ABE, Y., K. Kishino, Y. Suematsu, and S. Arai, ``GaInAsP/InP Integrated Laser With Butt-jointed Built-in Distributed-Bragg-Reflection Waveguide," Electron. Lett., 17(25), 945-47 (1981)
$H_2SO_4$:$H_2O_2$:$H_2O$ (3:1:1); Application: InGaAsP selective etch from InP for laser fabrication
HCl:$H_2O$ (4:1); InP selective etch from InP

ABERNATHY, C.R., F. Ren, and S.J. Pearton, ``Implant Isolation and Dry Etching of InN," InP and Related Material Conference Proceedings, 1994, (IEEE cat. no. 94CH 3369-6), paper WE5, pp. 387-90
ECR plasma etch; $CH_4/H_2$; $Cl_2/H_2$; $CCl_2F_2/Ar$; InN, presence of $H_2$ or $F_2$ is necessary for equirate removal of group III and nitrogen etch products

ABRAHAM-SHRAUNER, B., K.J. Nordheden, and Y.-S. Lee, ``Model for etch depth dependence on GaAs via hole diameter," J. Vac. Sci. Technol., B, 17(3), 961 (1999)
Reactive ion etch of via holes in GaAs using $Cl_2/BCl_3/Ar$; model of etch rate dependence on via depth

ABRAHAMS, M.S., and C.J. Buiocchi, ``Etching of Dislocations on the Low-index Faces of GaAs," J. Appl. Phys., 36(9), 2855-63 (1965)

$H_2O:AgNO_3:CrO_3:HF$ (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):
A solution: $H_2O:AgNO_3:HF$ (40 ml:0.3 g:40 ml)
B solution: $CrO_3:H_2O$ (40 g:40 ml)Mix A + B (1:1) for fresh etchant

ADACHI, H., and H.L. Hartnagel, "GaAs Schottky Light Emitters for the Study of Surface Avalanching and Electroluminescence," J. Vac. Sci. Technol., **19**(3), 427–30 (1981a)
Surface cleaning effects on GaAs light emission from Schottky contacts; assessment of etching on electronic surface behavior for:
$NH_4OH$
$HCl:H_2O$ (1:1)
$HCl:H_2O_2:H_2O$ (1:20:50)
$NH_4OH:H_2O$ (1:1)
$H_2SO_4:H_2O_2:H_2O$ (20:1:1)
$H_2SO_4:H_2O_2:H_2O$ (1:1:250)
$NaOH:H_2O$ (1:2)
$NaOH:H_2O_2:H_2O$ (1:3:30)
$NaOH:H_2O_2:H_2O$ (1:3:150)
$H_3PO_4:H_2O_2$ (10:1)
$H_3PO_4:H_2O_2:H_2O$ (10:1:1)

ADACHI, S., "Chemical Etching of InP and InGaAsP/InP," J. Electrochem. Soc., **129**(3), 609–13 (1982a)
$HBr:CH_3COOH:K_2Cr_2O_7$ (1:1:1); InP (1 0 0) etch rate = 3 μm/min non-stirring; = 25 μm/min with stirring
$HBr:CH_3COOH:K_2Cr_2:O_7$(1:2:1); InP (1 0 0) etch rate = 1.5 μm/min, non-stirring; etch pit free surfaces; etch pits form at lower $K_2Cr_2O_7$ concentrations; data is given on etch rate dependences on concentrations, surface quality, and photolithography etch profiles; nearly equal etch rates on InP and InGaAsP. $HBr:H_3PO_4:K_2Cr_2O_7$ (2:2:1); InP and InGaAsP equal etch rate = 1.5 μm/min; does not attack photoresist

ADACHI, S., "Etching of InP: Overview," Properties of Indium Phosphide, EMIS Datareview Series, No. 6 (INSPEC, The Inst. of Elect. Eng., London 1990a), Chapter 15.1, pp. 335–36
Review: InP etching overview; wet chemical and dry etching

ADACHI, S., "Wet Etching of InP," Properties of Indium Phosphide, EMIS Datareview Series, No. 6 (INSPEC, The Inst. of Elect. Eng., London 1990b), Chapter 15.2, pp. 337–43
Review: InP wet chemical etching; with: (1) defect or damage revealing etchant table, (2) polishing etchant table, and (3) pattern etchant table

ADACHI, S., and H. Kawaguchi, "Chemical Etching Characteristics of (0 0 1) InP," J. Electrochem. Soc., **128**(6), 1342–49 (1981b)
InP photolithography: vee and dovetail groove cross-section etch profiles:
HCl; InP etch rate at 25°C ~12 μm/min
$HCl:H_2O$ (1:1); InP etch rate at 25°C ~0.07 μm/min
$HCl:H_2O_2$ (1:1); InP etch rate at 25°C ~2.3 μm/min

$HCl:CH_3COOH$ (1:1); InP etch rate at 25°C ~6.0 μm/min
$HCl:H_3PO_4$ (1:1); InP etch rate at 25°C ~4.0 μm/min
$HCl:H_2O_2:H_2O$ (1:1:1); InP etch rate at 25°C ~0.1 μm/min
$HCl:CH_3COOH:H_2O_2$ (1:1:1); InP etch rate at 25°C ~4.0 μm/min
$HCl:H_3PO_4:H_2O_2$ (1:1:1); InP etch rate at 25°C ~2.0 μm/min
$HCl:HNO_3$ (1:1); InP etch rate at 25°C ~6.5 μm/min
$HCl:HNO_3$ (1:2); InP etch rate at 25°C ~7.0 μm/min
$HCl:HNO_3$ (2:1); InP etch rate at 25°C ~8.5 μm/min
$HCl:HNO_3:H_2O$ (1:1:2); InP etch rate at 25°C ~0.15 μm/min
$HCl:HNO_3:H_2O_2$ (1:1:2); InP etch rate at 25°C ~0.5 μm/min
$HCl:HNO_3:CH_3COOH$ (1:1:2); InP etch rate at 25°C ~1.0 μm/min
HBr; InP etch rate at 25°C ~6.5 μm/min
$HBr:H_2O_2$ (1:1); InP etch rate at 25°C ~23 μm/min
$HBr:CH_3COOH$ (1:1); InP etch rate at 25°C ~3.0 μm/min
$H_3PO_4:HBr$ (1:1); InP etch rate at 25°C ~2.0 μm/min
$HBr:HNO_3$ (1:1); InP etch rate at 25°C ~11.0 μm/min
$HBr:HNO_3:H_2O$ (1:1:5); InP etch rate at 25°C ~9.0 μm/min
$H_2SO_4:H_2O_2$ (1:1); InP etch rate at 60°C ~0.2 μm/min
$H_2SO_4:H_2O_2:H_2O$ (1:1:1); InP etch rate at 60°C ~0.17 μm/min
$H_2SO_4:H_2O_2:H_2O$ (3:1:1); InP etch rate at 60°C ~0.12 μm/min
$K_2Cr_2O_7:H_2SO_4:HCl$ (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

ADACHI, S., H. Kawaguchi, K. Takahei, and Y. Noguchi, "InGaAsP/InP Buried-Heterostructure Lasers (l = 1.5 μm) With Chemically Etched Mirrors," J. Appl. Phys., **52**(9), 5843–45 (1981c)
Br/methanol; Application: InGaAsP/InP laser mirror etch
$HCl:CH_3COOH:H_2O_2$ (1:2:1) {KKI etch}; Application: InGaAsP/InP laser mirror etch
$KI:I_2:H_2O$; Application: photolithography etchant for Au/Zn contact layer from InP

ADACHI, S., and H. Kawaguchi, "InGaAsP/InP Planar-Stripe Lasers Fabricated by Wet Chemical Etching," J. Appl. Phys., **52**(5), 3176–78 (1981d)
$Br_2$/methanol; Application: InGaAsP/InP laser mirror etch

ADACHI, S., H. Kawaguchi, and G. Iwane, "InGaAsP/InP Planar-Stripe Lasers with Chemically Etched Mirrors," J. Electrochem. Soc., **129**(4), 883–86 (1982b)
$Br_2$/methanol; Application: Photolithography: etch cross-section profiles; laser mirror etch; slight difference in etch rates between InGaAsP and InP

ADACHI, S., H. Kawaguchi, and G. Iwane, "A New Etchant System, $K_2Cr_2O_7$–$H_2SO_4$–HCl," J. Mater. Sci., **16**, 2449 (1981e)

| 1 M $K_2Cr_2O_7$:$H_2SO_4$:HCl | GaAs (1 0 0) etch rate (μm/min) | InP (1 0 0) etch rate (μm/min) |
|---|---|---|
| (3:1:0) (60°C) | 0.03 | None |
| (3:1:1) (60°C) | 12 | 0.25 |
| (3:1:2) (25°C) | 2.5 | 0.5 |
| (3:1:2) (60°C) | 20 | 1.5 |
| (3:1:3) (60°C) | 30 | 2.3 |

Gives GaAs and InP surface quality comparison for:
$Br_2$/methanol (0.3%); (attacks photoresists)
NaOH:$H_2O_2$:$H_2O$ (12:1:10); (no erosion of photoresists)
1 M $K_2Cr_2O_7$:$H_2SO_4$:HCl (3:1:2)
$H_2SO_4$:$H_2O_2$:$H_2O$ (3:1:1)
Gives GaAs and InP groove etch profiles for $H_2SO_4$:$H_2O_2$:$H_2O$ (1:1:1) and all the above concentrations of 1 M $K_2Cr_2O_7$:$H_2SO_4$:HCl

ADACHI, S., Y. Noguchi, and H. Kawaguchi, ‘‘Chemical Etching of InGaAsP/InP Double Heterostructure Wafer,’’ J. Electrochem. Soc., **129**, 1053 (1982c)
InP photolithography; vee and dovetail groove cross-section etch profiles:
$Br_2$/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:$H_2O_2$ (1:1); InGaAsP and InP etch rates are similar
HBr:$CH_3COOH$ (1:1); InP selective etch from InGaAsP
$H_3PO_4$:HBr (1:1); InP selective etch from InGaAsP
HCl; InP selective etch from InGaAsP
HCl:$H_2O$ (1:1); InP selective etch from InGaAsP
HCl:$H_2O_2$ (1:1); InP selective etch from InGaAsP
HCl:$CH_3COOH$ (1:1); InP selective etch from InGaAsP
HCl:$CH_3COOH$:$H_2O_2$ (1:1:1); InGaAsP and InP etch rates are similar
HCl:$H_3PO_4$:$H_2O_2$ (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
$H_3PO_4$:HCl (1:1); InP selective etch from InGaAsP
$H_2SO_4$:$H_2O_2$:$H_2O$ (1:1:1); InGaAsP selective etch from InP
$H_2SO_4$:$H_2O_2$:$H_2O$ (3:1:1); InGaAsP selective etch from InP
$K_2Cr_2O_7$:$H_2O_2$:HCl (3:1:2); InGaAsP selective etch from InP

ADACHI, S., Y. Noguchi, and H. Kawaguchi, ‘‘Use of HBr–$CH_3COOH$–$K_2Cr_2O_7$ Etchant to Etched-mirror Laser Fabrication,’’ J. Electrochem. Soc., **129**(7), 1524–27 (1982d)
HBr:$CH_3COOH$:$K_2Cr_2O_7$ (2:2:1); nearly equal etch rate ~ 2.5 μm/min for InGaAsP and InP
HBr:$CH_3COOH$:$K_2Cr_2O_7$ (1:1:1); Application: InGaAsP/InP laser; does not erode photoresist; provides very smooth and nearly vertical walls

ADACHI, S., and K. Oe, ‘‘Chemical etching characteristics of (0 0 1) GaAs,’’ J. Electrochem. Soc., **130**(12), 2427 (1983)

