Plasma etch; PCl$_3$/Ar, CCl$_2$F$_2$/Ar, CH$_4$/H$_2$/Ar; AlInP selective etch from GaAs.


Plasma etch; CH$_4$ + H$_2$; InP with SiO$_2$ and Si$_3$N$_4$ dielectric masks and with Al and Ti/Au metal masks.

Plasma etch; PCl$_3$ + Ar; GaAs with Au mask; dependence on bias.


ECR plasma etch; Application: mask patterning for AlGaAs/GaAs HBTs; O$_2$ discharge for polydimethylglutarimide mask etch; SF$_6$ discharge for SiN mask.


KOH:$\text{K}_3\text{Fe(CN)}_6$:$\text{H}_2\text{O}$ (8 g:0.5 g:100 ml); 10 min etching InGaAsP under illumination to reveal defects; etch rate $\sim 1.5$ μm/h; not useful on Zn-doped p-layers.

HNO$_3$:$\text{HBr}$ (1:3); InP dislocation delineation, superior reproducibility to $\text{H}_3\text{PO}_4$:$\text{HBr}$ (2:1) {Huber etch}.
HCl:H₂PO₄ (1:1); InP selective etch from InGaAsP
KOH:K₃Fe(CN)₆:H₂O (8 g:12 g:100 ml) solution used for InGaAsP selective etch from InP


KOH:K₃Fe(CN)₆:H₂O (8 g:0.5 g:100 ml); InGaAsP p–n junction delineation
A–B etch tried, but too fast attack


H₃PO₄:H₂O (1:9); n-InP photoetch study; etch rates are enhanced two to five times by added Cu metal ions


H₃PO₄:H₂O (1:9); n-InP photochemical etching study using 488 nm Ar+ laser; photoetch rate for via holes is 300 times greater for 0.002% duty cycle than for 100%; photoetch rate is controlled by local saturation


HCl:H₂O₂:H₂O (1:1:50); GaAs surface cleaning prior to S passivation
CH₃CSNH₂/NH₄OH solution; GaAs surface passivation
CH₃CSNH₂/H+ solution; GaAs surface passivation


tartaric acid (3w/o) buffered with NH₄OH: ethylene glycol (1:2); electrolyte for GaN photoassisted anodic etch; rate dependence on current and pH


NH₄OH:H₂O₂ (pH = 8.4); Application: selective etch of GaAs from InGaP
HCl:H₂O (1:1); Application: selective etch of InGaP from GaAs


(NH₄)₂S; surface passivation of GaAs; chemical structure study


FeCl₃:H₂O (40% w/v); Application: InP photoetching of mesas; etch rate = 0.5 μm/min under illumination, followed by clean-up etch of: Br₂:HBr:H₂O (1:18:81)

2 M HF:0.5 M KOH solution electrolyte; InP and InGaAsP holographic photoetch for diffraction gratings on a biased sample with a depeletion region at its surface


Thermal etching (degradation) in H₂; InP thermal etch in H₂ of LPE reactor


Plasma etch; Ar; InP; study of induced defects


Reactive ion etch using CH₄/H₂ on InP/InGaAsP for l/4 narrow grooves; alternating with O₂ ashing to remove polymer buildup

H₂SO₄:H₂O₂:H₂O (1:1:40); 30 s cleaning of InGaAsP after RIE. HCl:H₂O (1:10); 1 min cleaning of RIE roughness on InP facets


Reactive ion etch of deep grooves for multiple mirrors in InGaAsP MQW lasers using CH₄/H₂ and O₂ ashing to remove polymer buildup

H₂SO₄:H₂O₂:H₂O (1:1:40); step 1 in damage removal from RIE etched InGaAsP/InP; 0°C for 70 s

HCl:H₂O (1:10); step 2 in damage removal from RIE etched InGaAsP/InP 1 min at room temp


(NH₄)₂Sₓ; InP surface passivation study


Defect delineation etchants; Application to InP and InGaAsP: H₃PO₄:HBr (2:1) {Huber etch} at RT for ~2 min

HNO₃:H₂O:HCl (6:6:1) at 60°C for 90 s

HCl:HNO₃:Br₂ (40:80:1) {RRE etch} at 25°C for 10 s

H₂O:AgNO₃:CrO₃:HF (10 ml:40 mg:5 g:8 ml) {A–B etch} at 75°C for 30 min

HBr:HF (1:15) at RT for 1–5 min

Photoassisted dry etch; Cl$_2$; GaAs; self-terminating chloronation reaction followed by laser photodesorption of surface chlorides


$\text{I}_2$:KI:H$_2$O (65 g:113 g:100 g); selective removal of Al$_x$Ga$_{1-x}$As from GaAs if $x > 0.1$

HCl, hot; selective removal of Al$_x$Ga$_{1-x}$As from GaAs if $x > 0.42$

HF, hot; selective removal of Al$_x$Ga$_{1-x}$As from GaAs if $x > 0.38$


Ar ion etch of InP; study of surface atomic bond lengths


Reactive ion etch of Ni- and W-masked pattern structures on InP using SiCl$_4$; damage characterization


Citric acid:H$_2$O$_2$:H$_2$O; Study of GaAs versus Al$_{0.28}$Ga$_{0.72}$As etch rate dependence on citric acid:H$_2$O$_2$ ratio and on H$_2$O concentration

Citric acid:H$_2$O$_2$:H$_2$O (4:1:1); non-selective GaAs, AlGaAs etch rate $\sim$4000 Å/min

Citric acid:H$_2$O$_2$ (4:1); selective etch of GaAs from Al$_{0.28}$Ga$_{0.72}$As


H$_2$SO$_4$:H$_2$O$_2$:H$_2$O (4:1:1); Application: AlGaAs/GaAs mesa etch; HCl:H$_2$O$_2$:H$_2$O (1:4:40); Application: AlGaAs/GaAs stain for SEM cross-sections

Thermal oxidation; AlGaAs/GaAs; N$_2$ saturated with H$_2$O; 70 min at 425°C


in-vacuo maskless GaAs etching using ion or laser-induced reaction of adsorbed vapors of SO$_2$Cl$_2$ and 1,2-dichloroethane


H$_2$SO$_4$:H$_2$O$_2$:H$_2$O (3:1:1); Application: InP substrate cleaning first step for MBE, followed by: Br$_2$/methanol, followed by 5 min DI water rinse to form protective oxide
Reactive ion etch; Ar, He, CH₄/Ar, CH₄/He, CH₄/H₂/Ar; InP; study of surface modification by Raman scattering

Ar sputtering; In₀.₅₃Ga₀.₄₇As and In₀.₅₂Al₀.₅₃As; damage study
RIE; HBr; In₀.₅₃Ga₀.₄₇As and In₀.₅₂Al₀.₅₃As; damage study

H₂SO₄:H₂O₂:H₂O (5:1:1); GaAs substrate cleaning for MBE; surface analysis

H₂SO₄:H₂O₂:H₂O (2:1:1); InP etch rate = 500 Å/min at 20°C; surface study
HF-ethanol (10%): InP surface cleaning; surface deoxidation etch

HCl:H₃PO₄ room temperature etch rate data for (1:19), (1:9), and (1:4)
HCl:H₃PO₄ (1:9); etch rate dependence on temperature; lateral etch behavior at 60°C; Application to self-aligned HBTs

Cardiff, Wales, UK, (IEEE Catalog no. 91CH2950-4) pp. 256–59, Reactive ion etch; C₂H₆; Application: InP grating photolithography

Reactive ion etch; C₂H₆ + H₂; Application: InGaAsP/InP lasers; InGaAsP etch rate < InP etch rate; vertical etched edges

Reactive ion etch; C2H6:H2; InP, GaAs, InGaAs; excellent vertical walls and smooth surface are obtained at etching rate from 20 to 60 nm/min; this etchant gives high resolution and anisotropy with 2000 Å SiO2 mask

HCl:H2O (1:1); InP surface morphology after 80 s etch, and etch inhibition with 3 monolayer MBE GaAs deposit
Thermal degradation, InP surface morphology after 600°C anneal, and degradation inhibition by 1 monolayer of MBE GaAs deposit

1N K2Cr2O7:HBr:CH3COOH (3:1:1); Application: InP (1 0 0) grating etch for BH laser

Ion beam etch with subsequent annealing in H2 for 1 min at 200°C improves etched surface; Application: InGaAsP/InP distributed feedback laser diode

Saturated Br water: HBr: H2O (1:10:40); InP/InGaAsP photolithography for submicron patterns; InP etch rate = 0.45 μm/min; gives dependence of etch rate and mask undercutting on H2O + Br2 concentrations

HNO3:HBr:H2O (1:1:5); Application: InGaAsP/InP mesa etch for BH laser cavity

Review: ion beam milling and sputtering of InP; with summary table of ion beam etching giving etch conditions and etch rates

Review: laser assisted etching of InP; with summary table of etchants, etch conditions, and etch rates

Review: plasma etching of InP; with table of typical etchants, etch conditions and etch rates
Review: reactive ion etching and ion-beam etching of InP; with summary table of etchants, etch conditions, and etch rates

H2SO4:H2O2:H2O (3:1:1); GaAs planar surface etch prior to study of HCl treatment
HCl (36%); GaAs treatment to remove surface oxide; study of dependence on HCl temperature and H2O rinse

H2SO4:H2O2:H2O (1:8:1); Application: InGaAs InP mesa etch

ICP etch of InP using SiCl4/Ar

Inductively coupled plasma etch of InP using Cl2/Xe; vertical, smooth patterns

H2SO4:H2O2:H2O (1:1:50); photochemical, maskless grating etch; Application: GaAs submicrometer optical gratings

Cl2 exposure of InP surface with pattern projection, excimer laser desorption of InCl3; application: waveguide fabrication

Photoelectrochemical etch of InP using HCl:HNO3:H2O (1:1:20) electrolyte; Application: maskless diffraction grating fabrication

Thermochemical vapor etch of InP structure in Cl2 in a ECR system; optimum temperature of 280°C to minimize surface roughness
MAXIMOV, I., L. Landin, and L. Samuelson, “Effects of annealing on electron cyclotron resonance plasma-induced damage in GaAs/Ga_{0.5}Al_{0.5}P quantum well wires structures,” Microelectronic Engineering, 41/42, 419 (1999a)
ECR etch of GaAs/InGaP quantum wires using CH\textsubscript{4}/H\textsubscript{2}/Ar; annealing of damage

HCl:CH\textsubscript{3}COOH:H\textsubscript{2}O\textsubscript{2} (1:2:2); non-selective etch of InGaAs/InP; rate = 90–130 Å/s at 15°C
SBW/HBr:HNO\textsubscript{3}:H\textsubscript{2}O (1:1:8); (SBW is prepared by putting 3 ml Br into 100 ml deionized water. SBW and HBr are mixed in proportions of 1–50 vol.%
Color of HBr changes to light yellow; non-selective etch of InGaAs/InP; rate = 15–20 Å/s at 4°C;
etch of 500–1000 Å wide electron waveguide features with photoresist mask

HF:HNO\textsubscript{3}:H\textsubscript{2}O; Germanium etch rate dependence on composition

Magnetron RIE plasma etch; CH\textsubscript{4}/H\textsubscript{2}/Ar; GaAs surface damage study; H\textsubscript{2} passivation

Magnetron reactive ion etching; CH\textsubscript{4}/H\textsubscript{2}/Ar; GaAs etch damage study

Magnetron reactive ion etching of GaAs in CCl\textsubscript{2}F\textsubscript{2} and SiCl\textsubscript{4}; lower bias voltages than conventional RIE result in less damage

Magnetron ion etch; BCl\textsubscript{3}, SF\textsubscript{6}/BCl\textsubscript{3}, H\textsubscript{2}/BCl\textsubscript{3}, Ar/BCl\textsubscript{3}; of InGaN and InAlN (reactive ion etch with magnetic field to confine plasma electrons close to the surface)

Reactive ion etch; BCl\textsubscript{3} of InGaP; study of etch characteristics
  Reactive ion etch; CH₄/H₂; InP anisotropic etching

  Ar ion beam assisted Cl₂ etching of InP

  Thermochemical etch; Cl₂/H₂ for InP and GaAs; thermodynamic analysis of etching

  NaOH (3N); electrolyte for electrochemical etching of GaP; selective removal of p-type material from n-type

  Layer by layer etching of GaAs by Cl₂ adsorption followed by UV laser photochemical stripping

  Dry etch review; description of process mechanisms for ion etching and plasma etching

  Electrochemical dissolution study of GaP in electrolytes of NaOH, K₃Fe(CN)₆, H₂SO₄

  Saturated Br₂ water:H₂O:H₃PO₄ (2:15:5); InAlAs etch rate = 4000 Å/min for photolithography of second-order gratings
  HF conc.; pre-etch to remove surface oxides

  Acid electrolytes for photochemical dissolution and passivation: Application: InAsP for liquid junction solar cells

(succinic acid:NH₄OH, pH adjusted over the range 4.9–5.3):H₂O₂ (15:1), (25:1) and (50:1). AlₓGa₁₋ₓAs etch rate versus pH and x


CH₃OH:H₃PO₄:H₂O₂ (3:1:1); Application: GaAs mesa etch
KI:I₂:H₂O (113 g:65 g:100 ml); Au contact and masklayer removal from GaAs
H₂O₂:NaOH (1:5); GaAs etch gives rough surface texture
H₂SO₄:H₂O₂:H₂O (10:15:15); destroys the Au mask layer
Br₂/methanol; destroys the Au mask layer


NH₄OH:H₂O₂ (1:225) (pH ≈ 7); Application: GaAs selective etch from AlGaAs
HF; AlGaAs selective etch from GaAs
KI:I₂:H₂O (113 g:65 g:100 ml); Au contact/mask layer etch from GaAs


citric acid:H₂O₂:H₂O (3:15:150); GaAs gate recess etch for FETs
Electrochemical effects induced by electrical contact materials cause etch rate non-uniformities


Inductively couple plasma etch of GaAs using NH₃; damage of Schottky diode


HNO₃ (65%); GaAs oxidation under illumination
HNO₃ (without water) vapor etch; GaAs oxidation


Plasma oxidation; O₂, HNO₃; InP


Thermochemical vapor etch; HCl + H₂ + H₂O; GaAs

Reactive ion etch; CCl\(_4\)/O\(_2\); Application: InGaAsP/InP BH laser facet


Saturated Cl\(_2\) water; GaP etch rate temperature dependence is given; iodine solution etch rates were negligible


ECR etch; CH\(_4\)/H\(_2\)/Ar of GaSb and InSb


AZ400K photolithographic developer (KOH active ingredient); AZ400K:H\(_2\)O (1:5); AlN selective etch from either GaN or Al\(_2\)O\(_3\); little undercut at 65°C; significant undercut at 85°C; etching behavior is rate limited


HCl:CH\(_3\)COOH:H\(_2\)O\(_2\) (1:2:1) {KKI etch}; Application: InGaAsP/InP laser facet etch


In situ Ar sputter etching of GaAs for MBE


GaAs etch and electrochemical etch mechanism study


HCl:H\(_2\)O (1:10); photoelectrochemical etch of GaN; rates of a few hundred Å/min
KOH:H\(_2\)O (1:3); photoelectrochemical etch of GaN; rates of several \( \mu \text{m/min} \)


ECR etch; CF\(_3\)/CHF\(_3\) of AlGaAs; annealing of damage

Br2/methanol; Application: InGaAsP/InP non-selective mesa etch for BH laser


Magnetron ion etching of via holes in GaAs using SiCl4


Thermochemical vapor etch; Cl2; GaAs selective etch from InAs at 130°C in a MBE chamber


ECR plasma etch, Cl2/He; Application: InGaAs/AlGaAs HBT structures


ECR etch; Cl2/He; InGaAs/AlGaAs for HBTs


(NH4)2Sx InP surface cleaning for MOVPE regrowth; followed by hydrogen gas anneal at 450°C

HF; InP surface cleaning for MOVPE regrowth; impurities at interface

H2SO4:H2O2:H2O (1:1:40); InP surface cleaning for MOVPE regrowth; impurities at interface


citric acid:H2O2:H2O (20:1:50); InGaAs selective etch from InP; 7 Å/s

HCl:CH3COOH(1:4); selective etch of InP from InGaAs; 220 Å/s


HF:HNO3:H2O (1:3:4); GaAs first step etch followed by second step A–B etch to reveal growth striations in LEC material
Dry etch environmental hazard; CF₂Cl₂, CF₄, etc

citric acid:H₂O₂:H₂O (1:1.4–6.2:1); selective removal of GaAs from AlGaAs; etch dependence on Al-composition and H₂O₂
H₃PO₄:H₂O₂:H₂O (4:1:180); non-selective etch for GaAs/AlGaAs

NH₄OH:H₂O₂:H₂O (30:1:72 by weight); selective removal of GaAs substrate from Al₀.₇Ga₀.₃As etch stop layer
HF:H₂O (1:10); selective removal of Al₀.₇Ga₀.₃As etch stop layer from wafer bonded GaAs template layer
H₂O₂:H₂O (1:1); 2 min oxidation of GaAs surface features, followed by HCl:H₂O (1:1) 2 min etch removal of oxide

Br₂/methanol (1%); Application: InGaAsP surface cleaning for Schottky contacts

H₂SO₄:H₂O₂:H₂O (5:1:1); InP surface etch prior to OMVPE growth, 2 min at 60°C
H₃PO₄:H₂O₂:H₂O (3:1:50); InGaAs and InAlAs thinning etch for differential Hall measurement profiles

H₃PO₄:H₂O₂:H₂O (3:1:50); GaAs etch rate = 0.18 μm/min at 24°C
H₃PO₄:H₂O₂:H₂O (1:9:210); GaAs etch rate = 0.2 μm/min at 24°C
H₃PO₄:H₂O₂:H₂O (7:3:3); GaAs etch rate = 2 μm/min at 24°C
H₃PO₄:H₂O₂:H₂O (1:9:1); GaAs etch rate = 3 μm/min at 24°C
No dependence on GaAs doping is seen; shows etch rate dependence on concentration, temperature and GaAs orientation