$HCl:CH_3COOH:H_2O_2$ (1:1:1); masked pattern etch profiles on (0 0 1) GaAs
$HCl:H_3PO_4:H_2O_2$ (1:1:1)
$HCl:CH_3COOH:(1N\ K_2Cr_2O_7)$ (1:1:1)
$HCl:H_3PO_4:(1N\ K_2Cr_2O_7)$ (1:1:1)
$HNO_3:H_2O_2$ (1:1)
$HNO_3:CH_3COOH:$ (1:1)
$HNO_3:H_3PO_4$ (1:1)
$HNO_3:CH_3COOH:H_2O_2$ (1:1:1)
$HNO_3:H_3PO_4:H_2O_2$ (1:1:1)
$HBr:HNO_3$ (1:1)
$HBr:HNO_3:H_2O$ (1:1:1)
$HBr:CH_3COOH:(1N\ K_2Cr_2O_7)$ (1:1:1)
$HBr:H_3PO_4:(1N\ K_2Cr_2O_7)$ (1:1:1)
$H_3PO_4:H_2O_2:H_2O$ (1:1:1)
$H_3PO_4:CH_3COOH:H_2O_2$ (1:1:1)
$H_3PO_4:CH_3OH:H_2O_2$ (1:1:1)
$H_3PO_4:C_2H_5OH:H_2O_2$ (1:1:1)
$H_2SO_4:H_2O_2:H_2O$ (1:1:1)
$H_2SO_4:CH_3COOH:H_2O$ (1:1:1)
$H_2SO_4:H_3PO_4:H_2O$ (1:1:1)
$H_2SO_4:HCl:(1N\ K_2Cr_2O_7)$ (1:1:1)
$HF:HNO_3:H_2O$ (1:1:1)
$HF:HNO_3:H_2O_2$ (1:1:1)
$HF:HNO_3:CH_3COOH$ (1:1:1)
$HF:HNO_3:H_3PO_4$ (1:1:1)
$HF:H_2SO_4:H_2O_2$ (1:1:1)
$Br_2:CH_3OH$ (4%)
$Br_2:CH_3OH$ (1%); $[Br_2:CH_3OH$ (1%)$]:CH_3COOH$ (1:1)
$[Br_2:CH_3OH$ (1%)$]:H_3PO_4$ (1:1)
NaOCl(aqueous solution)
NaOCl(aqueous solution):HCl (1:1)
$1N\ NaOH:H_2O_2:H_2O$ (1:1:10)
$1N\ NaOH:H_2O_2:NH_4OH$ (5:1:1)
$NH_4OH:H_2O_2:H_2O$ (1:1:5)
$1N\ KOH:H_2O_2:H_2O$ (1:1:10)
$1N\ KOH:H_2O_2:NH_4OH$ (5:1:1)

ADAMS, A.C., and B.R. Pruniaux, "Gallium Arsenide Surface Film Evaluation by Ellipsometry and Its Effect on Schottky Barriers," J. Electrochem. Soc., **120**(3), 408–14 (1973)
Evaluation of GaAs surface oxides for various cleaning methods. Cleanest surface has ~8 Å film which grows due to air oxidation to ~30Å

ADESIDA, I., "Selective Etching if InGaAs and Its Heterostructures," Properties of Lattice-Matched and Strained Indium Gallium Arsenide, EMIS Datareview Series No. 8 (INSPEC, The Inst. of Elect. Eng., London 1993a), Chapter 8.3, pp. 250–56
Review of InGaAs selective etches:

Citric acid:$H_2O_2$ (1:1); InGaAs selective etch from InAlAs
$NH_4OH$:$H_2O_2$ (1:30)
$H_2SO_4$:$H_2O_2$:$H_2O$ (1:1:10)
$H_3PO_4$:$H_2O_2$:$H_2O$ (1:1:8)
HCl:$H_2O$ (3:1)
Reactive ion etching: $CH_4$:$H_2$; $CH_3$:Br; HBr

ADESIDA, I., E. Andideh, A. Ketterson, T. Brock, and O. Aina, "Reactive Ion Etching of Submicrometer Structures in InP, InGaAs and InAlAs," GaAs and Related Compounds, 1988 (Inst. Phys. Conf. Ser. No. 96 1989), pp. 425–30
Reactive ion etch; $CH_4$/$H_2$; $CH_4$/He; $CH_4$/Ar; Application: InP, InGaAs, InAlAs; InP etch rate = 800 Å/m; InGaAs etch rate = 400 Å/m

ADESIDA, I., A. Mahajan, E. Andideh, M.A. Khan, D.T. Olsen, and J.N. Kuznia, "Reactive Ion Etching of Gallium Nitride in Silicon Tetrachloride Plasmas," Appl. Phys. Lett., **63**(20), 2777–79 (1993b)
Reactive Ion Etch; $SiCl_4$:Ar (1:1) and $SlCl_4$:$SiF_4$ (1:1); GaN

ADESIDA, I., A. Mahajan, E. Andideh, M.A. Khan, D.T. Olsen, and J.N. Kuznia, "Reactive Ion Etching of Gallium Nitride in Silicon Tetrachloride Plasmas," Appl. Phys. Lett., **63**(20), 2777–79 (1993c)
Reactive ion etch; $SiCl_4$; $SiCl_4$:Ar (1:1); $SiCl_4$:$SiF_4$ (1:1); GaN; patterns masked with NiCr; profiles

ADESIDA, I., and A.T. Ping, "Chemically Assisted Ion Beam Etching of Anisotropic Structures in Gallium Nitride Using HCl Gas (EMC abstract)," J. Electron. Mater., **24**(7), A33 (1995)
CAIBE of GaN; Ar ion beam with HCl gas; lower etch rates than with $Cl_2$

AGARWALA, S., I. Adesida, C. Caneau, and R. Bhat, "Characteristics of Selective Reactive Ion Etching of InGaAs/AlGaAs Heterostructures Using HBr Plasma," J. Vac. Sci. Technol., B, **11**(6), 2258–61 (1993a)
Reactive ion etch, HBr; InGaAs selective etch from InAlAs followed by dilute HCl etch to remove surface residues

AGARWALA, S., I. Adesida, C. Caneau, and R. Bhat, "Reactive Ion Etching-Induced Damage in InAlAs/InGaAs Heterostructures," InP and Related Material Conference Proceedings, 1994, (IEEE cat. no. 94CH 3369–6), paper WE6, pp. 391–394
Reactive ion etch; assessment of damage in InAlAs/InGaAs heterostructures

AGARWALA, S., I. Adesida, C. Caneau, and R. Bhat, "Selective Reactive Ion Etching of InGaAs/InAlAs Heterostructures in HBr Plasma," Appl. Phys. Lett., **62**(22), 2830–32 (1993b)
Reactive Ion Etch; HBr; InGaAs selective etch from InAlAs; selectivity of 160

AGARWALA, S. ADESIDA, I., C. Caneau, and R. Bhat, "Selective Reactive Ion Etching of InGaAs/InAlAs Heterostructures in HBr Plasma," Appl. Phys. Lett., **62**(22), 2830–32 (1993c)
Reactive ion etch; HBr; selective etch of InGaAs from InAlAs

AGARWALA, S., S.C. Horst, O. King, R. Wilson, D. Stone, M. Dagenais, and Y.J. Chen, "High density inductively coupled plasma etching of GaAs/AlGaAs in $BCl_3/Cl_2/Ar$: A study using a mixture design experiment," J. Vac. Sci. Technol., B, **16**(2), 511 (1998)
Inductively coupled plasma etch; $BCl_3/Cl_2/Ar$ of GaAs/AlGaAs; high rate, low damage. Study of etch dependence on gas composition

AGARWALA, S., O. King, S. Horst, R. Wilson, D. Stone, M. Dagenais, and Y.J. Chen, "Response surface study of inductively coupled plasma etching of GaAs/AlGaAs in $BCl_3/Cl_2$," J. Vac. Sci. Technol., A, **17**(1), 52 (1999)
Inductively coupled plasma etch; $BCl_3/Cl_2$; rate/profile study of GaAs/AlGaAs

AGARWALA, S., K. Nummila, I. Adesida, C. Caneau, and R. Bhat, "InAlAs/InGaAs Heterojunction FET's Processed with Selective Reactive-Ion-Etching Gate-Recess Technology," IEEE Electron Device Lett., **14**(9), 425–27 (1993d)
Reactive ion etch; HBr; Application: InGaAs selective etch from InAlAs; selectivity $> 150$

AGNELLO, P.D., and S.K. Ghandhi, "In situ Etching of InP by a Low Pressure Transient HCl Process," J. Cryst. Growth, **73**, 453–59 (1985)
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 $Ea = 0.25$ 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

AHAITOUF, A., A. Bath, E. Losson, and E. Abarkan, "Stability of sulfur-treated n-InP Schottky structures, studied by current–voltage measurements," Mater. Sci. Eng. B, **B52**, 208 (1998)
$(NH_4)_2S_x$; InP surface passivation, study of Schottky contact stability

AHMAD, K., and A.W. Mabbitt, "Gallium Indium Arsenide Photodiodes," Solid-State Electron., **22**, 327–33 (1979)
A–B etch; Application: InGaAs dislocation etch pit delineation

AHN, J.-H, K.R. Oh, D.-K Kim, S.W. Lee, B.-T. Lee, H.M. Kim, K.E. Pyun, and H.M. Park, "Successful utilization of $CH_4/H_2$/RIE for the fabrication of 1.3 μm InGaAsP/InP integrated laser with butt-coupled passive waveguides," InP and Related Material Conference Proceedings, 1996, p. 121
Reactive ion etch of InGaAsP/InP lasers using $CH_4/H_2$
$HBr:H_2O_2:H_2O$ removal of RIE damage before MOCVD regrowth

AHOPELTO, J., V.-M Airaksinen, E. Sirén, and H.E.-M. Niemi, "Fabrication of Sub-100 nm GaAs Columns by Reactive Ion Etching using Au Islands as Etching Mask," J. Vac. Sci. Technol., B, **13**(1), 161–62 (1995)
Reactive Ion Etch; $SiCl_4$/He/Ar; nanoscale columns in GaAs using gold islands as masks

AKASAKI, I., H. Amano, Y. Koide, K. Hiramatsu, and N. Sawaki, "Effects of an ALN buffer layer on crystallographic structure and on electrical and optical properties of GaN and GaAlN films grown on sapphire substrate by MOVPE," J. Cryst. Growth, **98**, 209 (1989)

$H_3PO_4$:$H_2SO_4$ (1:3); hot solution to clean sapphire substrates for MOVPE growth of GaN

AKATSU, Y., H. Ohno, H. Hasegawa, and T. Hashizume, "Effect of a Coincident Pb Flux During MBE Growth on the Electrical Properties of GaAs and AlGaAs Layers," J. Cryst. Growth, **81**, 319–25 (1987)

$H_2SO_4$:$H_2O_2$:$H_2O$ (7:1:1); Application: GaAs substrate cleaning for MBE, 1 min 3 M ammonium tartarate; GaAs, electrolyte for electrochemical *C–V* profiling

AKIBA, S., K. Sakai, Y. Matsushima, and T. Yamamoto, "Effects of Double-Cladding Structure on LPE-Grown InGaAsP/InP Lasers in the 1.5 μm Range," Jpn. J. Appl. Phys., **19**(2), L79–L82 (1980)

HF:$HNO_3$; Application: InGaAsP/InP LPE layer cross-section delineation

AKITA, K., "Photoluminescence intensities from GaAs immersed in HCl aqueous solutions diluted with organic solvents," J. Electrochem. Soc., **137**(7), 2081 (1990)

HCl (36% aqueous solution):methanol (from 1:10 to 1:1000); protects GaAs surface from oxidation to improve photoluminescence intensity

AKITA, K., T. Kusunoki, S. Komiya, and T. Kotani, "Observation of Etch Pits in InP by New Etchants," J. Cryst. Growth, **46**, 783–87 (1979)

HBr:$CH_3COOH$ (1:10); InP defect delineation; etch rate = 1.7 μm/min
HF:HBr (1:10); InP defect delineation; etch rate = 0.9 μm/min
HBr:$H_3PO_4$ (1:2) {Huber etch}; InP defect delineation; etch rate = 0.25 μm/min
{Gives data is given on etch rates and etch pit delineation versus etchant composition.}

AKITA, K., Y. Sugimoto, and H. Kawanishi, "Electron-beam-induced maskless HCl pattern etching of GaAs," Semicond. Sci. Technol., **6**, 934–36 (1991a)

Electron beam-induced HCl maskless pattern etching of GaAs

AKITA, K., Y. Sugimoto, and H. Kawanashi, "HCl Aqueous Solution Diluted with Methanol as an Electrolyte for *C–V* Profiling of GaAs and InP," J. Electrochem. Soc., **138**(7), 2095–97 (1991b)

Electrochemical *C–V* profiling; InP n- and p-GaAs with HCl (36%) 1 vol.% in methanol electrolyte

AKITA, K., M. Taneya, Y. Sugimoto, H. Hidaka, and Y. Katayama, "Etching of GaAs for Patterning by Irradiation with an Electron Beam and $Cl_2$ Molecules.," J. Vac. Sci. Technol. B, **7**(6), 1471– 74 (1989)

Electron-beam-induced $Cl_2$ etching of GaAs patterns

AKRAM, S., H. Ehsani, and I.B. Bhat, "The Effect of GaAs Surface Stabilization on the Properties of ZnSe Grown by OMVPE," J. Cryst. Growth, **124**, 628–32 (1992)

Dimethylzinc; Application: thermochemical vapor etch of GaAs above 380°C in $H_2$ for OMVPE growth

AMBRIDGE, T., and D.J. Ashen, "Automatic electrochemical profiling of Hall mobility in semiconductors," Electron. Lett., **15**(20), 648 (1979a)
Electrochemical $C$–$V$ profiling; GaAs carrier concentration and electron mobility using Tiron electrolyte (1,2-dihydroxybenzene-3,5-disulphonic acid, disodium salt, aqueous solution)

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$KOH:K_3Fe(CN)_6:H_2O$; Application: InGaAs/InP and p–n junction cleaved cross-section layer delineation

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KOH, molten (400°C); GaAs {1 0 0}; dislocation etch pit delineation; 30 min

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$NH_4OH:H_2O_2:H_2O$ (1:3:16); Application: selective removal of GaAs from AlGaAs

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$H_2SO_4:H_2O_2:H_2O$ (1:8:1); Application: InGaAs selective etch from InP

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$I_2:KI:H_2O$ (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

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$Br_2$/methanol; Application: InGaAsP/InP non-selective mesa etch for laser fabrication. $HCl:H_2O$ (4:1); InP selective etch from InGaAsP

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$NH_4OH:H_2O_2:H_2O$ (10:1:10) Application: GaAs (1 0 0) substrate cleaning for MBE. $H_2SO_4$:-$H_2O_2:H_2O$ (10:2.8:10); GaAs (1 0 0) photolithography ridge and groove etch showing profiles

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$CH_3COOH:HCl:H_2O_2$ (20:1:1); GaInP surface cleaning; 10 s; prior to photoluminescence measurements

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$CH_3COOH:HClO_4:HNO_3:HCl$ (1:1:5:1); Application: InP-n substrate preparation etch for ion implantation
$Br_2$/methanol (1%); InGaAsP/InP mesa etch

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$Br_2$/methanol (3 vol.%): $H_3PO_4$ (1:1); Application: InP mesa etch at 45°C
HCl:$HNO_3$:$CH_3COOH$:$HClO_4$ (1:6:1:1); InP (1 0 0) jet thinning etch

ARNOT, H.E.G., R.W. Glew, G. Schiavini, L.J. Rigby, and A. Piccirillo, "Selective Etching of InP and InGaAsP Over AlInAs Using $CH_4/H_2$ Reactive Ion Etching," Appl. Phys. Lett., **62**(24), 3189–91 (1993a)
Reactive ion etch, $CH_4/H_2$; InP and InGaAsP selective etch from InAlAs

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HCl:$H_2O$ (5:1); InP substrate removal from InGaAs/InAlAs structure for transfer to glass substrate

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citric acid:$H_2O_2$ (10:1); selective, anisotropic etch for shaping cantilevers in 2 μm GaAs layers with InGaP etch stop layer
HCl:$H_3PO_4$ (3:1) and (1:1); selective etch of InGaP from GaAs
$H_3PO_4$:$H_2O_2$:$H_2O$ (2:1:10); anisotropic etch of GaAs substrate supporting cantalever stripes

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Review; chlorine-based dry etching of III–V semiconductors; advantages of ECR/RIBE over conventional RIE

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$H_3PO_4$:$H_2SO_4$ (1:3); Surface cleaning (hot) of $Al_2O_3$ (0001) substrates for GaN growth by MOVPE

ASHBY, C.I.H., "GaAs Etching: Overview," Properties of Gallium Arsenide, 2nd Ed., EMIS Datareview Series, No. 2 (INSPEC, The Inst. of Elect. Eng., London 1990a), Chapter 20.1, pp. 653–54
Review: GaAs etching overview; wet and dry etching

ASHBY, C.I.H., "Ion-assisted Etching (RIE, RIBE, IBAE, and RBIBE) of GaAs," Properties of Gallium Arsenide, 2nd Ed., EMIS Datareview Series, No. 2 (INSPEC, The Inst. of Elect. Eng., London 1990b), Chapter 20.5, pp. 665–75

Review: ion-assisted etching of GaAs; RIE, RIBE, IBAE, and RBIBE techniques; with tables of etchants, etch conditions, and etch rates

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Photochemical dry etching of GaAs in plasma-decomposed $HCl + He$

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Review: plasma etching of GaAs; with table of etchants, etch conditions, and etch rates

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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)

$Br_2$/methanol; InGaAs surface treatment followed by $H_2O$ rinse and $H_2O:NH_4OH$ (1:1) gives best contaminant-free interface

$H_2O_2$ (30%); InGaAs surface treatment leaves 8–10 Å of $In_2O_3$ and $Ga_2O_3$

ASPNES, D.E., and H.J. Stocker, ‘‘Peroxide Etch Chemistry on 100 InGaAs,’’ J. Vac. Sci. Technol., **21**(2), 413–14 (1982)

$H_2SO_4:H_2O_2:H_2O$ $(1:1:x)$ $\{10 < x < 100\}$; InGaAs surface study; behavior depends on solution pH

ASPNES, D.E., and A.A. Studna, ‘‘Chemical Etching and Cleaning Procedures for Si, Ge, and Some III–V Compound Semiconductors.,’’ Appl. Phys. Lett., **39**(4), 316–18 (1981)

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)

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$K_3Fe(CN)_6$: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

AURET, F.D., "An AES Evaluation of Cleaning and Etching Methods for InSb," J. Electrochem. Soc., **129**(12), 2752–55 (1982)

InSb surface cleaning for AES studies:
Lactic acid:$HNO_3$ (10:1)
HF:$H_2O_2$:$H_2O$ (1:1:4)
HF:$HNO_3$:$CH_3COOH$:Br (15:25:15:0.3)
HF:$HNO_3$:$CH_3COOH$ (1:2:5)
$Br_2$/methanol (1%)
KOH:tartaric acid:ethylenediamine tetra-acetic acid:$H_2O$ (70 g:4 g:8 g:78 g), mixed with $H_2O_2$ (5:2)
$CH_3COOH$:$HNO_3$:HF (15:30:15) {CP-4 etch}

AURET, F.D., S.A. Goodman, G. Myburg, and W.E. Meyer, "Electrical Characteristics of Ar-ion Sputter-Induced Defects in Epitaxially Grown n-GaAs," J. Vac. Sci. Technol., B, **10**(6), 2366–70 (1992)

$NH_4OH$:$H_2O_2$:$H_2O$ (3:1:120); Application: GaAs surface cleaning, 1 min followed by $H_2O$ rinse followed by: HCl:$H_2O$ (1:1); 2 min oxide removal

AYDIL, E.S., Z.H. Zhou, R.A. Gottscho, and Y.J. Chabal, "Real Time in situ Monitoring of Surfaces During Glow Discharge Processing: $NH_3$ and $H_2$ Plasma Passivation of GaAs," J. Vac. Sci. Technol., B, **13**(2), 258–67 (1995)

Plasma passivation of GaAs; $NH_3$ and $H_2$; in situ monitoring of surface reactions with attenuated-total-reflection Fourier-transform-spectroscopy (ATR FTIR)

AYDIL, E.S., Z. Zhou, K.P. Giapis, Y. Chabal, J.A. Gregus, and R.A. Gottscho, "Real-Time, in situ Monitoring of Surface Reactions During Plasma Passivation of GaAs," Appl. Phys. Lett., **62**(24), 3156–58 (1993)

Plasma surface oxidation; GaAs; FTIR study of surface chemical reactions

AYTAC, S., and A. Schlachetzki, "Diffusion-profile Measurement in InP with Schottky Diodes," Solid-State Electron., **25**(11), 1135–39 (1982)

KOH:$H_2O$ (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°C
$Br_2$/isopropanol (1.5%) InP etch rate = 0.5 μm/min at −10°C
$Br_2$/isopropanol (2.5%) InP etch rate = 0.86 μm/min at −10°C

AYTAC, S., A. Schalchetzki, and H.J. Prehn, "Thinning of InP by Chemical Etching," J. Mater. Sci. Lett., **2**, 447–50 (1983)
$HCl:HNO_3:CH_3COOH:HClO_4$ (3:2:1:3); InP thinning etch; etch rate = 7 μm/min

BAHL, S.R., W.J. Azzam, and J.A. del Alamo, "Strained-insulator InAlAs/n + InGaAs Heterostructure FET," IEEE Trans. Electron Devices, **38**(9), 1986 (1991)
$H_2SO_4:H_2O_2:H_2O$ (1:10:220); Application: InGaAs/InAlAs mesa etch; selective from InP stop layer
$H_2SO_4:H_2O_2:H_2O$ (3:1:1); followed by: $Br_2$/methanol (0.5%); InP substrate cleaning for MBE growth

BAHL, S.R., and J.A. del Alamo, "Elimination of Mesa-sidewall Gate Leakage in InAlAs/InGaAs Heterostructures by Selective Sidewall Etching," IEEE Electron Device Lett., **13**(4), 195–97 (1992)
$H_2SO_4:H_2O_2:H_2O$ (1:10:220); Application: InAlAs/InGaAs selective etch from InP
Succinic acid:$H_2O_2$ (6:1) pH = 5.5 by adding $NH_4OH$; InGaAs selective etch from InAlAs

BAILEY III, A.D., M.C.M. van de Sanden, J.A. Gregus, and R.A. Gottsco, "Scaling of Si and GaAs trench rates with aspect ratio, feature width, and substrate temperature," J. Vac. Sci. Technol., B, **13**(1), 92 (1995a)
ECR plasma; Ar/$Cl_2$; Study and modeling of trench profile dependence in GaAs and Si on etch temperature
$NH_4OH:H_2O$ (3%); native oxide removal from GaAs to demonstrate that plasma etch rates do not depend on initial presence of oxides

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ECR etch; trench etching in GaAs; scaling of etch rates to pattern aspect ratio

BAILEY, S.G., D.M. Wilt, F.L. DeAngelo, and E.B. Clark, "Preferentially Etched Epitaxial Lift-off of Indium Phosphide," The Conference Record of the 23rd IEEE Photovoltaics Specialists Conference 1993, Louisville, KY, (IEEE Cat. No. 93CH3283-9), pp. 783–85
$HF:H_2O_2:H_2O$ (1:1:10); citric acid:$H_2O:H_2O_2$ (1:1:8); AlAs selective etch from InP as a sacrifice layer to lift-off InP epilayer from the substrate

BALLEGEER, D.G., S. Agarwala, M. Tong, A.A. Ketterson, I. Adesida, J. Griffen, and M. Spencer, "Selective reactive ion etching effects on GaAs/AlGaAs/MODFETs," Mat. Res. Soc. Symp. Proc., **240**, 335 (1992)
Reactive ion etch; $SiCl_4/SiF_4$; selective removal of GaAs from AlGaAs; damage effects on MODFETs

BALLEGEER, D.G., S. Agarwala, M. Tong, K. Nummila, A.A. Ketterson, I. Adesida, J. Griffen, and M. Spencer, "Selective Reactive Ion Etching in $SiCl_4/SiF_4$ Plasmas for Gate Recess in GaAs/AlGaAs Modulation-doped Field Effect Transistors," J. Vac. Sci. Technol., B, **11**(3), 618–27 (1993)
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

BAN, V.S., and S.L. Gilbert, "Chemical Processes in Vapor Deposition of Silicon," J. Electrochem. Soc., **122**(10), 1382–88 (1975)
Thermochemical vapor etch; $HCl + H_2$; silicon

BARDWELL, J.A., I.G. Foulds, J.B. Webb, H. Tang, J. Fraser, S. Moisa, and S.J. Rolfe, "A simple wet etch for GaN," J. Electron. Mater., **28**(10), L24 (1999)
KOH solution + 0.02 M $K_2S_2O_8$; photoenhanced etching of GaN using a Pt mask
$HCl:HNO_3:H_2O$ (7:1:8); Pt mask removal from GaN; 85°C for 4 min

BARKER, R.A., T.M. Meyer, and R.H. Burton, "Surface Composition and Etching of III–V Semiconductors in $Cl_2$ Ion Beams," Appl. Phys. Lett., **40**(7), 583–86 (1982)
Reactive ion etch; $Cl_2$; InP