HCl:CH₃COOH:H₂O (2:6:1); Application: InP channel etch
HCl:CH₃COOH:H₂O (1:2:1); InP groove etch

H₃PO₄ (85%); GaN etchant at T = 100–200°C; gives etch rate and morphology dependence on temperature


KOH:H₂O (1 and 5%); Photoetch of n-GaAs; no etch without illumination; does not attack AuGe contacts; Application: focused laser beam microetching

HCl:H₂O (1%); Photoetch of GaAs

H₂SO₄:H₂O₂:H₂O (10:13:250); Photoetch of GaAs


HCl:H₂O (5:1); InP rate ~15 μm/min

HCl:H₂O (1:1); InP rate < 100 Å/min

HCl:H₂O (5:3); selective etchant to remove a sacrificial InP layer from between an InGaAs mask and an InGaAs etch stop layer to form micromachined cantilevers


FeCl₃ (21% diluted); laser scanned photochemical etch for vee-grooves in InP (1 0 0)


Thermochemical Cl₂ and Ar ion beam assisted Cl₂ in situ etching of GaAs surfaces for MBE GaAs regrowth; surface study

MUKHERJEE, S.D., “Vertical sidewall reactive ion etching (RIE) of GaAs and AlₓGa₁₋ₓAs (x = 0.76) using BCl₃/CCl₂F₂/He at equal rates,” SPIE Proc., Advanced Processing of Semiconductor Devices, 797, 110 (1987)

Reactive ion etching; BCl₃/CCl₂F₂/He; GaAs and Al₀.7₆Ga₀.2₄As at equal rates; for vertical sidewall etch


Review of GaAs etching and surface preparation; discusses etching mechanisms, diffusion and reaction rate limiting etching, anodic etching, and surface preparation

Gives GaAs etching summaries for: citric acid:H₂O₂; H₃PO₄:H₂O₂:H₂O; HN₄OH:H₂O₂:H₂O; H₂SO₄:H₂O₂:H₂O; H₂O:AgNO₃:CrO₃:HF {A–B etch}; HCl:H₂O₂:H₂O

H₂SO₄:H₂O₂:H₂O (3:1:1); GaAs etch rate ~1000 Å/s at 0°C
N-methyacetamide (CH₃CONHCH₃); electrolyte for anodization of GaAs

tartaric acid:H₂O₂:H₂O (1:1:10); selective etch of InGaAs from 75 Å InP etch stop layer; InGaAs rate (room temperature) = 750 Å/min; a bluish surface appears with the final removal of InGaAs then disappears as etching terminates at the InP stop layer


reactive ion etch; SiCl₄/SiF₄/HBr; selective etch of InGaAs and InP from InAlAs; pattern etch with masks of Si₃N₄ or NiCr

reactive ion etch, SiCl₄/SiF₄; addition of O₂ increases selectivity of etching GaAs from AlGaAs

Review of dry etch damage in III–V semiconductors; techniques for differentiating sidewall damage from surface damage. Damage is greatest when neutral ions are present

Reactive ion etch; SiCl₄/SiF₄; for damage free GaAs/AlGaAs MESFETs and HEMTs

Reactive ion etch of GaAs and AlGaAs in SiCl₄; conditions for selective and non-selective behavior

Reactive ion etch, SiCl₄; GaAs with AlGaAs stop layer; GaAs:Al₀.₃Ga₀.₇As etch rate ratio is >10,000:1
HCl:H₂O (4:1); Application: InP selective etch from InGaAsP

Br₂/methanol; Application: InGaAsP/InP stripe and mesa etch for BH laser
HBr:CH₃COOH; InP (1 0 0) orientation determination etch

NH₄OH(30% aq.):H₂O₂(30% aq.) (3:100); AlGaAS on GaAs layer delineation; a few seconds

Br₂/methanol; Application: InGaAsP surface cleaning for Schottky contact

Br₂/methanol; Application: InP substrate cleaning for LPE

HBr:H₂PO₄ (1:2) (Huber etch); Application; InP and InGaAsP epilayer etch pit defect delineation at room temperature

NARAYANAN, H., (private communication), (1974)
HCl:H₂O₂:H₂O (40:4:1); III–V non-preferential thinning for TEM specimens

H₂SO₄:H₂O₂:H₂O (5:1:1); InP substrate cleaning, first step
Br₂/methanol; InP substrate cleaning, second step
KOH; InP substrate cleaning, 3rd step, followed by DI water rinse

In–Ga–As metal solution; Application: LPE in situ etch of InP for surface cleaning
HCl:H₂O (1:10); InP substrate cleaning to introduce chloride ion absorbed layer for surface
protection prior to LPE growth

NELSON, R.J., R.B. Wilson, P.D. Wright, P.A. Barnes, and N.K. Dutta, “CW Electro-optical
Properties of InGaAsP (1.3 μm) Buried-Heterostructure Lasers,” IEEE J. Quantum Electron., QE-
17(2), 202–06 (1981)
  Br₂/methanol; Application: InGaAsP/InP mesa etch

NELSON, R.J., P.D. Wright, P.A. Barnes, R.L. Brown, T. Cell, and R.G. Sobers, “High-output-
  Br₂/methanol; Application: InP (1 0 0) vee and dovetail groove etch
  H₂SO₄:H₂O₂:H₂O (10:1:1); Application: InGaAsP selective etch from InP
  HCl dilute; InP selective etch from InGaAsP

NÉMETH-SALLAY, M., G.M. Minchev, B. Pödör, L.D. Pramatarova, J. Szabó, and Szentpáli,
“Investigation of the surface preparation of GaAs substrates for MBE and VPE with whole sample
  Thermochemical vapor etch; AsCl₂ + H₂ in situ etch of GaAs prior to VPE growth; comparison of
etched surface roughness with initial surface reflection

NG, W.W., and P.D. Dapkus, “Growth and Characterization of 1.3 μm CW GaInAsP/InP Lasers by
  KOH:K₃Fe(CN)₆:H₂O; Application: InGaAsP/InP cleaved cross-section layer delineation

NG, W., C.S. Hong, H. Mansevit, and P.D. Dapkus, “Low Threshold 1.3 μm GaInAsP/InP
  HCl dilute; Application: InP selective etch from InGaAsP
  H₂SO₄:H₂O₂:H₂O (10:1:1); InGaAs selective etch from InP

  Anodization; H₃PO₄:H₂O, pH = 2.6–3.0, electrolyte; GaAs thinning
  NH₄OH:H₂O (1:1); oxide stripping etch
  HCl; alternative oxide stripping etch

NIGGEBRÜGGE, U., “Recent Advances in Dry Etching Processes for InP-Based Materials,” 3rd
Int’l Conf. on Indium Phosphide and Related Materials, Apr 8–11, 1991
  Cardiff, Wales, UK, (IEEE Catalog no. 91CH2950-4) pp. 246–51, Review: dry etch processes for
InP-based materials

Reactive ion etching; CH₄/H₂; InP; deep etching with photoresist and SiO₂ masks; near vertical sidewalls and flat bottoms

H₂SO₄:H₂O₂:H₂O (5:1:1); Application: InGaAsP selective etch from InP for laser fabrication

Saturated bromine water (SBW):HBr:H₂O (1:10:40); Application: grating fabrication; dependence of etch depth on pattern spacing

HF:CH₃COOH:KMnO₄(0.4 M) (1:1:1); Application: striation defect delineation in GaSb after 5.5 min etch
HNO₃:HCl:H₂O (1:1:1); Application: etch pit defect delineation in GaSb

ECR-RIBE etch; Cl₂; GaAs; optimization of etch conditions

H₂SO₄:H₂O₂:H₂O (100:0.92:5); InP surface cleaning prior to Br₂/methanol removal of surface polish damage; (1 0 0) etch rate = 0.02 µm/min; (1 1 1)B etch rate = 0.06 µm/min; gives etch rate dependence on H₂O₂ concentration

HF:H₂O₂:H₂O (1:1:10); GaAs photoetch dislocation etch pit delineation

ECR etch with hydrogen; GaAs; in situ surface cleaning for MBE regrowth of GaAs

Sulfidization of GaAs; thermal and photoinduced dissociation of H₂S

Reactive ion etch; CH₄/H₂/Ar; Application: mesa etch on InP for MOCVD regrowth
  
  Reactive ion etch; CH₄ + H₂; Application: InP mesa etch with SiNx mask
  K₃Fe(CN)₆:KOH:H₂O (1 g:1 g:16 g); InP/InGaAs layer delineation under illumination

  
  Reactive ion etch; CH₄/H₂; Application: mesa etch on InP prior to MOCVD regrowth

  
  Reactive ion etch; Cl₂/BCl₃/Ar; Application: GaAs photoresist patterned via holes

  
  Reactive ion etch; Cl₂/BCl₃/Ar slot via holes in GaAs

  
  A–B etch; GaAs etch pit defect delineation; 3 min at room temperature; etch rate ~3 μm/min
  NaOH–KOH eutectic, molten; GaAs etch pit defect delineation; 30 min at 350°C, etch rate
  ~0.08 μm/min; when used in sequence with A–B etch more information is revealed than with
  either etch individually

  
  Review of wet chemical etching of III–Vs, covering electrochemical mechanisms of etching and
  practical application of etchants; profile etching (Chapter 8), defect revealing etchants (Chapter 9),
  material and dopant selective etchants (Chapter 10)

131(11), 2641–44 (1984)
  
  HCl:H₂O; Shows data for InP etch rate dependence on dilution. InP electrochemical behavior
  shows HCl etching is purely chemical

NOTTEN, P.H.L., and A.A.J.M. Damen, “The Electrochemistry of InP in Br₂/HBr Solutions and Its
  
  Electrochemical etch study of InP in aqueous bromine solutions; CH₃COOH:HBr:Br₂; mechanism
  of p-InP etch rate in dark and under illumination
  Br₂:HBr:H₂O; etch rate is linearly proportional to the Br₂ concentration; rate is diffusion
  limited
GaAs photolithography profiles for: HCl:H2O2:H2O (160:4:1); HCl:H2O2:H2O (80:4:1); 1 M NaOCl:HCl (5:1); 1 M NaOCl in 0.1 M NaOH; 0.1 M Na2CO3; 0.05 M K3Fe(CN)6 pH = 13; 0.5 M K3Fe(CN)6 pH = 13

citric acid:H2O2 (5:1); selective removal of GaAs substrate from a AlAs (or AlGaAs) etch stop layer
H2SO4:H2O2:H2O (3:1:1); polishing etch for thinning GaAs
HF, dilute; selective removal of AlAs from GaAs; selectivity > 10^7

Plasma etch; C2F3Cl3; InP etch study; rate dependence on pressure and temperature

Plasma etch; C2F3Cl3;O2; InP etch study; best results with C2F3Cl3;O2 (7:3)

ECR plasma etch; CH3Cl/Ar/H2 of InP; smooth, residue-free surfaces above 120°C

Electrochemical etch; GaAs; NaOH electrolyte; removal of p substrate from n-layer

Reactive ion etch of InGaAsP/InP using CH4/H2; SiO2-masked grooves formed by alternating with O2 ashing to remove polymer buildup. (Followed by wet etch damage removal prior to MOVPE regrowth)
Reactive ion etch of SiO2 mask pattern using CF4
HCl:HNO3:H2O (1:2:3); step 1, 15 s, RIE damage removal from InGaAsP/InP grooves prior to MOVPE regrowth
HCl:CH3COOH (1:4); step 2, 5 s, selective RIE damage removal from InP in InGaAsP/InP grooves prior to MOVPE regrowth
H2SO4:H2O2:H2O (1:1:40); step 3, 15 s, selective RIE damage removal from InGaAsP in InGaAsP/InP grooves prior to MOVPE regrowth
Cl₂ focused ion beam etch; GaAs and InP maskless etching

Ion beam assisted, maskless etch with 35 keV Ga⁺ focused ion beam in Cl₂ gas atmosphere; InP and Si

Citric acid:H₂O₂ (5:1); Application InGaAs etch rate = 1000 Å/min

HCl:H₂O (4:1); Application: InP selective etch from InGaAsP

Citric acid:H₂O₂ (5:1); Application InGaAs etch rate = 1000 Å/min

Oxidation of GaAs in steam environment at 500–520°C; thickness versus time; patterns using SiO₂ mask

NaOH(0.1 mol/l); anodic etching of GaN films results in accumulated gallium oxide deposits and slow etch rates
NaOH (0.1 mol/l): NaCl (0.2 mol/l); anodic etching of GaN films with reduced surface deposits and accelerated etch rates

NaOH (0.1 mol l⁻¹): NaCl (0.03 mol l⁻¹); electrolyte for photoinduced electrochemical etching of GaN

H$_3$PO$_4$:H$_2$O$_2$:H$_2$O (1:1:38); Application: InGaAs and InAlAs etch rate = 1000 Å/min at 21.5°C; does not attack InP
H$_3$PO$_4$:H$_2$O$_2$:H$_2$O (1:1:8); InGaAs notch etch for FET; etch rate = 4700 Å/min


Reactive ion etch; CH$_4$/H$_2$/CO$_2$; Application: InGaAs(P)/InP mesa etch and laser mirror etch
o-H$_3$PO$_4$:H$_2$O$_2$:H$_2$O (1:1:8); Application: removal of REI residual InGaAs at bottom corner recesses
o-H$_3$PO$_4$:HCl (3:1); Application: mesa preparation for InP regrowth


AgNO$_3$ (10 mg):HF (4 ml):HNO$_3$ (6 ml):H$_2$O(8 ml), (RC etchant); etch pit delineation in GaP

bisdimethylaminochlorarsine; thermochemical vapor etch for gas source MBE GaAs surface cleaning


Reactive beam etching of InP using Br$_2$ + N$_2$; fabrication of 250 nm period diffraction grating

Cl$_2$/methanol (Cl$_2$-saturated solution): H$_3$PO$_4$ (1:1); GaP non-preferential chemical polish


GaAs (1 0 0) surface cleaning XPS study: NH$_4$OH:H$_2$O$_2$:H$_2$O (10:5:1000); HCl conc.; GaAs (1 0 0) (leaves a nearly stoichiometric surface) HF (50%); GaAs (1 0 0); H$_2$SO$_4$:H$_2$O$_2$:H$_2$O (5:1:1)


H$_2$SO$_4$:H$_2$O$_2$:H$_2$O (5:1:1); Application: GaAs surface cleaning for CVD and LPE overgrowth on carbon film masked substrate


A–B etch; two part mix for indefinite storage: A solution: H$_2$O:AgNO$_3$:HF (40 ml:0.3 g:40 ml) B solution: CrO$_3$:H$_2$O (40 g:40 ml) Mix A + B (1:1) for fresh etchant; Layer interface and defect
delineation in GaAs, InP, InGaAs, InGaP, GaP; for As-compounds several seconds at 20°C; for P-compounds many minutes at 50–75°C


\[ \text{H}_2\text{SO}_4: \text{H}_2\text{O}_2: \text{H}_2\text{O} (5:1:1); \text{Application: GaAs selective etch from InGaP} \]


\[ \text{Br}_2/\text{methanol}; \text{Application: InGaAsP groove, stripe and channel etch} \]
\[ \text{HNO}_3; \text{InGaAsP selective etch from InP} \]

A–B etch: layer interface delineation

\[ \text{H}_3\text{PO}_4: \text{HCl} (13:5); \text{InP selective etch from InGaAsP} \]
\[ \text{H}_2\text{SO}_4: \text{H}_2\text{O}_2: \text{H}_2\text{O} (5:1:1); \text{InGaAsP selective etch from InP} \]
\[ 0.4 \text{N} \text{FeCl}_3 \text{ in HCl; InP(1 0 0) orientation determination} \]


\[ \text{Br}_2/\text{methanol}; \text{Application: InGaAsP groove, stripe and channel etch} \]

\[ \text{H}_2\text{SO}_4: \text{H}_2\text{O}_2: \text{H}_2\text{O} (5:1:1); \text{InP surface cleaning following 30 min Br}_2/\text{methanol (0.7%); followed by (5:1:1). 0.4N FeCl}_3/\text{HCl solution; InP(1 0 0) orientation determination} \]


\[ \text{NH}_4\text{OH}: \text{H}_2\text{O}_2: \text{H}_2\text{O} (2:1:10); \text{GaAs substrate cleaning for OMVPE} \]


\[ \text{ECR etch; CF}_4/\text{O}_2/\text{Ar}; \text{Application: patterning SiN\textsubscript{x} films on GaAs} \]


\[ \text{H}_3\text{PO}_4: \text{H}_2\text{SO}_4 (1:4); \text{GaN defect delineation etch; 230°C for 10 min} \]


\[ \text{Reactive ion etch; C}_2\text{F}_6 \text{ and SiCl}_4; \text{damage assessment in GaAs/AlGaAs} \]
\[ \text{H}_2\text{SO}_4: \text{H}_2\text{O}_2: \text{H}_2\text{O} (1:8:600); \text{GaAs RIE damage removal} \]


\[ \text{Thermochemical etch; Cl}_2; \text{GaAs for MBE in situ surface cleaning} \]
H₂SO₄:H₂O₂:H₂O (1:1:1); Application: InP etch at 50°C using SiO₂ pattern mask

Selective photochemical laser-induced etching of InP and GaAs in CH₃Br

H₂SO₄:H₂O₂:H₂O (1:1.3:25); GaAs (1 0 0) Cr-doped semi-insulating, laser-induced etching for via holes and diffraction gratings (also for CdS undoped) KOH:H₂O (1:10); GaAs n-type laser-induced etch
HCl:HNO₃:H₂O (1:2:30); InP Fe-doped semi-insulating laser-induced etch