BASAK, D., K. Yamashita, T. Sugahara, Q. Fareed, D. Nakagawa, K. Nishino, and S. Sakai, "Reactive ion etching of GaN and $Al_xGa_{1-x}N$ using $Cl_2/CH_4$/Ar plasma," Jpn. J. Appl. Phys., Pt. 1, **38**(4b), 2646 (1999)
Reactive ion etching of GaN and AlGaN using $Cl_2/CH_4$/Ar

BECKER, R., "Sperrfreie Kontakte an InP," Solid-State Electron., **16**, 1241 (1973)
$HNO_3:HCl:H_2O$ (1:1:2); InP (1 0 0) etch rate = 5 μm/min
HCl (37%); InP (1 0 0) etch rate = 6.2 μm/min
$H_2SO_4:H_2O_2:H_2O$ (3:1:1); InP (1 0 0) etch rate = 0.25 μ/min
$HCl:HNO_3$ (1:1); InP (1 0 0) etch rate = 40 μm/min
$HCl:HNO_3:CH_3COOH$ (1:1:1); InP (1 0 0) etch rate = 5.5 μm/min
$HCl:HNO_3:CH_3COOH$ (3:1:5); InP (1 0 0) etch rate = 4 μm/min
$HCl:HNO_3:HClO_4:CH_3COOH$ (1:6:1:1); InP (1 0 0) etch rate = 2.5 μm/min
$HCl:HNO_3:HClO_4:CH_3COOH$ (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
$H_3PO_4$ (85%); InP (1 0 0) etch rate at 90°C = 0.15 μm/min

BEHFAR-RAD, A., S.S. Wong, J.M. Ballantyne, B.A. Soltz, and C.M. Harding, "Rectangular and L-Shaped GaAs/AlGaAs Lasers with Very High Quality Etched Facets," Appl. Phys. Lett., **54**(6), 493–95 (1989)
$Cl_2$ assisted Ar ion etching; Application: GaAs/AlGaAs laser facets

BÉLIER, B., M. Castagne, P. Falgayrettes, J. Bonnafé, A. Santoso, and J.L. Leclecq, "InP-based photonic micro-sensor for near field optical investigations," J. Vac. Sci. Technol., B, **18**(1), 90 (2000)

$H_3PO_4$: $H_2O_2$:$H_2O$ (1:1:38); Application: InP mesa fabrication
HCl:$CH_3COOH$ (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 (−1,−1,−1)," J. Electron. Mater., **27**(3), 114 (1998)
HCl:$CH_3COOH$:$H_2O_2$ (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; discuses etch mechanism. HCl:$HNO_3$ (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:$HNO_3$:$H_2O$ (2:1:2); GaP polish on (−1,−1,−1); pitted on (1 1 1) for T = 60°C

BERG, E.W., and S.W. Pang, "Electrical and optical characteristics of etch-induced damage in InGaAs," J. Vac. Sci. Technol., B, **16**(6), 3359 (1998)
$NH_4OH$:$H_2O_2$:$H_2O$ (3:1:130); mesa etch for AlGaAs/InGaAs; 3000 Å/min
citric acid:$H_2O_2$:$H_3PO_4$:$H_2O$ (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

BERG, E.W., and S.W. Pang, "Low-pressure etching of nanostructures and via holes using an inductively coupled plasma system," J. Electrochem. Soc., **146**(2), 775 (1999)
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

BERG, E.W., and S.W. Pang, "Time dependence of etch-induced damage generated by an electron cyclotron resonance source," J. Vac. Sci. Technol., B, **15**(6), 2643 (1997)
ECR etch damage, time dependence; GaAs

BERG, E.W., and S.W. Pang, "$Cl_2$ plasma passivation of etch damage in GaAs and InGaAs with an inductively coupled plasma source," J. Vac. Sci. Technol., B, **17**(6), 2745 (1999)
$Cl_2$ ICP plasma passivation of GaAs and InGaAs surface damage

BERKOVITS, V.L., V.P. Ulin, D. Paget, J.E. Bonnet, T.V. L'vova, P. Chiaradia, and V.M. Lantratov, "Chemical and photochemical processes in sulfide passivation of GaAs(1 0 0): In situ optical study and photoemission analysis," J. Vac. Sci. Technol., A, **16**(4), 2528 (1998)
$Na_2S$:$H_2O$ (2 and 0.4 M); sulfide passivation of GaAs

BERTONE, D., R.Y. Fang, G. Morello, and M. Meliga, "Selective growth of semi-insulating InP around masked non-planar structures using low-pressure pulsed metalorganic Epitaxy," J. Electrochem. Soc., **146**(3), 1167 (1999)
Reactive ion etch, first step pattern etch in InP using $CH_4$:$H_2$. (for MOVPE regrowth)
saturated bromine water: HBr: $H_2O$; second step following RIE etch for patterns in InP
FeCN:KOH:$H_2O$; cleaved cross-section layer delineation stain for SEM study

BERTRAND, P.A., "XPS Study of Chemically Etched GaAs and InP," J. Vac. Sci. Technol., **18**(1), 28–33 (1981)

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; $H_2SO_4$

BESLAND, M.P., Y. Robach, and J. Joseph, "In Situ Studies of the Anodic Oxidation of Indium Phosphide," J. Electrochem. Soc., **140**(1), 104–08 (1993)
Anodic oxidation; InP; study of oxidation mechanism

BESSOLOV, V.N., A.F. Ivankov, E.V. Konenkov, and M.V. Lebedev, "Sulfide passivation of GaAs in an isopropyl alcohol solution," Tech. Phys. Lett., **21**(1), 20 (1995a)
$Na_2S$:isopropanol (1:9); surface passivation of GaAs; reduces surface recombination and increases photoluminescence efficiency; comparison to passivation with:
$Na_2S:H_2O$ (1:9)
$Na_2S$:ethylene glycol (1:9)

BESSOLOV, V.N., A.F. Ivankov, and M.V. Lebedev, "Sulfide Passivation of III–V Semiconductors: The Starting Electronic Structure of a Semiconductor as a Factor in the Interaction Between its Valence Electrons and the Sulfur Ion," J. Vac. Sci. Technol., B, **13**(3), 1018–1023 (1995b)
$Na_2S:H_2O$ (1:9); sulfide passivation of GaAs, InP, GaP

BESSOLOV, V.N., E.V. Konenkova, and M.V. Lebedev, "Solvent effect on the properties of sulfur passivated GaAs," J. Vac. Sci. Technol., B, **14**(4), 2761 (1996)
$Na_2S$ 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

BESSOLOV, V.N., E.V. Konenkova, and M.V. Lebedev, "Sulfidization of GaAs in alcoholic solutions: a method having impact on efficiency and stability of passivation," Mater. Sci. Eng. B, **44**, 376 (1997a)
$(NH_4)_2S$ alcohol solutions
$Na_2S$ alcohol solutions
Study of passivation efficiency

BESSOLOV, V.N., M.V. Lebedev, B.V. Tsarenkov, and Yu M. Shernyakov, "Increase in the degree of catastrophic optical degradation of InGaAs/AlGaAs (977 nm) laser diodes after sulfidization in solutions based on isopropanol," Tech. Phys. Lett., **21**(7), 561 (1995c)3
$NaS_2$:isopropanol (1:9);sulfidization to reduce optical degradation in InGaAs/AlGaAs laser mirrors

BESSOLOV, V.N., M.V. Lebedev, and D.R.T. Zahn, "Raman scattering study of surface barriers in GaAs passivated in alcoholic sulfide solutions," J. Appl. Phys., **82**(5), 2640 (1997b)
Study of GaAs barrier height shift with surface sulfidization using:
$(NH_4)_2S(20\%)$:ethanol (1:9)
$(NH_4)_2S(20\%)$:isopropanol (1:9)
$(NH_4)_2S(20\%)$:*tert*-butanol (1:9)

BESSOLOV, V.N., M.V. Lebedev, N.M. Binh, M. Friedrich, and R.T. Zahn, "Sulphide passivation of GaAs: the role of the sulphur chemical activity," Semicond. Sci. Technol., **13**, 611 (1998)

Sulfide passivation study on GaAs; dependence on sulfur activity and solvent dielectric constant
$(NH_4)_2S$ (20%)
$Na_2S{:}H_2O$ (60%)
$S_2Cl_2{:}CCl_4$ (1:10)
$(NH_4)_2S{:}i\text{-}C_3H_7OH$ (20 v/o in isopropanol)
$(NH_4)_2S{:}t\text{-}C_4H_9OH$ (10 v/o in *tert*-butanol)
$Na_2S{:}i\text{-}C_3H_7OH$ $Na_2S{:}t\text{-}C_4H_9OH$

BHARADWAJ, L.M., P. Bonhomme, J. Faure, G. Balossier, and R.P. Bajpai, "Chemically assisted ion beam etching of GaAs and GaSb using reactive flux of iodine and Ar+ beam," SPIE Proceedings, Dry Etch Technology, **Vol. 1593**, 186 (1991)

CAIBE; $I_2/Ar+$; GaAs and GaSb

BHAT, R., B.J. Baliga, and S.K. Ghandhi, "Vapor-phase Etching and Polishing of GaAs using HCl Gas," J. Electrochem. Soc., **122**(10), 1378 (1975)

Thermochemical vapor etch; $HCl + H_2 + AsH_3$; GaAs (1 0 0) and (1 1 1)B in cold wall reactor

BHAT, R., C. Caneau, C.E. Zah, M.A. Koza, W.A. Bonner, D.M. Hwang, S.G. Schwarz, S.G. Menocal, and F.G. Favire, "Orientation Dependence of S, Zn, Si, Te, and Sn Doping OMCVD Growth of InP and GaAs: Application to DH Lasers and Lateral p–n Junction Arrays Grown on Non-planar Substrates," J. Cryst. Growth, **107**, 772–78 (1991)

$H_3PO_4{:}HCl$ (3:1); Application: InP photolithography; faceted grooves

BHAT, R., and S.K. Ghandhi, "The Effect of Chloride Etching on GaAs Epitaxy (OMCVD) Using TMG and $AsH_3$," J. Electrochem. Soc., **125**(5), 771–76 (1978)

Thermochemical etch; $AsH_3$, HCl; GaAs in situ etch for OMVPE

BHAT, R., and S.K. Ghandhi, "Vapor-phase Etching and Polishing of GaAs using Arsenic Trichloride," J. Electrochem. Soc., **124**, 1447 (1977)

Thermochemical vapor etch; $AsCl_3 + H_2$; GaAs (1 0 0) and (1 1 1)B in cold wall reactor

BHAT, R., J.R. Hayes, H. Schumacher, M.A. Koza, D.M. Hwang, and N.W. Meynadier, "High Gain InP/InGaAs Heterojunction Bipolar Transistors Grown by OMCVD," J. Cryst. Growth, **93**, 919–23 (1988)

$H_2SO_4{:}H_2O_2{:}H_2O$ (4:1:1); InP etch rate = 500 Å/min

BICKNELL, R.W., "A Simple Rotating Jet-thinning Apparatus for Producing Taper Sections and Electron Microscope Specimens from Silicon and Compound Semiconductors," J. Phys. D, **6**, 1991–97 (1973)

$Cl_2$/methanol; GaAs, InP, GaP, AlGaAs jet thinning of electron microscope specimens

BICKNELL, R.W., “A Simple Rotating Jet-thinning Apparatus for Producing Taper Sections and Electron Microscope Specimens from Silicon and Compound Semiconductors,” J. Phys. D, **6**, 1991–97 (1973)
$Cl_2$/methanol; GaAs, InP, GaP, AlGaAs jet thinning of electron microscope specimens

BIEDERMANN, E., and K. Brack, “Preparation of GaAs Specimens for Transmission Electron Microscopy,” J. Electrochem. Soc., **113**, 1088 (1966)
NaOCl:$H_2O$ (1:5); GaAs jet etch thinning; etch gives a grainy structure
HCl:$H_2O_2$:$H_2O$ (40:4:1); GaAs jet etch thinning; gives smooth, uniform etch

BIEFELD, R.M., “The Preparation of InSb and InAsSb by Metalorganic Chemical Vapor Deposition,” J. Cryst. Growth, **75**, 255–263 (1986)
$H_2SO_4$:$H_2O_2$:$H_2O$ (10:1:1); GaAs substrate cleaning for MOCVD
lactic acid:$HNO_3$ (10:1); InSb substrate cleaning for MOCVD
HF:$H_2O$ (1:1); InAs substrate cleaning for MOCVD