Analysis of resolution for light defined patterns in photoelectrochemical etching of InP

Photoetch of p-GaAs; 0.1 M H₂SO₄:0.1 M NaSCN solution electrolyte; maximum etch rate = 1300 Å/min

InP; light intensity controlled etch to form spherical lenses on n+ nP LED substrates

HNO₃:H₂O₂ (1:1); attacks photoresists. NH₄OH:H₂O₂:H₂O; attacks photoresists
Br₂/methanol; attacks photoresists
Citric acid:H₂O₂ (25:1); GaAs etch rate = 20 Å/s; does not attack photoresists

In situ CBE digital etching of InP for selective epitaxy using trisdimethylaminophosphorus adsorption/desorption at 400°C

In situ CBE digital etching of InP for selective epitaxy using tert-butylphosphine (TBP) adsorption/desorption at 390°C
Ion beam etch of AlGaAs using nitrogen; etch damage profiles

Reactive ion etch; SiCl4; GaSb and GaAlSb etch study for selective and non-selective etch conditions

HCl:H3PO4 (1:10); Application: InP selective etch from InGaAs using SiN mask for HBT fabrication
H2SO4:H2O2:H2O (1:1:20); Application: InGaAs selective etch from InP
HF dilute; Application: SiN passivation layer removal from InP

Thermochemical vapor etch; HCl + H2 + PH3; InP in situ etch for OMVPE

HF:HNO3:H2O (15:10:300) {p-etch (Si)}; Application: patterning of electron beam irradiated SiO2 mask

H2SO4:H2O2:H2O (20:1:1); GaAs striation delineation etch
H2SO4:H2O2:H2O (15:1:1); GaAs striation delineation etch
H2SO4:H2O2:H2O (8:1:1); GaAs striation delineation etch
AB etch; GaAs striation delineation etch
AB:H2O (1:5); GaAs striation delineation etch
Diluted Sirtl etch; GaAs striation delineation etch

chemically assisted Ar ion beam etch with Cl2; InP/InGaAs quantum dots prior to InP MOCVD regrowth

Thermochemical etch; Cl2; InP/InGaAs pattern etching at ∼300°C for fabricating quantum wires
ECR etch; CCl₂F₂, BCl₃, Cl₂; study of GaAs and InP etch characteristics and comparison with RIE

ECR plasma; Cl₂, BCl₃; Study: comparison on GaAs and InP; shows etch rate dependences on microwave power, RF power, sample placement, and temperature

Reactive ion etch; Cl₂, CCl₂F₂; GaAs and InP

Polysulfide solution (50 ml (NH₄)₂S, dissolving 5 g sulfur into the solution, then flowing oxygen through the solution, bubbling for 45 min); first step in passivation of InP/InGaAs MSM photodetectors
(NH₄)₂S (8.9% S); second step in passivation of InP/InGaAs MSM photodetectors

NaOH (0.1N) electrolyte for etching GaN

H₃PO₄:H₂O₂:H₂O (3:1:40); GaAs etch rate = 100 nm/min; isotropic etch
Ar ion milling and plasma etch; cathodoluminescence study of surface damage; best surface combines ion milling with 1 min wet etch

RIE; CH₄/H₂; Application: InGaAs/InP photodiode fabrication

ceric sulfate (saturated solution);HNO₃ (9:1); chromium etchant from semiconductor surface
I₂:KI:H₂O (56 g:112 g:500 ml); gold etchant from semiconductor surface

Thermochemical etching of GaAs/AlGaAs structure using laser-induced etch in CCl$_2$F$_2$ and C$_2$H$_2$F$_4$


ECR etch in situ surface roughness measurement with a laser reflectometer


InP surface cleaning in H$_2$ and H$_2$/CH$_4$/Ar plasmas; removes surface carbon and oxygen but depletes some surface phosphorus


HF:H$_2$O$_2$ (1:20); InP surface cleaning for MBE regrowth gives high surface defect density citric acid:H$_2$O$_2$ (1:1); InP surface cleaning for MBE regrowth gives high surface defect density Br$_2$:methanol (1%); InP surface cleaning for MBE regrowth gives high surface defect density H$_2$SO$_4$:H$_2$O$_2$:H$_2$O (1:4:50); InP surface cleaning for MBE regrowth; best morphology

UV light/ozone InP surface oxidation; surface cleaning for MBE regrowth


Thermochemical vapor etch; Br$_2$; GaAs (1 1 0); etching and desorption of etching products above ~575 K

PATRIN, J.C., and J.H. Weaver, “Br$_2$ and Cl$_2$ adsorption and etching of GaAs (1 1 0) studied by use of scanning tunneling microscopy,” Phys. Rev. B: Condens. Matter, 48(24), 17913 (1993b)

Scanning tunneling microscopy study of halogen atom interactions on GaAs (1 1 0) surfaces; shows dissociative adsorption and etching at steps and terraces depending on temperature fluence and flux


H$_3$PO$_4$(85%); AlN dissolution


NH$_4$OH:H$_2$O$_2$:H$_2$O (1:1:20); Application: selective pattern etch through GaAs mask layer onto AlGaAs spacer layer

KI:I$_2$:H$_3$PO$_4$ (pH < 2); Application: selective AlGaAs etch to transfer and undercut the GaAs mask pattern onto underlying GaAs for shadowed MOVPE regrowth

HF:H$_2$O (1:10); Application: AlGaAs spacer layer lift-off (10 h) to reveal microlens pattern

NH₄OH: H₂O (1:20); oxide removal from GaAs for bonding to Si
NH₄OH:H₂O₂:H₂O (1:1:20); selective removal of polycrystalline GaAs from Si mask

Br₂/methanol (1%); Application: InGaAs mesa etch
H₂SO₄:H₂O₂:H₂O; InGaAs mesa etch

Br₂/methanol; Application: InP substrate cleaning for LPE

Br₂/methanol; Application: InGaAs mesa etch
H₂SO₄:H₂O₂:H₂O (1:6:10); Application: InGaAs mesa etch at 50°C; etch rate = 20 μm/min

Review; high ion density dry etching; ECR; ICP; of GaAs, GaSb, InP, AlGaAs, GaN, InGaN, InGaAs

ECR etch of InP and GaAs using Cl₂, BCl₃ and CH₄–H₂ plasmas

ECR etch; Cl₂/CH₄/H₂; InGaAsP/InP; small dimension mesas and via holes

ECR etch; CH₄/H₂; InP and GaAs; comparison of multipolar and magnetic mirror ECR sources

ECR plasma etch; CH₄ + H₂; AlGaAs
ECR plasma etch; CH$_4$/H$_2$/Ar and Cl$_2$/H$_2$; InN, AlN and GaN dry etching characteristics

ECR etch; study at low temperature; Cl$_2$/Ar, BCl$_3$/Ar for GaAs, AlGaAs, GaSb; CH$_4$/H$_2$/Ar for InP

ECR plasma etch; CH$_4$/H$_2$/Ar; InGaAsP smooth surfaces
ECR plasma etch; BCl$_3$/Ar; InGaAsP; In enriched surfaces for T < 130°C

ECR etch; BCl$_3$/Ar or Cl$_2$/Ar; GaAs, AlGaAs and GaSb, etch behavior at temperatures from +25°C to –30°C; low temperature minimizes photoresist undercutting

ECR plasma etch; Cl$_2$/CH$_4$/H$_2$/Ar; GaN and AlN; comparison with RIE. AZ400K photoresist developer; AlN; rate depends on crystal quality

ECR plasma etch; CH$_4$/H$_2$/Ar; InGaAsP anisotropic dry etch; etch rates are independent of p- and n-doping levels

Plasma etch; HBr/H$_2$, HBr/CH$_4$, HBr/Ar; GaAs, GaSb, AlGaAs, InP, InSb, InGaAs, InAlAs; gives data on etch rates and photolithographic etch profiles

ECR plasma etch; CH$_4$ + H$_2$ + Ar; InP; addition of PCl$_3$ eliminates surface degradation

Thermochemical vapor etch; HI/H₂/Ar, CH₄/H₂/Ar; GaAs, InP, InAs, InSb, InGaAs, InAlAs, InAlP

ECR plasma etch; PCl₃ + Ar; Application; In₀₂Ga₀₈As–GaAs QW ridge waveguide lasers

ECR plasma etch; BCl₃, CCl₂F₂/O₂, SF₆/Ar, CH₄/H₂/Ar; processing for GaAs/AlGaAs and InP/InGaAs structures

ECR etch; CH₄/H₂/Ar with PCl₃ added; InP and InGaAs

ECR plasma; CH₄:H₂:Ar; CCl₂F₂:Ar; InGaAIAs/InP alloys; bias controlled etch selectivity

ECR plasma etch with CH₄/H₂/Ar under various conditions for InP/GaP/GaAs/InGaAs/AlGaAs/InGaAsP

ECR and RIE etch damage from Ar plasmas on InN, InGaN, and InAlN

ECR high power plasma etch; CH₄/H₂/Ar; of InP, GaAs, GaP, AlGaAs, InGaAs, InGaAsP

Plasma damage; H₂ and Ar; on InGaAs and InP

ECR etch damage of GaAs p–n junctions in O₂ and H₂ discharges
ECR plasma etch; HI/H₂, CH₄/H₂ and C₂H₆/H₂; InP submicron gratings

ECR plasma etch; CCl₂F₂, BCl₃/SF₆, SiCl₄/SF₆; GaAs selective etch from AlGaAs or InGaAs; These require removal of residual etch stop surface components: HF₃ or InCl₃ or InF₃
NH₄OH:H₂O with DI water rinse; removal of dry etch residues
ECR plasma; H₂; alternative dry etch for removal of residues

HCl:H₂O (1:1); InGaP mesa etch
H₃PO₄:H₂O₂:H₂O (1:1:1); GaAs and AlGaAs mesa etch. ECR etch; BCl₃/Ar; GaAs and AlGaAs ECR etch; CH₄/H₂/Ar; InGaP
(NH₄)₂Sₓ; InGaP surface passivation

ECR etch; CCl₂F₂/O₂, CH₄/H₂/Ar processing of GaAs/AlGaAs HEMTs

ECR etch of patterns in GaN; CH₄/H₂/Ar

HCl:H₂O (1:1); InGaP mesa etch
H₃PO₄:H₂O₂:H₂O (1:1:1); GaAs and AlGaAs mesa etch. ECR etch; BCl₃/Ar; GaAs and AlGaAs ECR etch; CH₄/H₂/Ar; InGaP
(NH₄)₂Sₓ; InGaP surface passivation

InGaP/GaAs surface recombination study: HCl:H₂O (11:1); Application: InGaP mesa etch
H₃PO₄:H₂O₂:H₂O (1:1:1); Application: GaAs and AlGaAs mesa etch
ECR etch; CH\textsubscript{4}/H\textsubscript{2}/Ar; Application: InGaP mesa etch
ECR etch; BCl\textsubscript{3}/Ar; Application: GaAs and AlGaAs mesa etch
(NH\textsubscript{4})\textsubscript{2}S\textsubscript{x}; Application: surface passivation of InGaP


H\textsubscript{3}PO\textsubscript{4}:H\textsubscript{2}O\textsubscript{2}:CH\textsubscript{3}OH (2:1:1); Application: AlGaAs/GaAs mesa etch; near identical etch rates for GaAs and Al\textsubscript{x}Ga\textsubscript{1-x}As for x < 0.33


ECR etch of GaAs using Cl\textsubscript{2}/CH\textsubscript{4}

PEREIRA, R.G., M. de Potter, and M. Van Rossum, “Influence of CH\textsubscript{4}/H\textsubscript{2} reactive ion etching on the deep levels of Si-doped Al\textsubscript{x}Ga\textsubscript{1-x}As (x = 0.25),” J. Vac. Sci. Technol., B, 14(3), 1773 (1996a)


PEREIRA, R.G., M. Van Hove, and M. Van Rossum, “Modifications of the three-dimensional transport properties of Si-doped Al\textsubscript{0.25}Ga\textsubscript{0.75}As exposed to CH\textsubscript{4}/H\textsubscript{2} reactive ion etching,” J. Vac. Sci. Technol., B, 14(1), 106 (1996b)


H₂O, thermal oxidation of AlInAs


RIE of InP using CH₄/H₂/N₂; etch study


Excimer laser-assisted etch; CH₃Br or CF₃Br at 193 or 248 nm wavelength; InP, Si, Al;
Application: InP/InGaAs avalanche photodiodes


HCl:H₃PO₄ (1:1); InP selective etch from InGaAsP; gives etch rate dependence for (1 1 1)A and (1 1 1)B on etch composition

HCl does not attack GaAs but reacts with InAs and InP
HNO₃ reacts little with arsenides but has no effect on InP. H₃PO₄ does not attack GaAs


RIE plasma etch; SiCl₄, Ar of n-GaN; damage effects on Ohmic contacts


Chemically assisted ion beam etch; Ar/Cl₂ of AlGaN


CAIBE etching of GaN; with HCl and H₂/Cl₂


HNO₃:HF:H₂O (3:1:4); GaAs delineation of growth striae; 2 min at 20°C


KOH:K₃Fe(CN)₆; etch for GaP; etch rate dependence on solution concentrations and temperature

H₂SO₄:H₂O₂:H₂O; photoelectrochemical etch electrolyte for n- and p-GaAs; etch study

GaAs; UV illuminated etch for deep features, via holes, etc.; higher etch rates than for visible light

<table>
<thead>
<tr>
<th>Etch Solution</th>
<th>n-type (μm/min)</th>
<th>Si-type (μm/min)</th>
<th>p-type (μm/min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>H₂SO₄:H₂O₂:H₂O (1:1:100)</td>
<td>18</td>
<td>13</td>
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<tr>
<td>HNO₃:H₂O (1:20)</td>
<td>12</td>
<td>10</td>
<td>1.0</td>
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<tr>
<td>KOH:H₂O (1:20)</td>
<td>8</td>
<td>6</td>
<td>0.5</td>
</tr>
</tbody>
</table>

H₂SO₄:H₂O₂:H₂O (1:1:100); GaAs laser-enhanced maskless grating etch

HNO₃:H₂O (1:20); Photoetching of deep features in GaAs; role of optical waveguiding

Plasma etch of patterns in SiO₂ mask on InP using CHF₃/O₂
CAIBE etch of undercut stripe in InP using Cl₂/Ar with tilted sample

First step: place device wafer in OCG OPD 4262 positive photoresist developer
Second step: mix 2-propanol: H₂SO₄ (1:1) (an exothermic reaction; color changes from clear to amber)
Third step: immediately ultrasonically agitate fresh mixture for 15 s and add to developer containing the wafer; agitate this fuming mixture for 1 min
Fourth step: decant the bath and spray rinse the wafer with 2-propanol; remove wafer and N₂ blow dry

Laser assisted dry etching of InP using Cl₂ for diffraction patterned periodic structures


H₂SO₄:H₂O₂:H₂O (5:1:1); InP(Fe) thinning, etch rate = 500 Å/min at 25°C to remove damage from Si-implanted InP prior to MBE regrowth


Saturated Br₂ water: H₃PO₄: H₂O (2:1:15); Application: InGaAsP and InP vee-groove grating etch; does not attack photoresists

H₂O:H₂O₂:HF (8:3:2) to remove SiO₂ mask and In droplets from first LPE step


Photochemical etching of n-GaSb; NaOH and HCl electrolytes; aerated solution to oxidize Sb; matte gray, faceted surface


Reactive ion etch using CH₄/H₂/O₂ on InP/InGaAsP device structures; use of photoresist, SiN, Ti, NiCr masks for mirrors and deep trenches

Reactive ion etch using SF₆ for Ti mask patterning and mask removal from InP/InGaAsP

HF:H₂O (1:4); Ti/SiN mask removal from InP/InGaAsP


Reactive ion etch using CH₄/H₂ for InGaAs/InGaAsP ridge waveguide laser fabrication; damage profile


Reactive ion etch; CH₄/H₂; of InGaAsP/InGaAs lasers; low etch damage with low etch power and post etch anneal

HNO₃: photoelectrochemical etching of p-InP; dependence on carrier concentrations and etch pit densities; study of photoetch mechanism

HNO₃:H₂O; study of photoelectrochemical etching of p-InP; dependence on light intensity, HNO₃ concentration, and potential

Thermochemical vapor etch, HCl in VPE-hydride growth; InGaAs

KOH (0.1 M), electrolyte for anodic oxidation of n-InP

HNO₃ (12 M)
HNO₃ (12 M):sulfamic acid (0.1 M); p-InP etch mechanism study

Plasma etch damage modeling; GaAs

Review: Photochemical processing of semiconductors

Photoetch of micrometer size features in GaAs using a scanned focused laser beam; KOH electrolyte

RAZEGHI, M., F. Omnes, Ph. Maurel, Y.J. Chan, and D. Pavlidis, “Ga₀.₅₁In₀.₄₉P/GaₓIn₁−ₓAs lattice-matched (x = 1) and Strained (x = 0.85) Two-Dimensional Electron Gas Field-effect Transistors,” Semicond. Sci. Technol., 6, 103–07 (1991)
NH₄OH:H₂O₂:H₂O (10:4:500); Application: GaAs selective etch from InGaP for FET fabrication
H₃PO₄:HCl (1:1); InGaP selective etch from GaAs

Low energy Ar⁺ ion sputter etching of Si
Thermochemical vapor etch; CCl₄; GaAs in situ pregrowth etch for OMVPE
Thermochemical vapor etch; VCl₄; GaAs in situ pregrowth etch for OMVPE

ECR etch; Cl₂; GaAs selective removal from InGaAs; indium chloride by-products stop etching of InGaAs at room temperature
citriger acid:H₂O (1 g of anhydrous citric acid to 1 ml water); Application: InGaAs selective removal from GaAs; GaAs 40 Å/min; In₀₂Ga₀₈As 751 Å/min
NH₄OH:H₂O (1:18); GaAs surface oxide removal prior to MBE overgrowth

ECR etch; CH₄/H₂; InGaAs/InAlAs HEMT structures; excessive H₂ flux causes donor passivation

ECR etch; BCl₃/N₂ of InGaP/GaAs structures and InP

inductively coupled Ar plasma; GaAs; FET device degradation study. ECR Ar plasma; GaAs; FET device degradation study

ECR etch; BCl₃, BCl₃/Ar, BCl₃/N₂; InAlN surface damage

ECR plasma etch; BCl₃, BCl₃/Ar, BCl₃/N₂; of an InAlN and GaN FET structure
Surface N loss produces poor rectifying gate contacts for metals deposited on etched surfaces

NH₄OH:H₂O (1:20); Application: GaAs surface cleaning for Ohmic contact deposition; 30 s then spin dried for native oxide removal

Ar ion in situ etch prior to contact metal deposition for low resistance contacts

Reactive ion etch; Application: CCl₂F₂; GaAs mesa etch

H₃PO₄:HCl:H₂O; Application: InGaP selective etch from GaAs; selectivity dependence on composition

K₂Cr₂O₇:H₃PO₄:H₂O; Application: AlGaAs selective etch from GaAs


ECR plasma; CCl₂F₂; Application: GaAs selective etch from AlGaAs; selectivity > 200


ECR etch; Cl₂/CH₄/H₂/Ar; InP/InGaAsP mesa etch at 150°C; fast without mask narrowing


In situ Ar ion milling to remove oxide from GaAs prior to Ge/Ni/Au–Ge/Mo contact deposition to improve Ohmic contact


ECR and ICP etch of SiO₂ patterned GaN; SF₆/Ar and CF₄/O₂


ECR etch; CH₄/H₂/Ar; InGaAsP; Application: quantum well etch dimensions

ECR etch; BCl₃/Ar; GaN; Application: quantum well etch dimensions


ECR plasma; Study: SiO₂ mask etch on GaAs and InP; SF₆ gives superior SiO₂ sidewall smoothness than CF₄


AlGaAs etch inhibition by oxygen implantation

Br₂/methanol (1%); Application: InP substrate cleaning for LPE
Indium metal in situ etch surface cleaning prior to LPE layer growth
KOH:K₃Fe(CN)₆:H₂O (6 g:4 g:50 ml); Application: InGaAsP/InP cleaved cross-section layer delineation; ~5 s at 20°C


NH₄OH:H₂O₂ (1:30); Application: selective removal of GaAs from AlGaAs etch stop layer for micromachining; undercutting etch rate is 2 μm/min; non-uniform etching after 5 min
NH₄OH:H₂O₂ (1:50); Application: selective removal of GaAs from AlGaAs etch stop layer for micromachining; undercutting etch rate is 1 μm/min; non-uniform etching after 5 min
(Succinic acid:NH₄OH):H₂O₂ (15:1); Application: selective removal of GaAs from AlGaAs etch stop layer for micromachining; very slow lateral etch rate. citric acid:H₂O₂ (5:1); Application: selective removal of GaAs from AlGaAs etch stop layer for micromachining; undercutting etch rate is 0.09 μm/min; excellent uniformity and reproducibility
H₂SO₄:H₂O₂:H₂O (1:8:1); Application: anisotropic GaAs etch for forming micromachined triangular cross-section structures; depth etch rate is 7 μm/min; undercutting etch rate is 4 μm/min
H₂SO₄:H₂O₂:H₂O (1:8:0); Application: anisotropic GaAs etch for forming micromachined triangular cross-section structures; depth etch rate is 10 μm/min; undercutting etch rate is 6 μm/min
H₃PO₄:H₂O₂:H₂O (1:13.8:13.2) at 0°C; Application: anisotropic GaAs etch for forming micromachined triangular cross-section structures; depth etch rate is 1 μm/min; undercutting etch rate is 0.25 μm/min; etch becomes isotropic with increasing temperature
NH₄OH:H₂O₂:H₂O (20:7:973); Application: anisotropic GaAs etch for forming micromachined triangular cross-section structures; depth etch rate is 0.5 μm/min; undercutting etch rate is 0.15 μm/min
NH₄OH:H₂O₂:H₂O (20:7:73); Application: anisotropic GaAs etch for forming micromachined triangular cross-section structures; depth etch rate is 0.6 μm/min; undercutting etch rate is 0.6 μm/min

AgNO₃:HF:HNO₃:H₂O (40 mg:16 ml:24 ml:32 ml) {RC etch}; GaAs (1 1 1) dislocation etch pit delineation. Added AgNO₃ reveals etch pits on both (1 1 1)A and (1 1 1)B

NaOCl:H₂O (1:20); GaAs chemi-mechanical polishing solution

Thermal oxidation of GaAs; effects of temperature and doping; studied with Raman scattering, AES, and ellipsometry

ECR plasma etch; CCl2F2/He; Application: GaAs quantum dot fabrication with metal mask

ECR plasma etch; CF4; Application: silicon nitride layer etch

ECR plasma; O2; Application: photoresist removal from GaAs


KOH (40%) at 60°C and ethylenediamine-pyrocatechol: Application: Si selective etch from B-doped > 1 x 10^20 cm^-3 Si layers

HF:H2O (1:50); Si3N4 removal

NH4OH:H2O2 Si surface cleaning


Reactive Ion Etch; SiCl4 gas; Application: patterned etch with Si3N4 mask on GaAs, AlGaAs, AlAs; vertical sidewalls


H2SO4 (0.25 M); oxide-free interface for STM surface imaging

HNO3 InP oxidation; 200 Å under illumination; then: HF oxide dissolution


Reactive ion etch; CH4 + H2; Application: InGaAs/InP MQW rib waveguide; 10 vol.% CH4 in H2 plasma at RF power of 100 W (0.44 W/cm^2) at 13.56 MHz; 30°C table temperature, 6–7 sccm CH4 and 60 sccm H2, 37 mTorr chamber pressure and 290 V bias voltage


Anodization; H2O2 electrolyte; Application: GaAs anodize-strip thinning of layers for FETs


Br2 assisted Ar ion beam etch; smooth, vertical sidewalls in GaAs and InP


AgNO3:CrO3:HF:H2O (40 mg:5 g:8 ml:10 ml) {A–B etch}; Application: InP layer delineation

- RIE multichamber to provide sequential etch steps without crosscontamination; InGaAsP laser arrays
- RIE pattern etch with SiN$_x$ mask; CH$_4$/H$_2$/Ar; InGaAsP laser arrays
- HCl:H$_3$PO$_4$ (1:8); selective removal of InP from InGaAsP in laser array process


- Review: projection lithography using excimer laser; includes photochemical etching


- KOH (0.5 M); electrolyte for photoinduced electrochemical smoothing-etch for GaN surfaces


- H$_2$ atomic beam cleaning of GaAs in situ for MBE


- HNO$_3$:H$_2$O (1:20); GaAs and AlGaAs photoetch with AlAs stop layer; hole confinement to the GaAs buried layer results in its lateral etching


- HNO$_3$:H$_2$O (1:20); GaAs photoetching p–n junction delineation; dopant selective: n-etching under illumination; p-type does not etch; no GaAs dark etching
- H$_2$SO$_4$:H$_2$O$_2$:H$_2$O; GaAs; discussion of reaction chemistry
- HF:H$_2$O (1:10); GaAs and InP photoetch p–n junction delineation; dopant selective; n-etches under illumination; p-type does not etch
- HNO$_3$:HCl:H$_2$O (1:1:100); InP photoetch p–n junction delineation


- ECR etch; Ar/Cl$_2$ of InP via holes; dependence on wafer temperature


- CAIBE; Cl$_2$ and BCl$_3$ with Ar ion beam; Application: laser mirrors in In$_{0.35}$Ga$_{0.65}$As/GaAs
CAIBE; mirror fabrication in InGaAs/GaAs/AlGaAs lasers; Cl₂/BCl₃/Ar at 60°C
CAIBE; mirror fabrication in InGaAs/InP lasers; IBr₃/Ar at 5°C

Angled reactive ion etch; Cl₂:Ar; InGaAsP/InP; Application: heterostructure laser diode; TiO₂ mask

Reactive ion etch; Cl₂:Ar; Application: InGaAsP/InP etched mirror laser

Reactive ion etch; Cl₂:Ar; Application: InGaAsP/InP for 1.3 μm laser; TiO₂ mask; 55° tilted sample resulted perpendicular etched walls to junction plane; 50° tilted sample in Cl₂:Ar

Angled reactive ion etch; Cl₂ + Ar; Application: InGaAsP/InP 1.3 μm laser diode
Cl₂–Ar gas mixture (4 sscm Cl₂, 1 sccm Ar at 0.45 Pa and power of 0.16 W/cm²); the ‘windward’ site is perpendicular at 40° tilted substrate; etch rate is maximum at 10° tilted sample; TiO₂ mask is used

Reactive ion etch; Cl₂ + Ar; Application: 1.3 μm InGaAsP/InP laser array with microcoated reflector, this etch gives one perpendicular facet and another 60° inclined to the plane; the steep facet is used as mirror and the 60° inclined facet is used as reflector; smooth surface is achieved

Saturated Br₂ water:H₃PO₄:H₂O (2:1:15); InP etch rate = 56 Å/s at 22°C; InGaAs etch rate = 43 Å/s
Saturated Br₂ water:HCl:H₂O (10:1:20); gives etch rate dependence on acid concentration

KOH:K₃Fe(CN)₆:H₂O; Application: InGaAsP/InP cleaved cross-section layer delineation
HCl:H₂O (4:1); InP SiO₂ masked channel etch on InGaAs etch stop layer
H₂SO₄:H₂O₂:H₂O (1:8:1); InP 1 min substrate cleaning followed by 3 min Br₂/methanol (0.6%)

HCl:CH₃COOH:H₂O₂ (1:1:1) {KKI etch}; Application: InGaAsP/InP non-selective mesa etch at 25°C


Tartaric acid (3%):propylene glycol (1:3), pH = 7.2 adjusted with NaOH; anodization; Application: InP for InGaAsP/InP stripe laser


Anodization; InP; Application: antireflective coating on InGaAsP/InP photodiodes


citric acid (1 mol l⁻¹): thiourea (1/3 mol l⁻¹): isopropanol; electrolyte for anodic passivation of GaSb


Br₂/methanol (0.1–1%); and H₂SO₄:H₂O₂:H₂O (2:1:1); GaAs and InP etch procedures to obtain the best morphologies. HF:ethanol (1:9); deoxidization post etch solution


Reactive ion etch of via holes in GaAs using Cl₂/SiCl₄


Review: chemical etching principles: dissolution of ionic crystals; dissolution of semiconductors; etch pit formation; electrochemical etching; photoetching; gas phase etching


Bi(NO₃)₃:H₂O₂:HCl (0.38 g (Bi(NO₃)₂5H₂O) in 15 ml H₂O₂ mixed with conc. HCl in the ratio 3:1); subsurface defect delineation on polished GaAs
Br₂/methanol; Application: InP substrate cleaning for LPE
H₂SO₄:H₂O₂:H₂O (10:1:1); InGaAs selective etch from InP

Thermal degradation of InP; correlation of thermal pits to crystal defects; enhancement of dark defects in the crystal volume

HF:H₂O (10 wt.%); selective etch of AlAs layer from GaAs for lift-off separation. HF:H₂O (10 wt.%) with a surfactant and antifoaming agent (Morita Chemicals, Ltd.); selective etch of AlAs layer from GaAs for lift-off separation; increase of rate with temperature
Apiezon W black wax etch mask

HCl:H₂O (3:1); Study: In₀.₅₂Al₀.₄₈As selective etch from In₀.₅₅Ga₀.₄₇As; etch rate = 108 Å/s; InGaAs etch rate < 200 Å/h; more dilute solutions will not etch InAlAs; (InGa)₀.₈Al₀.₂As exhibits no etch rate; (InGa)₀.₆₆Al₀.₃₄As etch rate = 18.3 Å/s

GaP defect delineation using:
H₂O:AgNO₃:CrO₃:HF (10 ml:40 mg:5 g:8 ml); 15–60 min at 75°C; {A–B etch}
H₂O:AgNO₃:HNO₃:HF (8 ml:10 mg:6 ml:4 ml); 1–3 min at 60°C; {RC etch}
H₂O:KOH:K₃Fe(CN)₆ (50 ml:6 g:4 g); 1–2 min at 100°C; etch rate = 20–25 μm/h
H₂O:HCl:HNO₃: (10 ml:10 ml:5 ml); at 50°C; etch rate = 2–5 μm/min
The higher temperatures and changes in compositions are necessary to retard precipitates which accumulate on the etched surface

NaClO:(CH₃CO)₂O:KOH:H₂O; solution for mechano-chemical polishing of AlGaAs (1 1 1)A flat surfaces

H₂SO₄:H₂O₂:H₂O (4:1:1); Application: InP substrate cleaning for LPE followed by surface treatment in:
Br₂:HBr:H₂O (1:17:300); etch rate = 0.8 μm/min for 2–4 min
(NH₄)₂S \( (3.5 \text{ ml suprasaturatd solution; Ref. (Iyer, R., 1991): 45 ml } \text{H}_2\text{O}) \); InP passivation; 15 min at 50°C under illumination of a 250 W tungsten lamp; reduction in dark current of MSM photodetectors; good stability

CAIBE; Cl₂/Ar; Application: Patterned hole etch in InGaAs/InGaAsP QWs

Reactive ion etch; CH₄/H₂/CO₂; Application: InP waveguide and mirror facet etch

HCl:CH₃COOH:H₂O₂ (1:1:1) \{KKI etch\}; Application: InP; SiO₂-masked recess etch at 12°C for selective LPE growth of InGaAs; shows profiles; etch rate ~3000 Å/min

HBr:CH₃COOH:K₂Cr₂O₇; Application: InP and InGaAs etch with patterned Ti mask for quantum wires
HF (1%); Ti mask removal from InP

Study: Si (1 0 0) dislocation etch pit delineation etches:
HF:CrO₃ (5 M) (1:1) \{Sirtl etch\}; Si non-linear etch rate ~3.5 μm/min
HF:K₂Cr₂O₇ (0.15 M) \{Secco etch\}; Si etch rate = 1.5 μm/min with ultrasonic agitation
HF:CrO₃ (0.15 M) \{Alternate Secco etch\}; Si etch rate ~1 μm/min with ultrasonic agitation
HF:HNO₃:CH₃COOH (1:3:1) \{Dash etch\}; Si non-linear etch rate ~0.1 μm/min, n-substrate with illumination
HF:HNO₃ (155:1) \{Schimmel etch\}; Si non-linear etch rate ~1.8 μm/min, n-substrate with illumination

HCl (37%):CH₃COOH(99.8%):H₂O (31:62:7); mesa etchant for AlGaInP/GaAs LED structures; 2.2 μm/min; gives etch rate dependence on etchant composition
Reactive ion etch; CH$_4$/H$_2$; Application InGaAsP/InP heterostructures

HBr:CH$_3$COOH (1:1); Application: InGaAs/InP quantum dot patterning; at 5°C for 3 s
H$_2$O$_2$ (30%) buffered with NH$_4$OH to pH = 7.0; GaAs etch rate = 740 Å/min; In$_{0.18}$Ga$_{0.82}$As etch rate = 67 Å/min

Anodization; InP with tartaric acid (3%):propylene glycol (1:3) electrolyte
H$_3$PO$_4$ (10%); InP etch rate = 0.27 µm/min with no mask undercutting
H$_2$SO$_4$ (10%); InP etch rate ~ 8 µm/min; undercutting
HCl (10%); InP etch rate = ~ 40 µm/min; undercutting
HF:NH$_4$F (45:500) {buffered HF}; InP etch rate + 0.04 µm/min with no mask undercutting

Reactive ion etch; SiCl$_2$/Cl$_2$ at 240°C; Application: InP/InGaAsP waveguides and mirrors

citric acid:H$_2$O$_2$ (100:1); study of oxidation/dissolution etch mechanism and selectivity of GaAs and AlGaAs
NH$_4$OH:H$_2$O (1:5); initial oxide removal from GaAs prior to etching

Reactive ion etch; O$_2$/CH$_4$/H$_2$/Ar; InP, use of O$_2$ to prevent etch limiting polymer build-up in 10 µm deep laser mirror fabrication

reactive ion etching; CH$_4$/H$_2$/O$_2$/Ar; InP-based materials; 10 µm vertical etch profiles

Reactive ion etch; CH$_4$/H$_2$/Ar; InGaAs selective etch from InAlAs
Reactie ion etch surface damage assessment; InAlAs/InGaAs HEMTs

HF buffered; Ti mask removal from vee-groove patterned InP
HF (5%) for 10 s followed by H2SO4 (80%) for 60 s to clean InP vee-grooved surface prior to MOVPE regrowth without affecting vee-groove shape

H3PO4:H2O2:H2O (1:1:20); Application: InGaAs selective etch from InP for MISFET gate recess

AsBr3 thermochemical in situ etching for molecular beam epitaxy; temperature dependent etch rate selectivity for InAs from GaAs and GaAs from AlGaAs; vee-groove pattern dependence on material and temperature

NH4:H2O2:H2O (1:10:10); selective patterning of a GaAs mask on AlGaAs
HF conc.; selective undercut pattern in AlGaAs masked by GaAs

H2O2; H2O2:NH4OH, pH = 7; and H2O; Application: GaAs surface oxidation for study of effects on laser degradation

GaAs anodization in:
H3PO4:H2O, (acidic electrolyte)
NH4OH:H2O, (basic electrolyte)
(NH4)2HPO4:H2O, (neutral electrolyte)

HF:HNO3:H2O; Silicon etch kinetics; dependence on concentrations
Se passivation of GaAs surfaces