BISCHOPINK, G., and K.W. Benz, “THM growth of AlGaSb bulk crystals,” J. Cryst. Growth, **128**, 470–74 (1993a)
HF:$CH_3COOH$:$KMnO_4$ (1:1:1) (0.05 M); AlGaSb striation delineation etch

BISCHOPINK, G., and K.W. Benz, “THM Growth of $Al_xGa_{1-x}Sb$ Bulk Crystals,” J. Cryst. Growth, **128**, 470–74 (1993b)
HF:$CH_3COOH$:$KMnO_4$ (0.05 M) (1:1:1); AlGaSb striation and defect delineation etch

BLAAUW, C., A. Szaplonczay, K. Fox, and B. Emmerstorfer, “MOCVD of InP and Mass Transport on Structured InP Substrates,” J. Cryst. Growth, **77**, 326–33 (1986)
HCl:$HNO_3$:$H_2O$ (1:2:1); InP pattern etch for OMVPE regrowth; etch rate $\sim$ 4 μm/min

BOLAND, J.J., and J.H. Weaver, “A surface view of etching,” Physics Today, **51**(8), 34 (1998)
Review: STM study of surface reconstruction and effect on etching behavior

BÖNSCH, P., D. Wüllner, T. Schrimpf, A. Schlachetski, and R. Lacmann, “Ultrasmooth vee-grooves in InP by two-step wet chemical etching,” J. Electrochem. Soc., **145**(4), 1273 (1998)
HBr(37%); InP vee-groove etch using titanium mask, first step to form sharp vees with minimal undercutting; 20 s at 20°C
HBr:$K_2Cr_2O_7$ (3:1); InP vee-groove sidewall smoothing (step 2) using titanium mask
HF(40%):$HNO_3$(65%):$H_2O$ (5:24:64); selective removal of titanium mask from InP; 10 s at 20°C

BOSCH, M.A., L.A. Coldren, and E. Good, “Reactive Ion Beam Etching of InP with $Cl_2$,” Appl. Phys. Lett., **38**(4), 264–66 (1981)
Reactive ion etch; $Cl_2$; InP masked with Ti. InP etch rate $= 0.2$ μm/m 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 $O_2$; etch rate could go up to 0.75 μm/min

BÖTTNER, TH, H. Kräutle, E. Kuphal, K. Miethe, and H.L. Hartnagel, "Surface- and sidewall-damage of InP-based optoelectronic devices during reactive ion etching using $CH_4/H_2$," InP and Related Material Conference Proceedings, 1996, p. 115

Reactive ion etch of InP-based materials with $CH_4/H_2$; damage study

BOUADMA, N., P. Devoldere, B. Jusserand, and P. Ossart, "Ion Beam Etching and Surface Characterization of Indium Phosphide," Appl. Phys. Lett., **48**(19), 1285–87 (1986)

Ar ion sputter etch of InP; $LN_2$ cooled sample to improve surface morphology

$Ar^+$ ion beam etch; $LN_2$ 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/cm$^2$ and incident angle of 50°C; etch rate is higher when sample is cooled with $LN_2$

BOUADMA, N., J.F. Hogrel, J. Charil, and M. Carre, "Fabrication and Characteristics of Ion Beam Etched Cavity InP/InGaAsP BH Lasers," IEEE J. Quantum Electron., **QE-23**(6), 909–14 (1987)

Ar ion sputter etch; Application: InP/InGaAsP BH Laser cavity etch

$Br_2$/methanol (0.5%); 2–3 s etch to remove ion damage

BOURNE, O.L., D. Hart, D.M. Rayner, and P.A. Hackett, "Digital Etching of III–V Multilayer Structures Combined with Laser Ionization Mass Spectroscopy: Photon-assisted Depth Profiling," J. Vac. Sci. Technol., B, **11**(3), 556–61 (1993)

Photoassisted dry etch; $Cl_2$/He (1:3); GaAs monolayer by monolayer etch by surface chlorination followed by laser desorption of surface chlorides

BOURY, P., and G. Landgren, "Versatile reactive ion beam etching (RIBE) of InP-based materials using $CH_4/H_2$/Ar chemistry," InP and Related Material Conference Proceedings, 1996, p. 119

RIBE of InP-based materials with $CH_4/H_2$/Ar; etch is non-corrosive

BOWERS, J.E., B.R. Hemenway, and D.P. Wilt, "Etching of Deep Groves for the Precise Positioning of Cleaves in Semiconductor Lasers," Appl. Phys. Lett., **46**(5), 453–55 (1985)

HCl:$H_2O$ (1:20); Application: InP n-type photoelectrochemical etch with the sample biased to form a surface depletion layer; forms deep narrow grooves

BRAKE, J., C.Y. Cha, B.Y. Han, D.W. Owens, and J.H. Weacer, "Coverage-dependent etching pathways for Br–GaAs (1 1 0)," J. Vac. Sci. Technol., B, **15**(3), 670 (1997)

Br thermochemical etch of GaAs; STM study of etch mechanism dependence on Br concentration at 700°K

BRENNER, T., and H. Melchior, "Local Etch-Rate Control of Masked InP/InGaAsP by diffusion-Limited Etching," J. Electrochem. Soc., **141**(7), 1954–56 (1994)

$Br_2$/Methanol (0.2%); InP/InGaAsP; with $SiO_x$ 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

BREWER, P., S. Halle, and R.M. Osgood, "Photon-assisted Dry Etching of GaAs," Appl. Phys. Lett., **45**(4), 475–77 (1984)
UV photochemical etching of GaAs in $CF_3Br$ or $CH_3Br$

BREWER, P.D., D. McClure, and R.M. Osgood, "Dry, Laser-Assisted Rapid HBr Etching of GaAs," Appl. Phys. Lett., **47**(3), 310–312 (1985)
Photochemical dry etching of GaAs in HBr

BREWER, P.D., D. McClure, and R.M. Osgood, "Excimer Laser Projection Etching of GaAs," Appl. Phys. Lett., **49**(13), 803–805 (1986)
Photochemical dry etch of GaAs in HBr

BROEKAERT, T.P.E., and C.G. Fonstad, "AlAs Etch-stop Layers for InGaAlAs/InP Heterostructure Devices and Circuits," IEEE Trans. Electron Devices, **ED-39**(3), 533–39 (1992a)
$H_3PO_4$:$H_2O_2$:$H_2O$ (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:$H_2O$ (15 g; 2 l), pH = 6.3 (by adding ammonia)
OCA = oxalic acid:$H_2O$:citric acid (25 g:2 l:100 g), pH = 6.3
MA = malonic acid:$H_2O$ (75 g:1 l), *pH* = 6.1
SA = succinic acid:$H_2O$ (200 g:1 l), pH = 4.2
Etchant solutions (for InGaAs selective etch from InAlAs and InAlAs selective etch from AlAs):

| | $In_{0.53}Ga_{0.47}As$ (nm/min) | $In_{0.52}Al_{0.48}As$ (nm/min) | AlAs (nm/min) | GaAs (nm/min) |
|---|---|---|---|---|
| OA:$H_2O_2$ (20:1) | 40 | 20 | 0.57 | – |
| OCA:$H_2O_2$ (25:1) | 75 | 5 | 0.20 | – |
| MA:$H_2O_2$ (25:1) | 100 | 6 | 1.23 | – |
| SA:$H_2O_2$ (15:1) | 120 | 60 | 0.12 | 180 |

BROEKAERT, T.P.E., and C.G. Fonstad, "Novel, Organic Acid-Based Etchants for InGaAlAs/InP Heterostructure Devices with AlAs Etch-stop Layers," J. Electrochem. Soc., **139**(8), 2306–09 (1992b)
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) $Br_2$/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 $Br_2$, F; demonstrates need for high purity water rinse to reduce ionic contaminants

(B) $HCl:H_2O_2:H_2O$ (150:1:100); InAs surface cleaning 5 min; leaves surface pitting and chloride contamination

BROWN, E.R., S.J. Eglash, G.W. Turner, C.D. Parker, J.V. Pantano, and D.R. Calawa, ''Effect of Lattice-Mismatched Growth on InAs/AlSb Resonant-Tunneling Diodes,'' IEEE Trans. Electron Devices, **41**(6), 879–81 (1994)

$H_2SO_4:H_2O_2:H_2O$ (1:8:80); Application: InAs/AlSb mesa etch

BROWN, G.T., B. Cockayne, and W.R. MacEwan, ''Etch Features in Czochralski Grown Single Crystal InP,'' J. Mater. Sci., **15**, 2539–49 (1980)

$HBr:H_3PO_4$ (1:2) {Huber etch}; InP, delineation of pits, ridges, and striations, 1–2 min at 20°C

$CrO_3:AgNO_3:H_2O:HF$ (1 g:8 mg:2 ml:1 ml) {A–B etch}; InP, delineation of pits, ridges, and striations, 30–90 min at 60°C

BROWN, G.J., S.M. Hegde, J. Hoff, C. Jelen, S. Slivken, E. Michel, O. Duchemin, E. Bigan, and M. Razighi, ''Intersubband hole absorption in GaAs–InGaP quantum wells grown by gas source molecular beam epitaxy,'' Appl. Phys. Lett., **65**(9), 1130–1132 (1994)

$H_3PO_4:H_2O_2:H_2O$ (1:1:10); selective etch of GaAs from InGaP. HCl; selective etch of InGaP from GaAs

BRUNEMEIER, B.E., B.C. Schmukler, W.A. Strifer, D.H. Rosenblatt, and R.D. Remba, ''A High-selectivity Citric Buffer Etch for Practical GaAs Devices with AlGaAs Etch Stop Layers,'' 1993 Electronic Materials Conference, UCSB, Santa Barbara, CA, June 23–25; paper S3; Abstract in J. Electron. Mater., **22**(A7), A47 (1993)

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

buffer:$H_2O_2$ (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 $Al_{0.35}Ga_{0.65}As$ or 8 Å AlAs. The buffered solution is insensitive to dilution or contamination. GaAs etch rate = 45 Å/s

BUBAR, S.F., and D.A. Vermilyea, ''Explosion of a Chemical Polishing Solution,'' J. Electrochem. Soc., **113**, 519 (1966)

Lactic acid:$HNO_3$:HF (50:8:2); Safety caution: This etchant evolves heat and gas when stored which can explosively burst capped containers

BUCKMANN, P., and J.N. Houghton, ''Optical Y-junction and S-bends Formed by Preferentially Etched Single-mode Rib Waveguides in InP,'' Electron. Lett., **18**, 850 (1982)

$H_3PO_4$:HCl (3:1); Application: InP (1 0 0) photolithography; rectangular cross-section rib etch

BUDA, M., E. Smallbrugge, E.-J Geluk, F. Karouta, G.A. Acket, T.G. van der Roer, and L.M.F. Kaufmann, "Controlled anodic oxidation for high precision etch depth in AlGaAs III–V semiconductor," J. Electrochem. Soc., **145**(3), 1076 (1998)

Citric acid (3 g in 100 ml $H_2O$):ethyleneglycol (1:2), with pH adjusted to 6 using ammonia; electrolyte for anodizing $Al_xGa_{1-x}As$. $HCl:H_2O$ (1:10); anodic oxide removal from $Al_xGa_{1-x}As$ (to thin $Al_xGa_{1-x}As$ by repeated discrete incremental steps)

BURKE, T.M., M.A. Quierin, M.P. Grimshaw, D.A. Ritchie, M. Pepper, and J.H. Burroughes, "Surface decontamination of patterned GaAs substrates for molecular beam epitaxy regrowth using a hydrogen radical source," J. Vac. Sci. Technol., B, **15**(2), 325 (1997)

Surface cleaning of GaAs in hydrogen radicals for MBE epilayer regrowth

BURTON, R.H., C.L. Hollien, L. Marchut, S.M. Abys, G. Smolinsky, and R.A. Gottscho, "Etching of GaAs and InP in RF Discharges Through Mixtures of Trichlorofluoromethane and Oxygen," J. Appl. Phys., **54**(11), 6663–71 (1983)

Plasma etch; $CCl_3F/O_2$; GaAs and InP

BURTON, R.H., and G. Smolinsky, "$CCl_4$ and $Cl_2$ Plasma Etching of III–V Semiconductors and the Role of Added $O_2$," J. Electrochem. Soc., **129**(7), 1599–1604 (1982)

Plasma etching kinetics of InP, GaAs, and GaP at 300°C in combinations of $O_2$ with either $Cl_2$ or $CCl_4$

BURTON, R.H., H. Temkin, and V.G. Keramidas, "Plasma Separation of InGaAsP/InP Light Emitting Diodes," Appl. Phys. Lett., **37**(4), 411–12 (1980)

Plasma etch; $CCl_4/O_2$; Application: InGaAsP/InP separation of LEDs

BUTCHER, K.S.A., R.J. Egan, T.L. Tansley, and D. Alexiev, "Sulfur contamination of (1 0 0) GaAs resulting from sample preparation procedures and atmospheric exposure," J. Vac. Sci. Technol., B, **14**(1), 152–158 (1996)

$H_2SO_4:H_2O_2:H_2O$ (3:1:1); study of sulfur contamination of GaAs from etchant
$HCl:H_2O$; removal of sulfur contamination from GaAs following etch in $H_2SO_4:H_2O_2:H_2O$

CABANISS, G.E., "Improved Electrolyte Solutions for Carrier Concentration Depth Profiling of Compound Semiconductors by Electrochemical Capacitance–Voltage (ECV) Analysis," Materials Research Society, Fall Meeting, Boston, MA Nov. 28–Dec. 3, 1988, poster #D5.17

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)

CAMACHO, A., and D.V. Morgan, "Reactive Ion Etching of GaAs through Wafer Via Holes using $Cl_2$ and $SiCl_4$ gases with Regressive Statistical Approach," J. Vac. Sci. Technol., B, **12**(5), 2933–40 (1994)

Reactive ion etch; $Cl_2$ and $SiCl_4$; GaAs; study of characteristics for etching via holes

CAMERON, N.I., S. Ferguson, M.R.S. Taylor, S.P. Beaumont, M. Holland, C. Tronche, M. Soulard, and P.H. Ladbrooke, "Selectively Dry Gate Recessed GaAs Metal–Semiconductor Field-Effect Transistors, High Electron Mobility Transistors, and Monolithic Microwave Integrated Circuits," J. Vac. Sci. Technol., B, **11**(6), 2244–48 (1993)

Reactive ion etch, $CCl_2F_2$: Application: GaAs selective etch with AlGaAs etch stop; GaAs:$Al_{0.3}Ga_{0.7}As$ selectivity $> 4000:1$

CAMERON, N.J., G. Hopkins, I.G. Thayne, S.P. Beaumont, C.D.W. Wilkinson, M. Holland, A.H. Kean, and C.R. Stanley, "Selective Reactive Ion Etching of GaAs/AlGaAs Metal–semiconductor Field Effect transistors," J. Vac. Sci. Technol., B, **9**(6), 3538–41 (1991)

Reactive ion etch; $CCl_2F_2$; Application: GaAs selective etch from $Al_{0.3}Ga_{0.7}As$ stop etch layer; selectivity $> 4000$; gas residence time dependent

CANEAU, C., R. Bhat, M. Koza, J.R. Hayes, and R. Esagui, "Etching of InP by HCl in an OMVPE Reactor," J. Cryst. Growth, **107**, 203–08 (1991)

Thermochemical vapor etch; $HCl + H_2 + PH_3$; InP etch through $SiO_2$ masks for OMVPE

CAPASSO, F., R.A. Logan, P.W. Foy, S. Sumski, and D.D. Manchon, "Low-Leakage Current and Saturated Reverse Characteristics in Broad-Area InGaAsP Diodes," Electron. Lett., **16**, 241–42 (1980)

$Br_2$/methanol; Application: InGaAsP/InP non-selective mesa etch. buffered HF (i.e. $NH_4F$:HF (10:1)); InGaAsP oxide removal

CARACCI, S.J., M.R. Krames, N. Holonyak Jr., C.M. Herzinger, A.C. Crook, T.A. DeTemole, and P.-A. Besse, "Native-Oxide-Defined Low-Loss AlGaAs–GaAs Planar Waveguide Bends," Appl. Phys. Lett., **63**(16), 2265–67 (1993)

$H_2SO_4:H_2O_2:H_2O$ (1:8:80); Application: $Al_{0.1}Ga_{0.9}As$ contact layer removal for waveguide fabrication

CARIDI, E.A., and T.Y. Chang, "Improved Techniques for Orientation of (1 0 0) InP and GaAs Wafers," J. Electrochem. Soc., **131**(6), 1440–41 (1984)

$H_3PO_4$:HBr (2:1) {Huber etch}; InP first step etch pit delineation; 1–2 min at 20°C gives symmetrical etch pits

$H_2SO_4:H_2O_2:H_2O$ (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

$HCl:H_2O_2:H_2O$ (1:1:1); GaAs first step surface roughening etch. 10 min

$H_2SO_4:H_2O_2:H_2O$ (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

CARLSTRÖM, C.F., S. Anand, and G. Landgren, "Trimethylamine: Novel source for low damage reactive ion beam etching of InP," J. Vac. Sci. Technol., B, **17**(6), 2660 (1999)

RIBE of InP using trimethylamine/Ar; damage study

CARLSTRÖM, C.F., G. Landgren, and S. Anand, "Low energy ion beam etching of InP using methane chemistry," J. Vac. Sci. Technol., B, **16**(3), 1018 (1998)

Reactive ion beam etch and chemically assisted ion beam etch using $N_2/CH_4/H_2$ and $Ar/CH_4/H_2$ of InP. CAIBE produces less polymer by-product

CARPI, E.L., M. Van Hove, J.L. Alay, and M. Van Rossum, "Optimization of Reactive Ion Etching of $Al_{0.48}In_{0.52}As$ in $CH_4/H_2$ by the Experimental Design Method," J. Vac. Sci. Technol., B, **13**(3), 895–901 (1995)

RIE etch; $CH_4/H_2$; $Al_{0.48}In_{0.52}As$ etch optimization

CARRABBA, M.M., N.M. Nguyen, and R.D. Rauh, "Effects of Doping and Orientation on Photoelectrochemically Etched Features in n-GaAs," J. Electrochem. Soc., **134**(7), 1855–59 (1987)

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

CARRABBA, M.M., N.M. Nguyen, and R.D. Rauh, "Photoelectrochemical Fabrication of Sawtooth Gratings in n-GaAs," Appl. Opt., **25**(24), 4516–18 (1986)

Photoelectrochemical etch of GaAs using electrolytes of either 1 M KCl or 0.5 M Tiron (4,5-dihydroxy-1,3-benzene disulfonic acid, disodium salt); pH = 7, non-corrosive, compatible with photoresists; Application: sawtooth grating fabrication

CARTER, A.J., B. Thomas, D.V. Morgan, J.K. Bhardwaj, A.M. McQuarrie, and M.A. Stephens, "Dry Etching of GaAs and InP for Optoelectronic Devices," IEE Proceedings, Pt. J, **136**(1), 2–5 (1989)

Plasma etching; $CH_4/H_2$; GaAs and InP etch characteristics dependence on temperature; gives favorable surface roughness compared with Cl-based etchants

CARTER-COMAN, C., R. Bicknell-tassius, R.G. Benz, A.S. Brown, and N.M. Jokerst, "analysis of GaAs substrate removal etching with citric acid:$H_2O_2$ and $NH_4OH:H_2O_2$ for application to compliant substrates," J. Electrochem. Soc., **144**(2), L29 (1997)

citric acid:$H_2O_2$ ($m$:1, with $1 < m < 9$); GaAs substrate removal using AlAs or AlGaAs etch stop layers; problems with etch stop layer oxidation

$NH_4OH:H_2O_2$; GaAs substrate removal using AlAs or AlGaAs etch stop layers

$NH_4OH:H_2O$ (1:10); GaAs surface oxide removal prior to other etching

CATANA, A., R.F. Broom, R. Germann, and P. Roentgen, "Regrowth of InP by MOVPE on Dry-etched Heterostructures of InP–GaInAsP," J. Cryst. Growth, **129**, 779–82 (1993)

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

CHA, C.Y., J. Brake, B.Y. Han, D.W. Owens, and J.H. Weaver, "Surface morphologies associated with thermal desorption: Scanning tunneling microscopy studies of Br–GaAs (1 1 0)," J. Vac. Sci. Technol., B, **15**(3), 605 (1997)

Br etch mechanism study of GaAs by STM

CHA, C.Y., and J.H. Weaver, ‘‘Layer-by-layer removal of GaAs (1 1 0) by bromine,’’ J. Vac. Sci. Technol., B, **14**(6), 3559 (1996)
Monolayer etching of GaAs in $Br_2$ vapor; study of etch kinetics

CHAI, Y.G., and R. Yeats, ‘‘$In_{0.53}Ga_{0.47}As$ Submicrometer FETs Grown by MBE,’’ IEEE Electron Device Lett., **EDL-4**(7), 252–54 (1983)
Citric acid:$H_2O_2$ (24:1); Application: InGaAs FET flat bottom gate recess etch

CHAI, Y.G., C. Yuen, and G.A. Zdasiuk, ‘‘Investigation on InGaAs for High-frequency Microwave Power FETs,’’ IEEE Trans. Electron Devices, **ED-32**(5), 972–77 (1985)
Citric acid:$H_2O_2$ (24:1); Application: $In_{0.53}Ga_{0.47}As$ FET gates; uses undercutting of photolithography mask to achieve submicron widths

CHAKRABARTI, U.K., S.J. Pearton, A. Katz, W.S. Hobson, and C.R. Abernathy, ‘‘Dry Etching of III–V Semiconductors in $CH_3I$, $C_2H_5I$, and $C_3H_7I$ Discharges,’’ J. Vac. Sci. Technol., B, **10**(6), 2378–85 (1992)
ECR plasma; $CH_3I$, $C_2H_5I$, and $C_3H_7I$ with Ar and $H_2$; Study: etch rates, surface morphology, damage, etch anisotropy for InP, InAs, InSb, GaAs, AlGaAs, GaSb, InAlAs, InGaAs, and InAlP

CHAKRABARTI, U.K., S.J. Pearton, and F. Ren, ‘‘Sidewall Roughness During Dry Etching of InP,’’ Semicond. Sci. Technol., **6**, 408–10 (1991)
Plasma etch; $CH_4 + H_2 + Ar$; InP; sidewall roughness is related to roughness of mask edge

CHAKRABARTI, U.K., F. Ren, S.J. Pearton, and C.R. Abernathy, ‘‘Effect of Substrate Temperature on Dry Etching of InP, GaAs, and AlGaAs in Iodine- and Bromine-Based Plasmas,’’ J. Vac. Sci. Technol., A, **12**(4), 1129–33 (1994)
ECR etch; HBr/$H_2$/Ar and HI/$H_2$/Ar; InP, GaAs, AlGaAs; effect of substrate temperature

CHAN, R.H., and K.Y. Cheng, ‘‘Optimizing the reactive ion etching of p-InGaP with $CH_4/H_2$ by a two-level fractional factorial design process,’’ J. Vac. Sci. Technol., B, **14**(5), 3219 (1996)
Reactive ion etch; $CH_4/H_2$ of p-InGaP and p-GaAs; etch rate study

CHAND, N., and R.F. Karlicek, ‘‘Real-time Monitoring and Analysis of Chemical Wet Etching of III–V Compound Semiconductors,’’ J. Electrochem. Soc., **140**(3), 703–05 (1993)
Real-time etch rate monitoring by optical interferometry of AlGaAs/GaAs and InGaAsP/InP structures
$NH_4OH$:$H_2O_2$:$H_2O$ (3:1:50); AlGaAs/GaAs thinning etch

CHANG, C.V.J.M., and J.C.N. Rijpers, ‘‘Reactive Ion Etching of AlInGaP and GaAs in $SiCl_4/CH_4$/Ar-Based Plasmas,’’ J. Vac. Sci. Technol., B, **12**(2), 536–39 (1994)
Reactive ion etch; $SiCl_4/CH_4$/Ar; AlInGaP and GaAs

CHANG, H.L., and L.G. Meiners, ‘‘A Low Temperature Process for Vapor Etching of Indium Phosphide,’’ J. Vac. Sci. Technol. B, **3**(6), 1625–30 (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

CHANG, R.P.H., C.C. Chang, and S. Darack, "Hydrogen Plasma Etching of Semiconductors and Their Oxides," J. Vac. Sci. Technol., **20**(1), 45–50 (1982)
Plasma etch; hydrogen etching of GaAs, GaSb, InP and their oxides. InP etching preferentially removes phosphorus and leaves In to accumulate on the surface