HCl:H₂O (3:1); selective removal of In₀.₅₂Ga₀.₄₈As from In₀.₅₃Ga₀.₄₇As for MEMS

Reactive ion etch; CCl₂F₂; study of the role of AlF₃ as etch stop in selective removal of GaAs from AlGaAs

HNO₃:CH₃COOH:HF (3:2:2); Si wafer chemical polish prior to etch pit study
HF:K₂Cr₂O₇ (0.15 M) (2:1) {Secco etch}; Study: Si dislocation etch pit delineation; etch rate = 1.5 μm/min

RIBE/ECR etch; CH₄/H₂/N₂; InP, Raman study of etch damage

ECR etch; CH₄/H₂/N₂; InSb damage study using Resonant Raman scattering

Thermochemical and photochemical etching; GaAs in HCl and Cl₂; study of etching mechanisms

(NH₄)₂Sₓ solution; study of AlGaAs and InGaP surface passivation

KOH molten at 450°C; GaAs defect etch pit delineation

Br₂/methanol (0.5%); InAs (1 1 1)B etch rate = 1 μm/min
HF:HNO₃:H₂O (1:3:2); InAs p–n junction delineation; 1–3 min
HNO₃:H₂O₂ (1:5); InAs cleaning; 1–2 min at 75°C


GaAs etching anisotropy and cross-sectional profiles for:
H₂SO₄:H₂O₂:H₂O (1:8:1)
H₂SO₄:H₂O₂:H₂O (1:8:40)
H₂SO₄:H₂O₂:H₂O (1:8:80)
H₂SO₄:H₂O₂:H₂O (1:8:160)
H₂SO₄:H₂O₂:H₂O (1:8:1000)
H₂SO₄:H₂O₂:H₂O (4:1:5)
H₂SO₄:H₂O₂:H₂O (8:1:1)
H₂SO₄:H₂O₂:H₂O (3:1:1)
HCl:H₂O₂:H₂O (1:1:9)
HCl:H₂O₂:H₂O (1:4:40)
HCl:H₂O₂:H₂O (40:4:1)
HCl:H₂O₂:H₂O (80:4:1)


H₂O; GaAs photowash surface passivation; reduces surface state density


H₃PO₄(85%); AlN etch rate at 60°C is dependent on layer quality


Inductively coupled plasma etch of GaN using Cl₂/Ar and Cl₂/N₂ gases


Laser-assisted Cl₂ etch; GaAs low temperature etch from physisorbed Cl₂


Photochemical removal of layers from surface adsorbed Cl₂; low temperature (140 K) enhances photo selectivity


Light controlled anodization; Application: GaAs anodize-strip thinning for MESFETs

Neutral charge fast atom etching of GaAs


Thermochemical etch of AlGaAs/GaAs in HCl with H₂ at 710°C; Application: for OMVPE regrowth


Measurement of GaAs residual surface oxide:
- etchant A = H₂SO₄:H₂O₂:H₂O (4:1:1)
- etchant B = HF conc.; etchant C = NaOH:H₂O₂ (1:1)

<table>
<thead>
<tr>
<th>Surface characteristics</th>
<th>Residual oxide (Å)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A at 50°C for 3 min</td>
<td>50</td>
</tr>
<tr>
<td>A + B for 5 min</td>
<td>30</td>
</tr>
<tr>
<td>A + B + C at 30°C for 1 min</td>
<td>&lt;10</td>
</tr>
<tr>
<td>C at 55°C for 10 min</td>
<td>60</td>
</tr>
<tr>
<td>C + B</td>
<td>25</td>
</tr>
<tr>
<td>C + B + C at 30°C for 1 min</td>
<td>10</td>
</tr>
</tbody>
</table>


InGaAs anodization; electrolyte is tartaric acid (3%) with pH adjusted to 7 by adding NH₄OH.
H₂O₂:NH₄OH (10:1); InGaAs surface cleaning prior to anodization


H₂O:AgNO₃:CrO₃:HF (10 ml:40 mg:5 g:8 ml) {A–B etch}; InGaAsP LPE layer defect delineation; 25 min at 65°C


(NH₄)₂S₉ sulfidation of GaAs for contact metalization


KOH molten (360°C); etch pit delineation in GaN layers; SEM and TEM observations
ECR etch; Cl$_2$/H$_2$/CH$_4$/Ar at 170°C; GaN, InN, AlN

ECR etch; Cl$_2$/H$_2$/Ar/CH$_4$; etch study on AlN, InN, InGaN, InAlN

ECR plasma etch; Ar, Ar/Cl$_2$, Ar/Cl$_2$/H$_2$ and Ar/Cl$_2$/H$_2$/CH$_4$; Study of etch dependence on temperature for InP, GaP, and GaAs

RIE (Cl$_2$/BCl$_3$/SiCl$_4$) and ECR (Cl$_2$/BCl$_3$) high rate plasma etch of via holes in GaAs

Reactive ion etch; SiCl$_4$, BCl$_3$, BCl$_3$/Cl$_2$, Cl$_2$; GaAs etch damage study

ECR and RIE etch of refractory metal contacts on GaAs; induced damage

ECR etch, Cl$_2$/Ar, BCl$_3$/Ar, Cl$_2$/BCl$_3$/Ar, and SiCl$_4$/Ar; GaAs, study of damage to p–n junction diodes

Inductively coupled plasma etching of GaAs, GaP, InP in Cl$_2$/Ar, Cl$_2$/N$_2$, BCl$_3$/Ar, and BCl$_3$/N$_2$; comparison to ECR etch rates

ICP etch of GaN in Cl$_2$/H$_2$/Ar


H2S gas sulfidization of GaAs
H2SO4:H2O2:H2O (1:8:500); GaAs etched surface contains elemental As
NaS solution GaAs sulfidization
(NH4)2S solution GaAs sulfidization


(NH4)2Sx solution; GaAs surface treatment to reduce carbon and oxide contamination prior to CBE regrowth, 40°C for 30 min
HCl:H2O (1:1); GaAs deoxidation, 1 min


(NH4)2Sx sulfur passivation of GaAs structures; study of dependence on S concentration in the solution


H3PO4:H2O2:H2O (1:1:38); Application: InGaAs slow thinning etch


Thermochemical etch mechanism study of Cl2 on GaAs (0 0 1) surfaces


A–B etch; Application: GaAs epilayer p–n junction delineation
H2SO4:H2O2:H2O (8:1:100); GaAs thinning etch

HF:H₂O (1:1); InP substrate cleaning; low C and O contamination. Auger analysis comparing:
Br₂/methanol
H₂SO₄:H₂O₂:H₂O (5:1:1)
CH₃COOH:H₂O₂ (3:1)

Ion-beam etching; Cl₂ assisted; AlGaAs; H⁺ enhances etch rate and roughness

Radical-beam ion-beam etch (separate control of Cl* and H* radicals and physical Ar⁺ ions);
Study; AlGaAs dry etching characteristics; etch rates; surface morphologies

Reactive ion etch; SiCl₄ + CF₄ + O₂ + He; GaAs selective etch from Al₀.₁₁Ga₀.₈₉As

HCl:H₂O (1:1); GaN surface cleaning; good removal of O and C
HCl:methanol (1:1); GaN surface cleaning; good removal of O and C
HF:H₂O (1:20); GaN surface cleaning; good removal of O and C
HF:H₂O (1:1); GaN surface cleaning; good removal of O and C
HF:methanol (1:1); GaN surface cleaning; best removal of O and C
Thermal desorption of GaN in vacuum; not effective for removing O and C; GaN decomposition occurs >800–900°C

Plasma etching characteristics:
HF, C₂F₆, CF₃Cl, CHF₃, C₂Cl₄, CBrCl₂, CHCl₃, PH₃, H₂, H₂O; these do not etch GaAs or its oxide
CCl₄, CCl₂F₂, PCl₃, HCl etch both GaAs and its oxide
Cl₂, COCl₂ etch GaAs but not its oxide
Cl₂ etches GaP and GaSb but not their oxides
HCl etches GaP and GaSb and their oxides but not InP

Plasma etch; CCl₄; HCl; InP and GaAs; HCl/graphite electrode exhibits constant etch rate; O₂ or Cl₂ presence in CCl₄ enhanced etch rate; HCl plasma is less effective than CCl₄ in etching InP;
CCl₄ and graphite electrodes should be used as less polychlorocarbon is produced and etch rate is increased.

KOH (11 M); selective etch of Si mask on GaAs from STM direct write oxidized Si pattern; 2 s at 60°C. Does not attack GaAs
HF 10%; second step (after KOH) to remove Si mask from GaAs
NH₄OH:H₂O₂:H₂O (1:2:1 by weight), diluted 1:100 by H₂O; GaAs pattern etch through Si mask

citric acid:H₂O₂ (x:1, for 1 < x < 10); study of GaAs and Al₀.₃Ga₀.₇As etched surface interface layers and roughness by variable angle spectroscopic ellipsometry

ECR etch; CH₄/H₂/Ar of GaAs and AlGaAs; study of surface damage with spectroscopic ellipsometry

sulfidization of GaAs(1 1 0) by gas phase polysulfide treatment; study of surface stabilization by S

SOLTZ, D., and L. Cescato, “Potential-induced changes in the surface morphology of (1 0 0) n-InP samples photoelectrochemically etched,” J. Electrochem. Soc., 143(9), 2815 (1996a)
HCl (1 M); photoelectrochemical etch study of InP; etch anisotropy dependence on etch conditions

HCl (1 M); monitoring of grating depth during photolithographic etching on n-InP

Etch thickness monitoring by use of ECV profiling with spaced marker layers

HCl:H₃PO₄ (1:3); Application: InGaP selective etch from GaAs; HBT fabrication

H2SO4:H2O2:H2O (4:1:1); GaAs(100), AFM surface study shows undulations
HCl (36%); GaAs 10–20 min etch shows monolayer flat surface; 10 s H2O rinse dissolves oxides leaving an As-rich surface


HBr(46%):H3PO4(85%):K2Cr2O7 (1N) (2:2:1); Application: etching of beveled surfaces on InGaAsP/InP structures to allow characterization of small angle cross-sections; etchant flow method to form the bevel


H3PO4:H2O2:H2O (7:3:3)
H3PO4:H2O2:H2O (3:1:6)
H3PO4:H2O2:H2O (3:1:10)
H3PO4:H2O2:H2O (3:1:50)
Chemical beveling of GaAs by lifting a sample through a constant flow of etchant


HNO3:H2O2 (1:1); InP {1 1 0} defect delineation etch at 100°C; etch rate ~2.5 μm/min
K3Fe(CN)6:H2O (15 g:100 ml) = part 1, and
KOH:H2O (15 g:100 ml) = part 2:
part 1:part 2 (3:1); InP etch pit defect delineation under illumination for 10 min, etch rate ~0.14 μm/min for both {1 1 0} and {1 1 0}


Br2/methanol 1 vol.%; InGaAs (1 0 0), MBE-grown, etch rate = 6 μm/min
InAlAs (1 0 0) etch rate = 8 μm/min
H2SO4:H2O2:H2O (3:1:1); InGaAs etch rate = 2.5 μm/min; InAlAs etch rate = 3 μm/min
H2SO4:H2O2:H2O (5:1:1); InGaAs etch rate = 1.9 μm/min; InAlAs etch rate = 2.5 μm/min
H2SO4:H2O2:H2O (8:1:1); InGaAs etch rate = 1.2 μm/min; {selective from InP}
H3PO4:H2O2 (2:1); InGaAs etch rate = 3.3 μm/min; InAlAs etch rate = 3 μm/min
H3PO4:H2O2 (5:1); InGaAs etch rate = 2.4 μm/min; InAlAs etch rate = 1.5 μm/min
H3PO4:H2O2 (10:1); InGaAs etch rate = 0.7 μm/min; InAlAs etch rate = 0.5 μm/min
H3PO4:H2O2:H2O (1:8:1); InGaAs etch rate = 1.6 μm/min; InAlAs etch rate = 1.5 μm/min
H3PO4:H2O2:H2O (1:8:40); InGaAs etch rate = 0.4 μm/min; InAlAs etch rate = 0.6 μm/min
H3PO4:H2O2:H2O (1:8:60); InGaAs etch rate = 0.2 μm/min; InAlAs etch rate = 0.16 μm/min
Gives InGaAs (1 0 0) etch rate dependence on orientation; shows etch profiles: For InGaAs only Br2/methanol forms positive angle sidewalls on both ⟨1 1 0⟩ directions, giving good morphology
and mesa shapes; same for InAlAs except also H$_3$PO$_4$:H$_2$O$_2$ (10:1) does not exhibit sidewall crystal habits

Reactive ion etch, CH$_4$/H$_2$/Ar; depth monitoring of quantum well thicknesses of ~5 nm in InGaAsP/InP

H$_2$SO$_4$:H$_2$O$_2$:H$_2$O; GaAs surface cleaning for electrical contacts inferior to low energy Ar ion beam cleaning
Ar ion beam etch; GaAs surface cleaning for low resistance contacts

Ga focused ion beam micromilling of GaN; rates up to 0.6 μm$^3$/nA s; rates two to five times lower for substrates (sapphire, SiC and Si)

HNO$_3$:HF:CH$_3$COOH (6:2:1); GaSb polycrystalline material cleaning prior to Czochralski growth
KOH:H$_2$O (45% solution); GaSb first step prior to defect etching; 2 min under continuous stirring at room temperature
CH$_3$COOH:HNO$_3$:HF (20:9:1); GaSb $\{111\}$ first step etch pit defect delineation for 1 min, followed by:
Br$_2$/methanol (5%) for 11 min

Reactive ion etch; SiCl$_4$, SiCl$_4$/Ar; InP and GaAs (1 0 0)

H$_2$SO$_4$:H$_2$O$_2$:H$_2$O (1:1:50); Application: InGaAs, removal of sputter damage following oxide removal

STEWART, T.R., and D.P. Bour, “Chemical Etching of (AlGa)$_{0.5}$In$_{0.5}$P Using Sulfuric and Hydrochloric Acids,” J. Electrochem. Soc., 139, 1217 (1992)
Compositional selectivity:
\[
\begin{array}{|c|c|c|c|c|}
\hline
x \text{ in } (\text{Al}_x\text{Ga}_{1-x})_{0.5}\text{In}_{0.5}\text{P} \text{ undoped (Å/s)} & 0 & 0.4 & 0.7 & 1 \\
\hline
\text{H}_2\text{SO}_4 (60^\circ\text{C}) & 2.5 & 29 & 97 & 217 \\
\text{H}_2\text{SO}_4 (70^\circ\text{C}) & 6.3 & 53 & 171 & 373 \\
\text{HCl} : \text{H}_2\text{O} (1:1) (25^\circ\text{C}) & 2.9 & 102 & 383 & 478 \\
\hline
\end{array}
\]

\[(\text{AlGa})_{0.5}\text{In}_{0.5}\text{P} \text{ dopant selectivity}
\]

\[
\begin{array}{|c|c|c|}
\hline
\text{n} = 1 \times 10^{18} \text{ (Å/s)} & \text{Undoped (Å/s)} & \text{p} = 5 \times 10^{17} \text{ (Å/s)} \\
\hline
\text{H}_2\text{SO}_4 (60^\circ\text{C}) & 148 & 97 & 7.0 \\
\text{H}_2\text{SO}_4 (70^\circ\text{C}) & 181 & 171 & 163 \\
\text{HCl} : \text{H}_2\text{O} (1:1) (25^\circ\text{C}) & 483 & 383 & 0.6 \\
\hline
\end{array}
\]


A–B etch; GaAs dislocation etch pit delineation study


H\text{SO}_4: \text{H}_2\text{O}_2: \text{H}_2\text{O} (3:1:1); GaAs removal of polish damages; 15 min at 45^\circ\text{C}

A–B etch; GaAs dislocation etch pit delineation

KOH molten at 300^\circ\text{C}; GaAs dislocation etch pit delineation


KOH molten at 400^\circ\text{C}; GaAs (1 0 0) 10 min for defect etch pit delineation

A–B etch; GaAs (1 0 0) 5 min at room temperature for defect etch pit delineation


Review of GaAs etchant types, defect types, and defect revealing etchants


KOH electrolyte; photochemical etching of Ti-masked patterns in GaN; reduction of surface roughness


KOH (molten); transverse (i.e., sidewall) etch for GaN; no etch in the (0 0 0 1) direction

KOH (30%) in ethylene glycol; transverse (i.e., sidewall) etch for GaN; no etch in the (0 0 0 1) direction

H\text{PO}_4; transverse (i.e., sidewall) etch for GaN; no etch in the (0 0 0 1) direction
TEAH (tetraethylammonium hydroxide) (40%):H₂O; transverse (i.e., sidewall) etch for GaN; no etch in the (0 0 0 1) direction

Br₂/methanol (1%); Application: InGaAs mesa photodiode etch, shows high dark current compared to peroxide etch
H₂SO₄:H₂O₂:H₂O (1:1:x) (10 < x < 500); InGaAs mesa photodiode etch; low dark current; InGaAs surface behavior depends on solution pH
H₂SO₄:H₂O₂:H₂O (1:1:50); InGaAs etch rate = 2200 Å/min

Thermochemical vapor etch; CCl₄ in MOCVD reactor; GaAs and InAs etch rates from 500 to 650°C; InAs > GaAs

H₂PO₄:HCl (1:1); Application: InP selective etch from InGaAsP
H₂SO₄:H₂O₂:H₂O (2:3:2); InGaAsP selective etch from InP

KMnO₄:acetone (1:25); anodization electrolyte for GaAs and GaAs₀.₆P₀.₄

ECR etch; Ar; AlGaAs; surface damage study; p-type more susceptible to damage than n-type

A–B etch; Application: GaAsP dislocation etch pit delineation

Br₂/methanol; p-type GaP; etch mechanism study

Br₂/methanol; n- and p-type GaP; etch mechanism study

HCl; InP (1 0 0) orientation determination identification of [1 1 0] and [1 1 0] directions


Thermochemical etch; Cl₂; GaAs; identification of the reaction products over the temperature range 330–950 K


HCl:H₂O (4:1); Application: InP (1 0 0) orientation determination; ⟨1 1 0⟩ versus ⟨1 1 0⟩


H₂SO₄:H₂O₂:H₂O (4:1:1); Application:

AlGaAs/GaAs mesa etch
HCl:H₂O₂:H₂O (1:4:40); Application: AlGaAs/GaAs cross section stain, 5 s
NH₄OH:H₂O₂ (pH 7.6); Application: GaAs selective substrate removal
Vapor oxidation of AlGaAs at 425°C with H₂O in N₂


Reactive ion etch; C₂H₆/H₂; Study: InP SiO₂ masked 240 nm period grating etch; shows profiles


Reactive ion etch; C₂H₆/H₂/O₂ mesa etch for InGaAsP/InP; suppressed side etching for laser diode mesa fabrication


Electron beam-induced Cl₂ etch; GaAs; oxidized surface is resistive to etching, whereas irradiated region etches easily for maskless patterning


Study of surface damage to InGaAs during Ar plasma exposure; suppression of damage in phosphine plasma
(NH₄)₂Sₓ-treated InP; study of surface S atoms; most S atoms on InP(0 0 1) form In–S–In bridge bonds in the first layer

Br₂/methanol; GaAs polishing

SeS₂ solution passivation of GaAs surfaces; study of bonding and electrical properties

KOH:K₃Fe(CN)₆:H₂O (6 g:4 g:50 ml); Application: InP cleaved cross-section layer delineation; ~5 min at 20°C
Br₂/methanol; InP substrate cleaning
HF:H₂O₂:H₂O (1:1:10); InGaAs/InP interface delineation
HF:HBr (5:1); InP dislocation etch pit delineation
NH₄OH:H₂O₂:H₂O; InGaAs dislocation etch pit delineation
H₂SO₄:H₂O₂:H₂O (3:1:1); InGaAs selective etch from InP

A–B etch:HF (1:3); Application: InGaAs dislocation etch pit delineation for 10 s at 60°C; HF slows the etch rate
HBr:HF (1:5); InP dislocation etch pit delineation for 5 min at 20°C. H₂SO₄:H₂O₂:H₂O (1:1:10); InGaAs/InP interface delineation
H₂SO₄:H₂O₂:H₂O (3:1:1); InGaAs mesa etch

H₂SO₄:H₂O₂:H₂O (3:1:1); Application: InGaAs/GaAs mesa etch

SUSA, N., Y. Yamauchi, H. Ando, and H. Kanbe, “Vapor-Phase Epitaxial Growth of InGaAs on (1 0 0) InP Substrate,” Jpn. J. Appl. Phys., 19(1), L17–L20 (1980c)
A–B etch:HF (1:3); Application: InGaAs dislocation etch pit delineation for 10 s at 60°C; HF slows the etch rate
HBr:HF (1:5); InP dislocation etch pit delineation for 5 min at 20°C
H₂SO₄:H₂O₂:H₂O (1:1:10); InGaAs/InP interface delineation
H₂SO₄:H₂O₂:H₂O (3:1:1); InGaAs mesa etch

HCl; deoxidation of GaAs surface; photoluminescence degradation caused by surface oxide


Photoelectrochemical etching of n-GaAs with H2SO4:H2O2:H2O and KOH electrolytes and n-InP with HCl:HNO3:H2O electrolyte. He–Ne laser (wavelength = 632.8 nm) at 1–10 W/cm2 current density with wet chemical solution of H2SO4 (98% conc.), H2O2 (30% conc.), HNO3 (65% conc.), HCl (36% conc.) and KOH; GaAs etch rate increases with laser power and concentration; GaAs etch rate in KOH solution is much lower compared in acid solution; GaAs etch rate increases with Ar-ion beam higher KOH conc.; lower InP etch rate is observed in acid solution; InP etch rate is decreased with increasing KOH conc.


n-InP photoetch with HeNe laser in:
- FeNH4(SO4)2:H2O (1:12)
- FeSO4(NH4)2SO4:H2O (1:6)
- FeCl3 HCl:HNO3:H2O (5:8:10)
- HCl:HNO3:H2O (5:2:10)
- HCl:HNO3:H2O (3:8:10)


Br2/methanol; Application: InGaAsP/InP laser cantilever etch for microcleaving
- K2Cr2O7:HBr:CH3COOH
- HCl:CH3COOH:H2O2 (1:2:1)
- HCl:HNO3: (1:1.2–2)
- HCl:HNO3:H2O: (1:2:1)
- HCl:HNO3:H3PO4 (1:1.2–2:1–1.5)
- HCl:HNO3:H3PO4:H2SO4 (1:1.2–2:1–1.5:0.005–0.1): Application:
  - InGaAsP/InP laser mirror etching. Wet chemical selective etch; freshly mixed
  - HCl:HNO3 etchant gives InP vertical and smooth walls; 2 step etchant
  - HCl:H3PO4 for InP and H2SO4:H2O2:H2O for InGaAs and InGaAsP and single step etchant of
    - K2Cr2O7:HBr:CH3COOH are difficult to control; InP vertical walls and flat etched bottom are
    obtained from (1:1.2) HCl:HNO3 but (1:2) ratio gives curved bottom; InP etch rate in HCl:HNO3(1:1.2) is doubled (8 μm/m) of (1:2) ratio (4 μm/m); for double heterostructures with
    - InGaAs cap, average etch rate of HCl:HNO3 (1:2) is 3 μm/m while (1:1.2) ratio etch rate is 6 μm/
m; InP etch rate in HCl:HNO3:H3PO4 (1:2:1) is 1.8 μm/m at RT; addition of H3PO4 helps the
    smoothness of etched surface; however, increasing from 1 to 1.5 parts of H3PO4 results negative
    slope; 0.2 parts of H2SO4 to HCl:HNO3:H3PO4 increases undercut for ternary and quaternary
    layers but positive slope for InP; cantilevers and bridge of double heterostructures are etched at
    room temperature in freshly mixed 1–2 vol.% of Br2–CH3OH; stirring solution results linear
    increase in depth etch with time compared with unstirring solution, etching stops at about 18 μm;
    depth etch rate depends on Br2 concentration

H$_2$SO$_4$:H$_2$O$_2$:H$_2$O (7:1:1); GaSb surface cleaning for MBE growth of GaSb layers
HCl:H$_2$O (1:1); p-GaSb surface cleaning first step, 30 s, followed by:
buffered HF:H$_2$O (1:1); p-GaSb surface cleaning, 30 s, for low resistance Au contacts


Reactive ion beam etch; Cl$_2$; GaAs and InP


Reactive ion beam etch; Cl$_2$; InP; photoluminescence study of surface damage


Reactive ion beam etch; Cl$_2$; GaAs and InP


Plasma etch; CH$_4$:H$_2$(1:5); Application: In$_{0.53}$Ga$_{0.47}$As/InP quantum well mesas
InP etch rate $\sim$InGaAs etch rate $\sim$ 750 A/min at 125 mTorr and 300 sccm (1:5)
CH$_4$:H$_2$ flowrate; 1 $\mu$m photoresist mask; during etching hydrocarbon deposit on photoresist at 50 A/m rate; horizontal etch rate is about 1/5 of vertical etch rate


ECR Plasma, O$_2$ oxidation of GaAs; Cl$_2$ etch; Study: in situ mask formation with electron beam patterning


KOH molten; GaAs defect delineation; 3 $\mu$m etch depth
AB etch; GaAs defect delineation; 10 $\mu$m etch depth; correlation of MBE layer defects to substrate etch pits


H$_2$SO$_4$:H$_2$O$_2$:H$_2$O (4:1:1); GaAs substrate cleaning for OMVPE growth; 2 min at 50°C
KOH molten at 350°C; defect delineation; for 5–10 min to reveal etch pits
Br2/methanol; Application: InGaAsP/InP non-selective etch for photodiodes

Br2/methanol; Application: InGaAsP/InP channel etch for BH laser fabrication

Thermochemical laser-induced dry etching of GaAs in SiCl4

Laser-induced thermochemical dry etch of GaAs with CCl4

Laser-induced thermochemical dry etch in Cl2; GaAs, InP, InSb and GaP

Thermochemical laser-induced dry etch of GaAs in CCl4

ECR plasma; hydrogen; surface cleaning of GaAs for MBE regrowth

Magnetron ion etch; SiCl4/Cl2 of GaAs; via hole sidewall passivation by etch residues

Laser assisted Cl2 etch of AlGaAs and GaAs. Laser desorbs non-volatile GaCl3

Cl2 photochemical etching using ArF excimer laser; selective removal of InAlAs from InGaAs
HF:H₂O₂:H₂O mixtures; GaAs; etch rate and sidewall profile dependence on etchant composition

A–B etch; Application: InP dislocation delineation; 60°C for 20–30 min; for InGaAs 3 min at 20°C
H₂SO₄:H₂O₂:H₂O (3:1:1); InGaAs selective mesa etch from InP

Br₂/methanol; Application: InP substrate cleaning for LPE
HCl:H₂O₂ (1:19); Indium cleaning for LPE
AgNO₃:HF:HNO₃:H₂O (40 mg:16 ml:24 ml:32 ml) {RC etch}; InP dislocation etch pit delineation
A–B etch; InGaAs dislocation etch pit delineation, 3 min at 20°C

KOH, molten (350°C); GaAs (1 0 0) dislocation etch pit delineation

Reactive ion etch; Br₂ + N₂; Br₂ + Ar; Application: etched facet laser of InP; etch rate = 2 μm/min; vertical walls of etched InP surface smoothness is improved with heating substrate; 4000 Å Ti is used as upper layer mask; 2000 Å Si₃N₄ is lower mask used to prevent reaction between Ti and InP; pure Br₂ caused roughness while 80% Br₂ and 20% N₂ can produce vertical walls; Br₂ + Ar can produce smoother etched surface at higher temperature; at 10°C, etch rate of Br₂ + Ar = 1.8 μm/min and at 40°C, etch rate = 2.1 μm/min

H₃PO₄:HBr (2:1) {Huber etch}; Application: InP dislocation etch pit delineation

H₃PO₄:HCl (1:1): Application: InP Si₃N₄ masked mesa etch

KMnO₄:H₂SO₄:H₂O (100 mg:10 ml:40 ml); polish etch for ZnSe; etch rate ~1 μm/min

ECR etch of InGaAsP/InP in Cl₂/H₂; surface damage study


Saturated Br₂ water:H₃PO₄:H₂O (4:15:2); Application: InGaAs submicron photolithography for quantum well dots

Citric acid:H₂O₂ (1:1); GaAs/AlGaAs/InGaAs blanket etch; AlGaAs etch rate is 1/3 that of GaAs and InGaAs


Br₂:methanol (2%); GaSb; study and modeling of diffusion limited etching


HCl:H₃PO₄ (3:1) wet chemical etchant is used for vee-groove in InP (1 0 0) in 20 s at RT at 630°C for 90 m without SiO₂ mask but does not affect on InP vee-groove with SiO₂ mask on shoulders; deformation increases with increasing ratio of H₂/(H₂ + N₂) under heat treatment; deformation saturated at H₂/(H₂ + N₂) ratio is higher than 0.1; deformation of vee-groove also happens in 1000 ppm PH₃ in H₂ but not after Ar+ ion sputtering treated surface; deformation area S ~ e (–Ea/KT) where Ea = activation energy, T = treatment temperature, k = const.; for deposition Ea = 1 eV; deformation happens in PH₃, H₂ and chemical residue


HBr gas; photochemical etch using a 172 nm excimer lamp, selective removal of InGaAs from InAlAs


Thermochemical etch; Cl₂ of GaAs; study of temperature dependence of surface composition and reconstruction


Ar+ low energy ion milling of InAs; damage study using Raman scattering

KOH molten at 350°C; GaAs defect etch pit delineation; relationship of pit density to structural defects


Br2/methanol (1 wt.%); GaAs (1 1 0) etch rate = 7.5 μm/min
GaAs (1 1 1)B etch rate = 8.5 μm/min
GaAs (1 1 1)A etch rate = 2 μm/min
GaAs (1 1 0) etch rate = 10 μm/min
H2SO4:H2O2:H2O (5:1:1); GaAs surface cleaning/polish prior to applying Al2O3 etch mask
CrO3:HF:H2O (33 w/o:46 w/o water solution) {Sirtl etch}; GaAs orientation determination from etch pit shape
H3PO4; Al2O3 mask removal etch; 4 min at 50°C
Gives etch profile orientation dependence


Thermochemical etch; CBr4; in situ MOCVD etch of GaAs and AlAs


Ar ion beam assisted Cl2 in situ etch for MBE InP; patterned by damage from a direct-write focused Ga ion beam. Focused Ga ion beam; Cl-ion beam etch; Application for in situ growth of InGaAs/InP heterostructures; 20 keV Ga ion beam causing damage which can be reduced by Cl-ions etching; etch rate for InP = 800 Å/min at 190°C with beam current density of 150 μA/cm²


HCl:H2O (3:1); InP selective etch from ~30 Å InGaAs mask layer; InP etch rate at 4°C ~300 Å/s
H2SO4:H2O2:H2O (1:1:10); InGaAs selective etch from ~30 Å InP mask layer; using direct-write lithography on the thin semiconductor mask with focused Ga ion beam
Ar ion assisted Cl2 selective etching of InP and InGaAs
High vacuum focused Ga ion beam; Application: lithography patterns on InP/InGaAs structures; exposed patterns are transferred to underlying layer by selective wet chemical etchant; HCl:H2O (3:1) attacks InP at 300 Å/s at 4°C; H2SO4:H2O2:H2O (1:1:10) selectively etch InGaAs


HCl:H3PO4 (3:1); Application: InP selective etch from InGaAsP

Photoenhanced reactive ion etch of GaN and BN using BCl$_3$/Cl$_2$/Ar/N$_2$


Reactive ion etch; CHF$_3$/H$_2$; Study: InP grating etch


H$_3$PO$_4$:HBr (2:1) {Huber etch}; InGaAsP dislocation etch pit delineation; 2 min at 25°C
HCl:HNO$_3$:H$_2$O (6:1:6); InGaAsP dislocation etch pit delineation; 90 s at 25°C
HNO$_3$:HCl:Br$_2$ (20:10:0.25) {RRE etch}; InGaAsP dislocation etch pit delineation; 10 s at 25°C
A–B etch, modified: H$_2$O:AgNO$_3$:CrO$_3$:HF (10 ml:140 mg:5 g:8 ml); InGaAsP dislocation etch pit delineation; 30 min at 75°C

THEUWIS, A., and W.P. Gomes, “Electrochemical and etching behavior of InP and In$_{0.53}$Ga$_{0.47}$As in alkaline hypobromite solutions,” J. Electrochem. Soc., 146(5), 1903 (1999a)

Br-containing alkaline electrolytes; study of electrochemical mechanism; selectivity of InGaAs over InP

THEUWIS, A., and W.P. Gomes, “A fundamental study on n- and p-In$_{0.53}$Ga$_{0.47}$As in H$_2$O$_2$ solution,” J. Electrochem. Soc., 144(4), 1390 (1997)

H$_2$SO$_4$ (1.3 mol/l); (photo)electrochemical and etching properties of n- and p-In$_{0.53}$Ga$_{0.47}$As
H$_2$SO$_4$:H$_2$O$_2$(1.3 mol/l); electrochemical and etching properties and mechanism of n- and p-In$_{0.53}$Ga$_{0.47}$As and InP; conduction band studies


H$_2$O$_2$ acidic solutions; etch and photoetch mechanism study on n- and p-InP

THEUWIS, A., and I.E. Vermeir, “On the selective etching if In$_{0.53}$Ga$_{0.47}$As and In$_{0.72}$Ga$_{0.28}$As$_{0.61}$P$_{0.39}$ versus InP in alkaline K$_3$Fe(CN)$_6$ solutions,” J. Electrochem. Soc., 146(3), 1172 (1999b)

K$_3$Fe(CN)$_6$ (0.05 M); selective removal of In$_{0.53}$Ga$_{0.47}$As and In$_{0.72}$Ga$_{0.28}$As$_{0.61}$P$_{0.39}$ from InP; selectivity ~200; electrochemical study of etch mechanism


Reactive ion etch; CH$_4$/H$_2$; Application: InGaAs/InP strip-loaded waveguides; sensitivity of optical loses to etch conditions
ECR etch; Ar plasma; InP; study of plasma temperature effects

ECR etch, optical monitoring; Cl₂/Ar; InP and GaAs

ECR etch; Cl₂/Ar of InP, GaAs and InGaAs; atomic force microscopy study of surface roughening

ECR plasma etch; Cl₂; InGaAs study of etch rates and surface damage

ECR Cl₂/Ar etch process for distributed Bragg mirrors in laser structures on InP and GaAs, using Ni mask

Anodic etching with a mechanically scanned jet of KOH (20%) electrolyte with the etching current controlled by IR transmitted intensity to achieve uniform thickness

Two step thinning: (1) p-GaAs substrate is anodically dissolved down to an n-blocking layer. (2) H₂SO₄:H₂O₂ (3:2) photoetch removes n-blocking layer from the thin p-layer

Chemically assisted ion beam etch (CAIBE); Cl₂/Ar of AlGaAs/GaAs laser mirrors; HCl conc.; removal of Cr mask from GaAs

Review of etching behavior; gives definitions:
Preferential-anisotropic etchants show markedly different etch rates on different low index crystallographic planes
Non-preferential etchants show etch rate independent of orientation
Selective etchants show markedly different etch rates for different semiconductor compositions
Non-selective etchants show etch rates independent of composition
Gives data on I$_2$:KI; AlGaAs/GaAs etchant selectivity dependence on I$_2$/KI ratio and on pH