CHAPLART, J., B. Fay, and N.T. Linh, "Reactive Ion Etching of GaAs Using $CCl_2F_2$ and the effect of Ar Addition," J. Vac. Sci. Technol., B, **1**, 1050 (1983)
Reactive ion etch; $CCl_2F_2$/Ar; GaAs

CHASE, B.D., D.B. Holt, and B.A. Unvala, "Jet Polishing of Semiconductors: I. Automatic Jet Thinning of GaP for Transmission Electron Microscopy," J. Electrochem. Soc., **119**(3), 310–313 (1972a)
$Cl_2$/methanol; GaP jet thinning for TEM samples

CHASE, B.D., D.B. Holt, and B.A. Unvala, "Jet Polishing of Semiconductors: I. Electrochemically Formed Tunnels in GaP," J. Electrochem. Soc., **119**(3), 314–317 (1972b)
$Cl_2$/methanol; GaP jet thinning for TEM samples

CHAVARKAR, P., D.S.L. Mui, T. Strand, L.A. Coldren, and U.K. Mishra, "Analysis of in situ etched and regrown AlInAs/GaInAs interfaces," J. Cryst. Growth, **175/176**, 393 (1997)
Thermochemical etch; $Cl_2$; in situ etch of InGaAs for regrowth of AlInAs by MBE

CHEN, C.-H., Y.-J. Chiu, and E.L. Hu, "Characterization of the radiation-enhanced diffusion of dry-etch damages in n-GaAs," J. Vac. Sci. Technol., B, **15**(6), 2648 (1997)
Ar ion etch damage of GaAs; study of Schottky diodes and DLTS

CHEN, C.P., K.S. Din, and F.S. Huang, "Reactive ion etching of TaSix in a $CF_4$–$O_2$ discharge," Mat. Res. Soc. Symp. Proc., **240**, 379 (1992)
Reactive ion etch; $CF_4$–$O_2$; GaAs pattern etch with TaSix contact mask for self-aligned MESFETs

CHEN, C.-H., D.L. Green, and E.L. Hu, "Diffusion and channeling of low-energy ions: The mechanism of ion damage," J. Vac. Sci. Technol., B, **13**(6), 2355 (1995)
Reactive ion etch damage; mechanism modeling; results with GaAs/AlGaAs

CHEN, C.-H., S. Keller, E.D. Haberer, L. Zhang, S.P. DenBaars, E.L. Hu, U.K. Mishra, and Y. Wu, "Reactive ion etching for gate recessing of AlGaN/GaN field effect transistors," J. Vac. Sci. Technol., B, **17**(6), 2755 (1999)
Reactive ion etching of AlGaN/GaN using $Cl_2$; Application to FET gate recessing

CHEN, C.-H., D.G. Yu, E.L. Hu, and P.M. Petroff, "Photoluminescence studies on radiation enhanced diffusion of dry-etch damage in GaAs and InP materials," J. Vac. Sci. Technol., B, **14**(6), 3684 (1996)

Ar ion etch damage study; GaAs and InP; enhanced defect diffusion with illumination energies above bandgap

CHEN, E.H., T.P. Chin, M.R. Melloch, and J.M. Woodall, "The Use of Annealed LTG-GaAs as a Selective Photoetch-Stop Layer (EMC abstract)," J. Electron. Mater., **24**(7), A33 (1995)

KOH (1 M); selective photoetch of n-GaAs from stop layer of low-temperature MBE grown GaAs:As

CHEN, K.L., and S. Wang, "Etched-coupled-cavity InGaAsP/InP Lasers," Electron. Lett., **21**(3), 94–95 (1985)

HCl:$H_2O$ (4:1); Application: InP selective etch from InGaAsP at 15°C for laser fabrication

CHEN, N., "Ultrasonic Etching of GaAs in $CrO_3$–HF Aqueous Solutions," J. Cryst. Growth, **129**, 777–78 (1993)

$CrO_3$:HF:$H_2O$ (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

CHEN, P.C., K.L. Yu, S. Margalit, and A. Yariv, "A New GaInAsP/InP T-Laser at 1.2 μm Fabricated on Semi-insulating Substrate," Jpn. J. Appl. Phys., **19**(12), L775–L776 (1981)

$Br_2$/methanol; Application: InP substrate cleaning. $H_2SO_4$:$H_2O_2$:$H_2O$ (3 1:1); InGaAsP selective etch from InP. HCl; InP selective etch from InGaAsP

CHEN, T.R., L.C. Chiu, K.L. Yu, U. Koren, A. Hasson, S. Margalit, and A. Yariv, "Low Threshold InGaAsP Terrace Transport Laser on Semi-insulating Substrate," Appl. Phys. Lett., **41**(12), 1115–17 (1982)

KOH: $K_3Fe(CN)_6$:$H_2O$; or $H_2SO_4$:$H_2O_2$:$H_2O$; Application: InGaAsP selective etch from InP for laser fabrication. HCl:$H_2O$ (1.5:1); InP selective etch from InGaAsP

CHEN, W.L., J.C. Cowles, G.I. Hadda, G.O. Munns, K.W. Eisenbeiser, and J.R. East, "Ohmic Contact Study for Quantum Effect Transistors and Heterojunction Bipolar Transistors with InGaAs Contact Layers," J. Vac. Sci. Technol., B, **10**(6), 2354–60 (1992)

HCl:$H_2O$ (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

CHEN, W.X., L.M. Walpita, C.C. Sun, and W.S.C. Chang, "Ion Beam Etching of InGaAs, InP, GaAs, Si and Ge," J. Vac. Sci. Technol. B, **4**(3), 701–05 (1986)

Ion beam etch; Ar/$O_2$; $CF_4$, $C_2F_6$ 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

CHENG, C.L., A.S.H. Liao, T.Y. Chang, E.A. Caridi, L.A. Coldren, and B. Lalevic, "Silicon Oxide Enhanced Schottky Gate $In_{0.53}Ga_{0.47}As$ FETs with a Self-aligned Recessed Gate Structure," IEEE Electron Device Lett., **EDL-5**(12), 511–14 (1984)

$H_3PO_4$:$H_2O_2$:$H_2O$ (1:1:38); Application: InGaAs FET channel recess

CHENG, C.C., A. Scherer, V. Arbet-Engels, and E. Yablonovitch, “Lithographic band gap tuning in photonic band gap crystals,” J. Vac. Sci. Technol., B, **14**(6), 4110 (1996)

Cl$_2$ chemically assisted Ar ion beam etching of GaAs to form 3D interlinked mesh structures

CHEUNG, R., Y.H. Lee, K.Y. Lee, T.P. III Smith, D.P. Kern, S.P. Beaumont, and C.D.W. Wilkinson, “Comparison of Damage in the Dry Etching of GaAs by Conventional Reactive Ion Etching and by Reactive Etching with an Electron Cyclotron Resonance Generated Plasma,” J. Vac. Sci. Technol. B, **7**(6), 1462–66 (1989)

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 $In_{0.52}Al_{0.48}As/In_{0.53}Ga_{0.47}As/InP$ high electron mobility transistors,” J. Vac. Sci. Technol., B, **14**(6), 3679 (1996)

reactive ion etch; $CH_4/H_2$; transistor gate recess etch; selective etch of InAlAs from InGaAs $H_3PO_4:H_2O_2:H_2O$ (1:1:150); non-selective InAlAs/InGaAs etch at 22°C. isopropanol:$H_2O$ (1:5); wetting agent post etch rinse

CHEUNG, R., R.J. Reeves, B. Rong, S.A. Brown, E.J.M. Fakkeldij, E. van der Drift, and M. Kamp, “High resolution reactive ion etching of GaN and etch-induced effects,” J. Vac. Sci. Technol., B, **17**(6), 2759 (1999)

Reactive ion etch of GaN patterns using SF$_6$ and Ar; damage study

CHEUNG, R., S. Thoms, M. Watt, M.A. Foad, C.M. Sotomayor-Torres, C.D.W. Wilkinson, U.J. Cox, R.A. Cowley, C. Dunscombe, and R.H. Williams, “Reactive Ion Etching-Induced Damage in GaAs and $Al_{0.3}Ga_{0.7}As$ using SiCl$_4$,” Semicond. Sci. Technol., **7**, 1189–98 (1992)

Reactive ion etch; SiCl$_4$; GaAs and $Al_{0.3}Ga_{0.7}As$-induced damage study

CHEVRIER, J., M. Armand, A.M. Huber, and N.T. Linh, “Vapor Growth of InP for MISFETs,” J. Electron. Mater., **9**(4), 745–61 (1980)

$Br_2:HBr:H_2O$ (1:17:1000); Application: InP FET channel etch preparation for Schottky contact

CHEVRIER, J., A.M. Huber, and N.T. Linh, “Effect of in situ Etching and Substrate Misorientation on the Morphology of VPE InP layers,” J. Cryst. Growth, **54**, 369–71 (1981)

Thermochemical vapor etch; $PCl_3 + H_2$; Application InP VPE growth

CHEW, N.G., and A.G. Cullis, “Iodine Ion Milling of Indium-containing Compound Semiconductors,” Appl. Phys. Lett., **44**(1), 142–44 (1984)

Ion milling; iodine, Ar, Xe; InP

CHI, G.C., F.W. Ostermayer, K.D. Cummings, and L.R. Harriott, “Ion Beam Damage-induced Masking for Photoelectrochemical Etching of III–V Semiconductors,” J. Appl. Phys, **60**(11), 4012–14 (1986)

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
$H_2SO_4$:methanol (3 ml:250 ml); electrolyte for InGaAs
$H_2SO_4$ (2 M); electrolyte for InGaAsP and InP

CHIN, B.H., and K.L. Barlow, "Bromine/methanol Polishing of $\langle 1\,0\,0\rangle$ InP Substrates," J. Electrochem. Soc., **135**(12), 3120–25 (1988)
$Br_2$/methanol; InP, polishing techniques for (1 0 0) substrates

CHIN, B.H., and K.L. Lee, "Bromine/methanol Polishing of $\langle 1\,0\,0\rangle$ InP: II. Dependence on Bromine Concentration," J. Electrochem. Soc., **137**(2), 663–65 (1990)
$Br_2$/methanol; InP (1 0 0) polishing; dependence on $Br_2$ concentration

CHIU, T.H., W.T. Tsang, R.M. Kapre, M.D. Williams, and J.F. Ferguson, "Monolayer Control of Chemical Beam Etching for Regrowth," InP and Related Material Conference Proceedings, 1994, (IEEE cat. no. 94CH 3369-6), paper ThF1, pp. 599–602
Thermochemical etch; $PCl_3$; InP in situ CBE chamber etch at 550°C. Thermochemical etch; $AsCl_3$; GaAs at 600°C

CHO, H., Y.-B. Hahn, D.C. Hays, C.R. Abernathy, S.M. Donovan, J.D. MacKenzie, and S.J. Pearton, "III-nitride dry etching: comparison of inductively coupled plasma chemistries," J. Vac. Sci. Technol., A, **17**(4), 2202 (1999)
Inductively coupled plasma etch of GaN, InN and AlN with $BI_3$, $BBr_3$, ICl and IBr

CHO, H., J. Hong, T. Maeda, S.M. Donovan, C.R. Abernathy, S.J. Pearton, and R.J. Shul, "Novel plasma chemistries for highly selective dry etching of $In_xGa_{1-x}N$: $BI_3$ and $BBr_3$," Mater. Sci. Eng., **B59**, 340 (1999)
Inductively coupled plasma etch, selective removal of InN and InGaN from GaN using $BI_3$ and $BBr_3$

CHO, H., C.B. Vartuli, S.M. Donovan, C.R. Abernathy, S.J. Pearton, R.J. Shul, and C. Constantine, "Comparison of inductively coupled plasma $Cl_2$ and $CH_4/H_2$ etching of III-nitrides," J. Vac. Sci. Technol., A, **16**(3), 1631 (1998a)
ICP of GaN, InN, AlN, InAlN and InGaN in $Cl_2$ and $CH_4/H_2$ plasmas

CHO, H., C.B. Vartuli, S.M. Donovan, J.D. MacKensie, C.R. Abernathy, S.J. Pearton, R.J. Shul, and C. Constantine, "Low bias dry etching of III-Nitrides in $Cl_2$-based inductively coupled plasmas," J. Electron. Mater., **27**(4), 166 (1998b)
Inductively coupled plasma etch; $Cl_2$/Ar, $Cl_2/N_2$, $Cl_2/H_2$ of InN, InGaN, GaN, InAlN and AlN; dependences on $Cl_2$ percent and pressure