Ce(SO$_4$)$_2$: Ce(NO$_3$)$_3$; AlGaAs selective etch from GaAs; p-type AlGaAs selective from n-type FeCl$_3$:FeCl$_2$; AlGaAs selective etch from GaAs
C$_6$H$_4$O$_2$:C$_4$H$_6$O$_2$ (quinone–hydroquinone) with NaOH or HCl to buffer the pH
GaAs selective etch from AlGaAs for pH = 10; AlGaAs selective etch from GaAs for pH = 1 KI:I$_2$ (0.3 mole/l KI + 0.04 mole/l I$_2$, with pH = 9.4); GaAs selective etch from AlGaAs; etch rate = 1 μm/min
KI:I$_2$ (0.3 mole/l KI + 0.1 mole/l I$_2$, with pH = 9); Al$_x$Ga$_{1-x}$As ($x < 0.15$) selective etch from GaAs; with pH = 11 is GaP selective etch from InGaP or AlGaAs

HNO$_3$ (10% solution); GaAs Cr-doped semi-insulating laser-induced etch

HCl:CH$_3$COOH:H$_2$O$_2$ (1:1:1) {KKI etch}; Application: InGaAsP/InP mesa etch

citric acid:H$_2$O$_2$ (1:1); InGaAs selective etch from InAlAs; selectivity 25
InGaAs etch rate 22 Å/s; InAlAs etch rate 0.89 Å/s

citric acid:H$_2$O$_2$ (10:1); Study: InAlAs selective etch from InP, selectivity > 187; InGaAs selective etch from InP, selectivity > 480. InGaAs selective from InAlAs, selectivity only 2.5. Shows etch profiles. InP etch rate at 20°C = 0.05 Å/s; InAlAs etch rate at 20°C = 10 Å/s; InGaAs etch rate at 20°C = 24 Å/s
Citic acid:H$_2$O$_2$ (1:1); InGaAs selective etch from InAlAs = 25. InGaAs etch rate at 20°C = 25 Å/s; InAlAs etch rate at 20°C = 1 Å/s

citric acid:H$_2$O$_2$ (4:1); GaAs selective etch from Al$_x$Ga$_{1-x}$As
<table>
<thead>
<tr>
<th>$x$</th>
<th>Etch rate ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.17</td>
<td>1.5</td>
</tr>
<tr>
<td>0.30</td>
<td>155</td>
</tr>
<tr>
<td>0.45</td>
<td>260</td>
</tr>
<tr>
<td>1.00</td>
<td>1450</td>
</tr>
</tbody>
</table>

Reactive ion etch; SiCl₄:SiF₄ (1:9); GaAs selective etch from AlGaAs


Ion beam etch of GaN using CO₂


H₂SO₄:H₂O₂:H₂O (5:1:1) {Caro’s etch}; Application: InP substrate cleaning first step, followed by:

Br₂/methanol (1%); Application: InP substrate cleaning second step for VPE


H₂SO₄:H₂O₂:H₂O (10:1:1); Application: InP substrate cleaning for LPE; needs careful H₂O rinse to remove S contamination


Br₂/methanol (3%); Application: via holes in InP FETs; rate ~8 μm/min


H₃PO₄:H₂O₂:H₂O (1:1:20); Application; InAlAs/InGaAs/InP mesa etch


AsCl₃ in situ MBE vapor etch; GaAs surface cleaning

PCl₃ in situ MBE vapor etch; InP pattern etching for regrowth


H₂SO₄:H₂O₂:H₂O (1:8:40); Application: GaAs (1 0 0) photolithography channel etch at 24°C; [0 1 1] and [0 1 1] cross-sectional profiles
Thermochemical vapor etch; PCl$_3$; InP in situ CBE etch

Reactive ion etch, laser enhanced; CCl$_4$ + H$_2$; GaAs

Plasma; H$_2$; InP, GaAs, InGaAs surface cleaning

H$_2$ plasma; high vacuum removal of surface contaminants form InP

Review of semiconductor etching; discusses chemical process, effect of illumination, effect of adding metal ions, and crystallographic effects. Gives tables of etchants for: Si, Ge, SiC, GaAs, GaP, GaSb, InAs, InP, InSb, ZnS, ZnSe, ZnTe, CdS, CdSe, CdTe, PbS

TUCK, B., and A.J. Baker, “Chemical Etching of (1 1 1) and (1 0 0) Surfaces of InP,” J. Mater. Sci., 8, 1559–66 (1973)
Br$_2$/methanol (1 vol.%); InP, etch rate = 3000 Å/min; (0.5 vol.%) etch rate = 2000 Å/min
0.4N FeCl$_3$ in HCl; InP (1 0 0) orientation determination from etch pit elongation

<table>
<thead>
<tr>
<th>Etch rates</th>
<th>(1 1 1)B (mg/cm$^2$/s)</th>
<th>(1 0 0) (mg/cm$^2$/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>HCl:HNO$_3$</td>
<td>0.27</td>
<td>0.08</td>
</tr>
<tr>
<td>HCl conc.</td>
<td>0.15</td>
<td>0.08</td>
</tr>
<tr>
<td>0.4N Fe$^{3+}$</td>
<td>0.03</td>
<td>0.03</td>
</tr>
<tr>
<td>Br$_2$/methanol (1%)</td>
<td>0.016</td>
<td>0.03</td>
</tr>
</tbody>
</table>

Thermochemical laser assisted dry etch of GaAs in Cl$_2$

Reactive ion etch; CCl$_2$F$_2$/Ar/O$_2$; InP and GaAs
H$_3$PO$_4$/HCl (4:1); Application: InP groove etch; gives etch rate dependence on composition; selective from InGaAsP; gives SiO$_2$ masked profiles
Br₂/methanol (0.5%); InP etch rate = 2 µm/min; gives SiO₂ masked profiles
HCl conc.; InP etch rate = ~ 12 µm/min at 25°C; gives SiO₂ masked profiles

HF:HBr (1:10); Application: InP selective etch from InGaAsP

HF:HBr (1:10); Application: InP selective etch from InGaAsP
Ar ion thinning for TEM

HCl:H₃PO₄ (5:95); InP (1 0 0) etch rate = 0.09 µm/min at 23°C
HCl:H₃PO₄ (10:90); InP (1 0 0) etch rate = 0.24 µm/min
HCl:H₃PO₄ (15:85); InP (1 0 0) etch rate = 0.40 µm/min
HCl:H₃PO₄ (20:80); InP (1 0 0) etch rate = 0.70 µm/min
HCl:H₃PO₄ (25:75); InP (1 0 0) etch rate = 1.05 µm/min
HCl:H₃PO₄ (20:80); InP (1 1 0) etch rate = 3.4 µm/min
HCl:H₃PO₄ (20:80); InP (1 1 1) etch rate = 2.6 µm/min

KOH molten at 400°C for 3–4 s; GaAs epilayer etch pit dislocation delineation

NH₄OH:H₂O₂ (1:30); selective etch of Al₀.₆Ga₀.₄As sacrificial layer for micromachining GaAs

Cl₂ assisted Ar ion beam etching; Application: vertical sidewall laser mirrors in AlGaAs/AlGaInP

NaOCl:HCl:H₂O (2:2:16); scanning jet polishing of GaP
NaOCl:HCl:H₂O (10:20:170); scanning jet polishing of GaAs

HCl:HNO₃:H₂O (2:1:2); GaP substrate etch to remove polish damage
I₂:KI:H₂O (25 g:50 g:500 ml); photolithographic pattern etch in deposited Au layer

H₃PO₄ (85%); GaP (1 1 1)B etch rate at 180°C = 15 μm/min; gives etch rate dependence on temperature, time, and orientation; gives cross-sectional profiles


H₂SO₄:H₂O₂:H₂O (3:1:1); Application: InGaAsP selective etch from InP

HCl:H₂O (4:1); InP selective etch from InGaAsP


H₂SO₄:H₂O₂:H₂O (3:1:1); Application: InGaAsP selective etch from InP

HCl:H₂O (4:1); InP selective etch from InGaAsP


Br₂/ethanol (20%), hot; GaP dislocation etch pit delineation; 30–60 s

FeCl₃:HCl:H₂O (27 g:250 ml:350 ml), boiling; GaP dislocation etch pit delineation; 12–18 min

KOH:K₃Fe(CN)₆:H₂O (6 g:4 g:50 ml) boiling; GaP dislocation etch pit delineation; 1–2 min


CrO₃:HCl:H₂O; GaAs defect delineation study; shows etch characteristics dependence on composition; gives high defect sensitivity for low HCl/CrO₃ ratios under illumination


GaAs n-type photoetching study


H₂O₂/H₂SO₄ and S₂O₈²⁻/H₂SO₄ aqueous solution electrolytes; Study: GaAs photochemical etch behavior


H₂SO₄:H₂O₂:H₂O; GaAs n-type photoetching behavior


CrO₃:HF; GaAs etch and photoetch chemical kinetics

Reactive ion etch; CH$_4$/H$_2$; AlGaAs/InGaAs/GaAs structure surface damage study. Superior smooth surfaces and etch rate controllability compared to chlorinated gases


HF (10%); GaAs epitaxial layer lift-off by selectively etching a thin Al$_{0.85}$Ga$_{0.15}$As release layer to separate from the substrate (up to 2 in. diameter)


Reactive ion etch; Cl$_2$ + CH$_4$ + H$_2$ + Ar; Application: mirror facet etch for InGaAsP/InP lasers


Ar ion surface cleaning of GaAs; damage effects on Schottky diodes


Reactive ion etch study; Cl$_2$/Ar/CH$_4$/H$_2$; InP photolithography sidewall damage


H$_2$SO$_4$:H$_2$O$_2$ (5:1); InP substrate cleaning; removal of surface contaminants and oxides prior to RIE

Reactive ion etching; Cl$_2$; InP


ECR and RIE with Cl$_2$/Ar and CH$_4$/H$_2$/Ar; rates for GaN, AlN, InN, and InGaN


ECR etch; Cl$_2$/Ar and BCl$_3$/Ar; AlGaN etch behavior


ECR etch study; IBr/Ar of GaN, InN, InAlN, AlN, and InGaN
ECR, high density plasma etch; CH₄/H₂, Cl₂H₂, HBr/H₂, HI/H₂ of GaN, InN and AlN

ECR etch; ICl/Ar of GaN, InN, InAlN, AlN, and InGaN

ICP etch; CH₄/H₂/Ar and CH₄/H₂/N₂; GaN, AlN, InN, InGaN, and InAlN

ECR plasma etch of GaN, InN, and InGaN in ICl/Ar and IBr/Ar; selective etch of GaN from InN, AlN, or InAlN

AZ400K photolithographic developer (active ingredient KOH); etch study of AlN and InAlN between 20 and 80°C

ECR plasma etching of GaN, AlN, InN, InGaN, and InAlN in Cl₂/Ar, CH₄/H₂/Ar, ICl/Ar, and IBr/Ar. Study of etchant selectivity. Cl-based etches maximize selectivity

Reactive ion beam etch, in situ optical monitoring; AlGaAs/GaAs

HF:HNO₃ (1:1); InSb polish etch, 2–5 s, following mechanical polishing to delineate dislocation etch pits

GaAs surface cleaning analysis by Auger analysis and Au layer epitaxy behavior:
H$_2$SO$_4$:H$_2$O$_2$:H$_2$O (3:1:1); NH$_4$OH:H$_2$O$_2$:H$_2$O (1:1:2); HF:HNO$_3$:H$_2$O (2:2:1)

I$_2$:KI:HCl; study of etch and photoelectrochemical etch of InP (0 0 1)

Iodic acid solutions; InP etch and photoetch chemical kinetics

VERPOORT, P.J., I.E. Vermeir, and W.P. Gomes, “Fundamental study on the selective etching of Al$_{0.25}$Ga$_{0.75}$As versus GaAs in acidic iodine solutions,” J. Electrochem. Soc., 142(10), 3589 (1995)
I$_2$:KI:H$_2$SO$_4$; study of etch and photoelectrochemical etch of Al$_{0.25}$Ga$_{0.75}$As and GaAs on etch conditions

Surface passivation; GaAs; nitridation with hyrazine

Etchant undercutting of SiO$_2$ masks on InP (1 0 0) for the following: Br$_2$ in dimethylformamide (5%), etch rate = 1.9 µm/min
HCl, etch rate = 8.2 µm/min HCl:H$_2$PO$_4$ (1:1), etch rate = 2.6 µm/min
HCl:CH$_3$COOH (1:1), etch rate = 4.0 µm/min HCl:HNO$_3$ (1:1), etch rate = 6.0 µm/min HBr, etch rate = 1.5 µm/min
HBr:H$_2$PO$_4$ (1:1), etch rate = 7.3 µm/min
HBr:CH$_3$COOH (1:1), etch rate = 0.9 µm/min
HNO$_3$:HCl:HClO$_4$:CH$_3$COOH (6:1:1:1), etch rate = 3.1 µm/min
HNO$_3$:HCl:H$_2$O:CH$_3$COOH (3:1:1:1), etch rate = 2.5 µm/min
All etchants show no undercutting in the (1 1 0)A direction and are suitable for self-limiting vee-grooves. Only the anhydrous Br$_2$ etch shows no undercutting in the (1 1 0)B direction

Modeling of resist pattern etching

Ar ion etching; Application: InP LED microlenses

Argon ion beam etching; Application: InP spherical lens formation


H₂SO₄:H₂O₂:H₂O (1:8:1); GaAs photolithography; use of undercutting of a metal layer as a fabrication step


Study of oxide formation on Br₂/methanol etched InP


NH₄OH electrochemical etch; GaAs; dislocation etch pit delineation; comparison with A–B etch and molten KOH etch


HCl:CH₃COOH:H₂O₂ (1:2:1) [KKI etch]; Application: InGaAsP groove and mesa etch


HgCl₂:dimethylformamide (100 g:100 ml); in droplet removal from LPE InP, InGaAs, InGaAsP surfaces; use ultrasonic agitation to free Hg reaction-by-product from surface. (saturated HgCl₂:DMF):NaOH (10:1) gives maximum In removal. Br/methanol; Safety

1.1. Protect against skin contact; capable of severe burns
1.2. Strong oxidizer; keep away from organic materials which can ignite; keep away from reducing agents (sodium, zinc, ammonium compounds) to avoid explosion
1.3. Spilled Br₂ or Br₂/methanol can be neutralized with 5–10% sodium thiosulfate solution


H₂SO₄:H₂O₂:H₂O (8:1:1); Application: InGaAsP selective etch from InP; HBr:H₂O₂:H₂O (1:1:10); InGaAsP/InP non-selective etch; HCl:H₂O (4:1); InP selective etch from InGaAsP at 4°C


Thermochemical vapor etch; CH₃I; GaAs in situ OMVPE gas etch at 450°–500°C
HBr:H₃PO₄:K₂Cr₂O₇ (2:2:1); InP vee-groove (1 1 1)A facet etch through SiO₂ mask at 23°C

Br₂/methanol (2%); vee-groove etching behavior with SiO₂ and photoresist masks
HBr:H₃PO₄:K₂Cr₂O₇ (2:2:1); vee-groove etching behavior with SiO₂ and photoresist masks
HCl:H₃PO₄ (5:1); vee-groove etching behavior with SiO₂, photoresist and InGaAs masks. Shows groove shape dependence on mask alignment. Citric acid (50 wt.%):H₂O₂ (3:1); selective etch to define InGaAs mask pattern for HCl etching of InP

Ar and Xe ion sputtering of GaAs (1 1 0); STM study of damage

HNO₃:HCl:H₂O; Application: GaP (1 0 0) substrate cleaning for OMVPE followed by: (NH₄)₂Sₓ solution surface treatment to remove oxide

HNO₃:HF:CH₃COOH:Br₂ (75:15:15:0.06); InSb {1 1 1}A and {1 1 1}B etch figures for determining orientation polarity

ECR plasma etch, electron-beam assisted; Cl₂ + Ar; GaAs etch rate is 10 × greater with e-beam
ECR plasma etch, electron-beam assisted; SF₆ + Ar; GaAs selective etch from AlGaAs
HCl:H₂O (1:10); GaAs native oxide removal at 25°C
H₃PO₄; AlGaAs native oxide removal at 60°C
H₃PO₄:H₂O₂:H₂O (4:1:90); Application: n-GaAs selective etch from Alₙ₀Gaₙ₀As at 25°C

Electron beam assisted dry etch; Cl₂ + SF₆; GaAs selective etch from AlGaAs
H₃PO₄:H₂O₂:H₂O (4:1:90); GaAs selective etch from AlGaAs
HCl:H₂O (1:10); GaAs native oxide removal, 3 min
ECR plasma cleaning of C-doped GaAs in situ for MBE

WEBB, A.P., “Development of a SIMS system for in situ monitoring end point detection during processing,” Semico. Int. ’86
Ion beam etch, in situ monitoring of secondary ion species

CAIBE etch, in situ monitoring of secondary ion species

Ion beam etch; Ar + O2; InP
cone appearance on InP surface when etched with Ar alone; reducing O2 concentration in Ar increases surface roughness; etch rate decreases by factor of two or more with increasing temperature; graphite target holder minimizes redeposited contamination; optimum etch temperature is 60°C

Ion beam; Ar, CCl2F2; GaAs, AlGaAs, InP; Application: stripe waveguide profiles

HCl (0.5 M); photoelectrochemical depth profile etch for AlGaAs/GaAs

reactive ion beam etch process; Cl2; GaAs process for fabricating antireflection surface structure

{SiO2 masked etch profile study.}
HCl conc.; InP
HCl:H3PO4 (1:3) and HCl:CH3COOH (1:1) give rectangular groove grating
HBr:CH3COOH (1:1) gives sawtooth grating

HCl:HNO₃:H₃PO₄ (1:1:5); InP (1 0 0) groove etch; rectangular shaped along <0 1 1>
HCl:H₂PO₄ (1:1); InP (1 0 0) groove etch; partial vee-shaped {1 1 1}B surface along <0 1 1>, and
vee-shaped {2 1 1} along <0 1 1>
Br₂/methanol (1%); InP (1 0 0) reverse-mesa shaped {1 1 1}A surfaced groove along <0 1 1>
and vee-groove {1 1 1}A surface along <0 1 1>
H₃PO₄:H₂O₂:H₂O (1:9:3); GaAs (1 0 0) groove etch, reverse-mesa shaped groove along <0 1 1>
H₂SO₄:H₂O₂:H₂O (3:1:1); GaAs (1 0 0) vee-groove {1 1 1}A surface along <0 1 1>

WESTPHALEN, R., H. Jurgensen, and P. Balk, “Epilayers with Extremely Low Dislocation
(1989)
H₃PO₄:HBr (2:1) {Huber etch}; InP dislocation etch pit delineation for 150 s
WEYHER, J.L., and L.J. Giling, “Revealing of Defects in InP Shallow (Submicron) Photoetching,”
CrO₃:HF:H₂O {Sirtl etch}; InP defect delineation under white or laser light
WEYHER, J., and Van de Ven, “Selective Etching and Photoetching of (1 0 0) GaAs in CrO₃–HF
CrO₃:HF:H₂O; GaAs (1 0 0) etch and photoetch defect delineation
CrO₃:HF:H₂O; GaAs (1 0 0) etch and photoetch defect delineation
WEYHER, J.L., and J. Van De Ven, “Selective etching and photoetching of GaAs in CrO₃–HF
CrO₃:HF:H₂O (DS, diluted Sirtl-like etch and DSL diluted Sirtl-like with light photoetch); defect
delineation in GaAs; comparison to KOH (molten) defect delineation
WEYHER, J.L., R. Fornari, and T. Görög, “HBr–K₂Cr₂O₇–H₂O etching system for indium
HBr–K₂Cr₂O₇–H₂O (BCA etch); InP etch dependence on solution composition; diffusion
controlled polishing etch to kinetically controlled defect etch
WEYHER, J.L., S. Müller, I. Grzegory, and S. Porowski, “Chemical polishing of bulk and Epitaxial
KOH (10–1N) NaOH Free etch and mechano-chemical polishing of GaN
WEYHER, J.L., T. Schober, K. Sonneberg, and P. Franzosi, “Identification of individual and aligned
microdefects in bulk vertical Bridgeman- and liquid encapsulated Czochralski-grown GaAs,” Mater.
H₂SO₄:H₂O₂:H₂O (5:1:1); jet thinning of GaAs for TEM
DSL (dilute Sirtl like) etch to reveal as precipitates for TEM study

Reactive ion etch; CH₄/H₂/Ar; facet formation in InGaAsP/InP lasers


ECR plasma etch; CH₄/H₂/Ar; InP etch process with rate in excess of 120 nm/min
RIE using CH₄/H₂/O₂; InP etch process with rate in excess of 135 nm/min


HCl:HNO₃:H₂O (2:1:2); GaAs discrimination of (1 1 1)A from (1 1 1)B Surfaces


HBr:H₃PO₄:1N.K₂Cr₂O₇ (2:2:1), dilute (1:1) with H₂O; Application: InP uniform thinning etch for incremental Hall measurements; etch rate ~300 Å/s

ECR etch; CH₄/Ar/H₂; InP nanometer size, Ag-masked features


HCl:HNO₃:H₂O (1:1:20); InGaAs and InP p–n junction delineation photoetch; dopant selective: n-etches under illumination; p-type does not etch; very sharp boundaries

K₃Fe(CN)₆:KOH:H₂O (10 g:10 g:100 ml) comparison

Anodization; InP and InGaAsP

Reactive ion etch; chemically assisted; Application: InGaAsP/InP photodiode facet etch

Review: dry etching of GaAs (Plasma, RIE, RIBE, Ion Milling)

WILLIAMS, R., “Wet Etching,” Chapter 5 in Modern GaAs Processing Methods (Artech House, Boston/London, 1990b), P. 95
Review: wet etching of GaAs
H_2SO_4:H_2O_2:H_2O; review of GaAs etch characteristics
Br_2/methanol; review of GaAs etch characteristics
electrochemical etching of GaAs; review of anodic and cathodic etch characteristics

Laser controlled photochemical etch of InP; HNO_3:HCl:H_2O (1:1:20); (negligible dark etch rate)
HF:H_2O (1:10); at incident laser power of 40 W/cm^2 InP (1 0 0) etch rate = 2.8 μm/min; (1 1 1A) InP = 1.1 μm/min and (1 1 1B)InP = 2.3 μm/min; under ultraviolet p-InP is etched about 18 times slower than n-InP; in visible light, p-InP is not etched at all; laser etching rate can be controlled externally by secondary light source

HF:HNO_3:H_2O (4:1:50); Application: GaAs photoetch for waveguide fabrication; AlGaAs/GaAs
Ar-laser-induced etch rate = 750 μm/min

Etch rate monitoring; in situ optical interferometric technique; H_2SO_4:H_2O_2:H_2O (1:4:60);
AlGaAs/GaAs; in situ measurement of growth rate temperature dependence; NH_4OH:H_2O_2:H_2O (20:2:100); AlGaAs/GaAs; in situ measurement of growth rate dependence on solution stirring

HCl:H_2O_2:H_2O (1:1:2); anisotropic stripe pattern etch on GaSb (1 0 0) at 5°C

H_2O:AgNO_3:CrO_3:HF (2 ml:8 mg:1 g:1 ml); A–B etch; Application: InP dislocation etch pit delineation

Indium metal solution etch; Application: for InP LPE in situ substrate cleaning

Br_2/methanol; Application: InGaAsP/InP laser mirror etch

Br_2/methanol; Application: InGaAsP/InP non-selective mesa etch
- Br2/methanol (0.2%); Application: photolithography, InP vee-grooves; laser mirror etch with (111)A facets; very little mask undercutting

- Br2/methanol; Application: InGaAsP/InP laser mirror etch
- H2SO4:H2O2:H2O (10:1:1); InGaAsP selective etch from InP
- HCl:H2O (4:1); InP selective etch from InGaAsP

- A–B etch; Application: InGaAsP/InP layer interface delineation a few seconds at 100°C
- Indium metal solution for in situ LPE cleaning InP substrates

- P2S5:(NH4)2S:Sx solution; Application: sulfur passivation of GaAs
- (NH4)2Sx + 6% S solution; Application: sulfur passivation of GaAs

- HF(48%); selective removal of AlxGa1−xAs from GaAs: AlxGa1−xAs etch rates versus x at 80°C

- H2SO4:H3PO4 (3:1); surface preparation of Al2O3 (0 0 0 1) substrates at 160°C for GaN growth by MBE

- HF:H2O (1:5); Silicon substrate contaminant removal step, 2 min; HCl:H2O2:H2O (3:3:5); Silicon substrate oxidation step, 2 min followed by HF:H2O step for three times prior to loading for CBE growth of GaAs

- Br2/methanol (1:2000); InGaAs best surface cleaning for InP OMVPE regrowth on patterned InGaAs, or alternative: Saturated Br2 water:HBr:H2O (1:1:10); InGaAs surface cleaning (etch rate = 80 Å/s, for 5 s; does not attack photoresist)
- HCl conc.; for InP cap layer removal
H2SO4:H2O2:H2O (1:8:5000); etch rate = 20 Å/s; for 30 s; InGaAs surface cleaning
H2SO4:H2O2:H2O (1:8:500); H2SO4:H2O2:H2O (1:8:50)
{Compares surface recombination velocity of regrown InP/InGaAs for various cleaning methods.}

YABLOKOVITCH, E., T. Gmitter, J.P. Harbison, and R. Bhat, “Extreme Selectivity in the Lift-off of
HF (10%): AlAs selective etch lift-off of a AlGaAs/GaAs layer; selectivity of >107 between AlAs
and Al0.4Ga0.6As; onset of etching occurs for compositions greater than 40–50% aluminum

YAMAGUCHI, K., and S. Tada, “Fabrication of GaAs microtips for scanning tunneling microscopy
H3PO4:H2O2:H2O (10:1:1); shaping of GaAs microtips for scanning tunneling microscopy; shape
dependence on H3PO4 concentration and etch temperature. (NH4)2Sx solution; GaAs passivation
by dipping in solution and annealing at 400°C

YAMAMOTO, A., S. Tohno, and C. Uemura, “Detection of Structural Defects in n-type InP Crystals
1 M NaOH is electrolyte; n-InP defect delineation electrochemical etch under illumination
H3PO4:HBr(2:1) {Huber etch}; defect delineation comparison

Photoelectrochemical etching of n-GaAs NaOH:EDTA electrolyte; use of N-ion surface damage
as an etch mask

YAMAMOTO, N., K. Kishi, Y. Kondo, S. Matsumoto, R. Iga, Y. Kadota, H. Okamoto, and H.
Mawatari, “Ammonium sulfide combined etching (ACE): an effective treatment for reducing
impurities prior to MOVPE InP regrowth in a process using hydrocarbon gas reactive ion etching
Reactive ion etch; CH4/H2; Application: InP laser diode mesa formation; followed by oxygen
plasma treatment to remove RIE etch polymer by-products
H2SO4; treatment to remove RIE etch polymer by-products
(NH4)2Sx (6.0–7.5% sulfur concentration); room temperature for 10 min; followed by H2SO4
treatment to reduce surface impurities; process acronym is (ACE); surface preparation of InP mesa
devices for InP MOVPE regrowth; study of regrown interface quality

YAMAMOTO, N., K. Kishi, S. Matsumoto, Y. Kadota, R. Iga, H. Okamoto, and H. Mawatari,
“Electrical evaluation of InP surface damage caused by reactive ion etching with a mixture of
methane (CH4) or ethane (C2H6) and hydrogen (H2),” J. Vac. Sci. Technol., B, 15(1), 103 (1997a)
Reactive ion etching; CH4/H2 & C2H6/H2; electrical measurement study of InP surface damage

drift phenomena due to deep donor defects induced by reactive ion etching (RIE) using mixture of
ethane (C2H6) and hydrogen (H2),” Jpn. J. Appl. Phys. Pt. 2, 36(6A), L654 (1997b)
Reactive ion etching; C2H6/H2 of InP; electrical drift from etch-induced deep donor defects
HF:H$_2$O$_2$:H$_2$O (1:1:10); Application: InGaAs diffused p–n junction cross-section delineation; 20–15 s under illumination

H$_2$SO$_4$:H$_2$O$_2$:H$_2$O (5:1:1); Application: InGaAsP surface preparation for Schottky contact

ECR plasma etch; BCl$_3$/Ar; GaAs
ECR plasma etc; CH$_4$/H$_2$/Cl$_2$/Ar; InGaP; Application InGaP/GaAs HBTs

Chlorox:H$_2$O (1:4) {where Chlorox household bleach is 5.25% NaOCl solution}; Application: GaAs selective etch from AlGaAs

HCl (1 M); InP surface etch and oxide removal prior to STM study in sulfuric acid solution

Ar ion beam assisted etch; Cl$_2$; Application: InGaAsP/InP laser mesa etch
Ar; 500 eV Ar beam, current density of 80 µA/cm$^2$, etching temperature = 190°C; at high temperature and low pressure, vertical wall is achieved; undercut may happen if etching temperature is too high

Ar ion beam assisted etch; Cl$_2$; Application: InGaAsP/InP laser mesa etch
Ion beam assisted etch; Cl$_2$; Ar; Application: InGaAsP/InP buried heterostructure laser; multilayer mask of phosphosilicate glass, Ti, Ni is used; heating substrate improves surface smoothness

YEATS, R.E., (Varian Report; ONR contract, N00014-75-C-0303), (1977)
NH$_4$OH:H$_2$O$_2$:H$_2$O (20:7:1000); GaAs vee-grooves through a Si$_3$N$_4$ mask
HNO$_3$:HCl (n:1); InGaAsP selective etch from InP for n > 5; does not attack photoresist.
HNO$_3$:HCl (1:1); InP rapid etch, but does not selectively attack metal–InP interfaces. HNO$_3$; oxidizes but does not etch InP
HCl: citric acid (4:5); InP photolithography; forms inverted sidewalls and flat bottoms

H₃PO₄:H₂O₂:H₂O (3:4:1); GaAs; uniform, high, isotropic etch rate for etching via holes

ECR plasma etch; Cl₂/Ar; InP etch profile dependence on Cl₂ concentration

Photoresist developer Microdeposit MF319 as etchant; GaSb and AlGaSb selective etch from InAs
NH₄OH dilute; GaSb and AlGaSb selective etch from InAs. H₃PO₄ non-selective etch for InAs/GaSb/AlGaSb

AgNO₃:HF:HNO₃:H₂O (40 mg:16 ml:24 ml:32 ml) {RC etch}; Application: GaAs dislocation propagation behavior study

RIE etch damage; CCl₂F₂/He; GaAs/AlGaAs QW; annealing and H₂ passivation

Surface study by AES and XPS of GaAs etched with: H₂SO₄:H₂O₂:H₂O (5:1:1) at 50°C for 1 min
NaOH (1N):H₂O₂ (1:1) at 30°C for 1 min

NH₄OH:H₂O (1:10–50); Application: GaAs patterned substrate cleaning prior to OMVPE regrowth; attacks primarily surface oxides
H₃PO₄:H₂O₂:H₂O; alternative etch attacks both GaAs and oxides

H₂S dry passivation of GaAs surface using excimer laser at room temperature
  KOH (5 g in 200 cc H2O); electrolyte for electrochemical pattern etching of GaN and AlGaN

  Reactive ion etch in Cl2 of InP, GaAs, ZnSe and ZnTe; conditions for smooth etching and assessment of surface damage

  CAIBE: comparison of Cl2/Ar and HCl/Ar for etching InP

  Cl2 assisted Ar ion beam etch of InGaAsP/InP; optimum parameters for vertical sidewalls; at 250°C to accommodate low indium chloride volatility

  KOH (0.005–0.04 M); photoelectrochemical etch of n-GaN selectively from intrinsic GaN and p-GaN

  CAIBE with Ar ion beam in Cl2 ambient; InP patterning; comparison of mask materials: Cr/SiO2, Ni, Ti, and hard baked photoresist

  RIE Ar ion damage study; comparison of GaAs and InP

  reactive ion etch, CH4/H2/Ar of InP; improved interfaces of regrown material due to hydrogen interaction with defects

  Dry etch ion damage in InP; diffusion of defects; modeling of diffusion
Iodic acid:H2O (10% solution); Application: InP groove etch with Si3N4 mask

Reactive ion etch of InP using H2/CH4; surface study using focused Ga+ ion beam-SIMS

Ar ion beam etch; InP for grating fabrication

Reactive ion etch; Cl, CCl2F2, CHF3; InP and GaAs (1 0 0) for grating fabrication

HCl:HIO3:H2O (1:1:x, where 5 < x < 100); non-selective etchant for GaAs/AlGaInP; etch rates from 300 to 2500 Å/min depending on x; good etch morphology and stability with time
HCl:KIO3 (1:1) with KIO3 at 0.1 mol/l; non-selective etchant for GaAs/AlGaInP; etch rates from ~1000 Å/min; good etch morphology and stability with time; undercutting of AlGaInP
HCl:K2Cr2O7; non-selective etchant for GaAs/AlGaInP; similar to HCl:KIO3

Review: ion beam assisted etching of semiconductors

Ar ion etch; InGaAsP/InP cross-section interface layer delineation

Reactive ion etch; CH4/H2 of InGaAs; optimization

ECR plasma etch; CH4/H2 + Ar; Application: InGaAsP tapered stripes using anisotropy dependence on bias voltage; Al2O3 or Ti masks

Inductively coupled plasma etching of GaN using Cl₂/Ar; damage in Schottky diodes


citric acid:H₂O₂; selective removal of GaAs substrate from Al₀.₇Ga₀.₃As etch stop layer
NH₄OH:H₂O₂; selective removal of GaAs substrate from Al₀.₇Ga₀.₃As etch stop layer
HF; selective removal of Al₀.₇Ga₀.₃As etch stop layer from GaAs layer
HCl:H₂O (1:1); selective removal of Al₀.₇Ga₀.₃As etch stop layer from GaAs layer
Alternate H₂O₂ 1 min soak followed by HCl:H₂O (1:1) 1 min soak (3 cycles) of GaAs surface to reduce roughness after AlGaAs layer removal


Thermochemical etch; AsBr₃; GaAs reaction mechanism study; rate is limited by formation/desorption of GaBr


UV laser ablation etch; GaN patterns
HCl; second step following UV laser ablation etch of GaN to remove accumulated Ga drops from surface


ICP etching of GaSb and AlGaAsSb using BCl₃/Ar and Cl₂/Ar


H₃PO₄ (14.61 M); study of etching Al₂O₃ dielectric films; etch rate dependence on temperature and concentration


H₂SO₄:H₂O₂:H₂O (3:1:1); Application: AlGaAs mesa etch at 50°C
K₃Fe(CN)₆:KOH:H₂O (8:12:100 by weight); AlGaAsGaAs layer delineation

HBr:H$_2$O$_2$:H$_2$O; InP pattern etch for OMVPE regrowth; for normal and reentrant sidewall profiles
Br$_2$/methanol (1%); InP; reentrant [1 0 0] direction profiles
HBr:H$_3$PO$_4$:H$_2$O$_2$:H$_2$O; InP; reentrant [1 0 0] direction profiles

HF (10%); Application: AlAs selective etch from GaAs; used for lift-off of InGaAs/GaAs layer for TEM analysis

Cl$_2$ reactive ion beam etching of Al$_{0.4}$Ga$_{0.6}$As to form trench grating for distributed Bragg reflectors