CHO, H.K., J.Y. Lee, B. Lee, J.H. Baek, and W.S. Han, "Control of wet-etching thickness in the vertical cavity surface emitting laser structure by in situ laser reflectometry," J. Vac. Sci. Technol., B, **17**(6), 2626 (1999)

$H_3PO_4$:$H_2O_2$:$H_2O$ (1:1:10); Application: non-selective etch of AlGaAs/GaAs and InAlGaAs/InAlAs. Etch depth monitoring with laser reflectometry

CHO, S.-J., and P.G. Snyder, ‘‘Real time monitoring and control of wet etching of GaAs/$Al_{0.3}Ga_{0.7}As$ using real time spectroscopic ellipsometry,’’ J. Vac. Sci. Technol., B, **17**(5), 2045 (1999)
Citric acid (1 wt.% anhydrous to 1 wt.% water):$H_2O_2$:$H_2O$ (5:1:75)
GaAs/$Al_{0.3}Ga_{0.7}As$ 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

CHOQUETTE, K.D., R.S. Freund, M. Hong, H.S. Luftman, S.N.G. Chu, J.P. Mannaerts, and R.C. Wetzel, ‘‘Hydrogen Plasma Processing of GaAs and AlGaAs,’’ J. Vac. Sci. Technol., B, **11**(6), 2025–31 (1993a)
ECR plasma etch, $H_2$; GaAs and AlGaAs surface oxide removal for MBE growth

CHOQUETTE, K.D., M. Hong, H.S. Luftman, S.N.G. Chu, J.P. Mannaerts, R.C. Wetzel, and R.S. Freund, ‘‘GaAs Surface Reconstruction Obtained Using a Dry Process,’’ J. Appl. Phys., **73**(4), 2035–37 (1993b)
ECR plasma; hydrogen surface cleaning of GaAs in situ for MBE

CHOQUETTE, K.D., M. Hong, S.N.G. Chu, H.S. Luftman, J.P. Mannaerts, R.C. Wetzel, and R.S. Freund, ‘‘Hydrogen Plasma Removal of AlGaAs Oxides Before Molecular Beam Epitaxy,’’ Appl. Phys. Lett., **62**(7), 735–37 (1993c)
$H_2$ plasma oxide removal; AlGaAs cleaning for MBE overgrowth

CHOQUETTE, K.D., R.J. Shul, A.J. Howard, D.J. Rieger, R.S. Freund, and R.C. Wetzel, ‘‘Smooth Reactive Ion Etching of GaAs Using a Hydrogen Plasma Pretreatment,’’ J. Vac. Sci. Technol., B, **13**(1), 40–41 (1995)
Reactive ion Etch; $SiCl_4$; GaAs, smooth surfaces with $H_2$ plasma pretreatment to remove oxides

CHOQUETTE, K.D., R.C. Wetzel, R.S. Freund, and R.F. Kopt, ‘‘Electron Cyclotron Resonance Plasma Etching Using Downstream Magnetic Confinement,’’ J. Vac. Sci. Technol., B, **10**(6), 2725–28 (1992)
ECR plasma etch; $SiCl_4$; Study: GaAs etch rates, etch profiles and uniformity

CHOY, W.H., R.W.M. Kwok, B.K.L. So, G.C.K. Hui, Y.J. Chen, J.B. Xu, S.P. Wong, and W.M. Lau, ‘‘Surface roughness and oxide contents of gas-phase and solution-phase polysulfide passivation of III–V surfaces,’’ J. Vac. Sci. Technol., A, **17**(1), 93 (1999)
$(NH_4)_2S_x$ sulfidation of GaAs and InP; study of surface roughness and oxygen content. $H_2S$ + 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

CHRISTOU, A., and K. Sleger, "A Comparison of Ta and Al Schottky-barrier gates for GaAs FETs Using μ-spot Auger Electron Spectroscopy," GaAs and Related Compounds, 1976 (Inst. Phys. Conf. Ser. No. 33b 1977), pp. 191–200
$HCl:HF:H_2O:H_2O_2$ (10 ml:10 ml:40 ml:5 drops) {NRL etch}; Application: GaAs surface cleaning for deposition of metal Schottky contacts
$H_3PO_4:HBF_4:H_2O$ (2:1:10); Al contact removal from GaAs

CHRISTOU, A., K. Varmazis, and Z. Hatzopoulos, "High Mobility GaAs/AlAs (2 1 1) Si Structures Grown by MBE," J. Cryst. Growth, **81**, 226–30 (1987)
$HF:H_2O$ (1:3); Application: Si-removal of thermal oxide as a step in Si substrate cleaning for GaAs MBE growth, followed by:
$NH_4OH:H_2O$ (1:10) for 30 s, followed by:
$HCl:H_2O$ (1:10) for 30 s, followed by:
HF dip, followed by DI water rinse and $N_2$ blow dry

CHU, S.N.G., C.M. Jodlauk, and A.A. Ballman, "New Dislocation Etchant for InP," J. Electrochem. Soc., **129**, 352 (1982)
$HNO_3:HBr$ (1:3); InP dislocation delineation on (1 1 1) and (1 0 0)

CHU, T.L., "Gallium Nitride Films," J. Electrochem. Soc., **118**(7), 1200 (1971)
$NaOH:H_2O$ (1:1); GaN etch at 5–90°C

CHYR, I., B. Lee, L.C. Chao, and A.J. Steckl, "Damage generation and removal in the Ga+ focused ion beam micromachining of GaN for photonic applications.," J. Vac. Sci. Technol., B, **17**(6), 3063 (1999)
$Ga^+$ ion micromachining of laser gratings in GaN

CLARKE, R.C., B.D. Joyce, and W.H.E. Wilgoss, "The Preparation of High Purity Epitaxial InP," Solid State Commun., **8**, 1125–28 (1970)
$KOH:K_3Fe(CN)_6:H_2O$(6 g:4 g:50 ml); Application: InP cleaved cross-section layer delineation; ~5 min at 20°C; selectively etches InGaAsP on InP

CLARKE, R.C., A.W. Robertson, and A.W. Vere, "A Preliminary Study of Dislocations in Indium and Gallium Phosphides," J. Mater. Sci., **8**, 1349 (1973)
$KOH:K_3Fe(CN)_6:H_2O$ (6 g:4 g:50 ml); Application: InP cleaved cross-section layer delineation; ~5 min at 20°C
$HNO_3:HCl:Br_2$ (20:10:0.25); InP and GaP dislocation delineation; 5 s for (1 1 1); 60 s for (1 0 0)

CLAWSON, A.R., "In situ Vapor-etch for InP MOVPE Using Ethylene Dibromide," J. Cryst. Growth, **69**, 346–56 (1984)
Thermochemical vapor etch; ethylene dibromide + $H_2$ + $PH_3$; InP (1 0 0) in situ etch for OMVPE

CLAWSON, A.R., "Thermally Activated Etching of InP Substrates for MOCVD," J. Vac. Sci. Technol., A, **3**(3), 1040 (1985)
Thermochemical vapor etch; ethylene dibromide + $H_2$ + $PH_3$; InP (1 0 0) in situ etch for OMVPE

CLAWSON, A.R., D.A. Collins, D.I. Elder, and J.J. Monroe, “Laboratory Procedures for Etching and Polishing InP Semiconductors,” NOSC Technical Note TN 592, Naval Ocean Systems Center, San Diego (1978)

{All data are at room temperature.}

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

$Br_2$/methanol (1 vol.%); InP (1 0 0) etch rate = 3000 Å/min

$Br_2$/methanol (0.5 vol.%); InP (1 0 0) etch rate = 2000 Å/min

HBr; InP (1 0 0) etch rate = 4–8 μm/min, highly pitted surface

HBr:$H_2O$ (1:10); InP (1 0 0) etch rate = 167 Å/min

HBr:$H_2O$ (1:5); InP (1 0 0) etch rate = 250 Å/min

$H_3PO_4$:$H_2O_2$ (1:1); InP (1 0 0) etch rate = 100 Å/min

$H_2O$:$AgNO_3$:$CrO_3$:HF (10 ml:40 mg:5 g:8 ml) {A – B etch); InP (1 0 0) etch rate = 600 Å/min at 20°C

Citric acid:$H_2O_2$ (3:1); InP (1 0 0) etch rate = 10 Å/min

Tartaric acid (40 wt.% solution):$H_2O_2$ (1:1); InP (1 0 0) etch rate = 6 Å/min

Tartaric acid (40 wt.% solution):$H_2O_2$ (3:1); InP (1 0 0) etch rate = 120 Å/min

Iodic acid (5 wt.% solution); InP (1 0 0) etch rate = 67 Å/min; smooth, uniform surfaces; thinning etch

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

Iodic acid (20 wt.% solution); InP (1 0 0) etch rate = 750 Å/min. Lactic acid:$HNO_3$ (10:1); InP (1 0 0) etch rate < 8 Å/min

Oxalic acid:$H_2O_2$; InP (1 0 0) etch rate ≤ 8 Å/min

CLAWSON, A.R., W.Y. Lum, and G.E. McWilliams, “Control of substrate degradation in LPE growth with $PH_3$ partial pressure,” J. Cryst. Growth, **46**, 300 (1979)

Thermal etching (degradation) of InP in $H_2$; $PH_3$ surface stabilization

COBURN, J.W., “Plasma Etching and Reactive Ion Etching,” AVS Monograph Series (Am. Inst. Phys., NY), (1982)

Review of plasma etching and reactive ion etching principles; Si

COLAS, E., A. Shahar, B.D. Soole, W.J. Tomlinson, J.R. Hayes, C. Caneau, and R. Bhat, “Diffusion-enhanced Epitaxial Growth of Thickness-modulated Low-loss Rib Waveguides Patterned on GaAs Substrates,” Appl. Phys. Lett., **56**(10), 955–57 (1990)

KOH:$K_3Fe(CN)_6$:$H_2O$ (12 g:9 g:70 ml); Application: GaAlAs/GaAs cleaved cross-section layer delineation

$H_2SO_4$:$H_2O_2$:$H_2O$ (1:8:40); GaAs dovetail mesa etch

COLAS, E., A. Shahar, B.D. Soole, W.J. Tomlinson, J.R. Hayes, C. Caneau, and R. Bhat, “Lateral and Longitudinal Patterning of Semiconductor Structures by Crystal Growth on Non-planar and Dielectric-masked GaAs Substrates: Application to Thickness-modulated Waveguide Structures,” J. Cryst. Growth, **107**, 226 (1991)

$H_2SO_4$:$H_2O_2$:$H_2O$ (1:8:40); Application: GaAs (1 0 0) mesa etch

COLDREN, L.A., K.J. Ebeling, J.A. Rentschler, C.A. Burrus, and D.P. Wilt, "Continuous Operation of Monolithic Dynamic-single-mode Coupled-cavity Lasers.," Appl. Phys. Lett., **44**(4), 368–70 (1984)
Reactive ion etch; $Cl_2 + O_2$; Application: InGaAsP/InP deep groove etch for laser fabrication; Ti mask

COLDREN, L.A., K. Furuya, B.I. Miller, and J.A. Rentschler, "Combined Dry and Wet Etching Techniques to Form Planar (0 0 1) Facets in GaInAsP/InP Double-heterostructures," Electron. Lett., **18**(5), 235–37 (1982a)
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)

COLDREN, L.A., K. Furuya, B.I. Miller, and J.A. Rentschler, "Etched Mirror and Groove-coupled GaInAsP/InP Laser Devices for Integrated Optics," IEEE J. Quantum Electron., **QE-18**, 1679 (1982b)
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)

COLDREN, L.A., K. Furuya, and B.I. Miller, "On the Formation of Planar-etched Facets in GaInAsP/InP Double-Heterostructures," J. Electrochem. Soc., **130**(9), 1918–26 (1983)
$KOH:K_3Fe(CN)_6:H_2O$ (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
$HCl:CH_3COOH:H_2O_2$ (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)

COLDREN, L.A., K. Iga, B.I. Miller, and J.A. Rentschler, "GaInAsP/InP Stripe-Geometry Laser with a Reactive-Ion-Etched Facet," Appl. Phys. Lett., **37**(8), 681–87 (1980)
Reactive ion etching; $Cl_2/O_2$; Application: InGaAsP/InP grooves and laser facets with vertical sidewalls and no undercutting

COLDREN, L.A., B.I. Miller, K. Iga, and J.A. Rentschler, "Monolithic Two-Section GaInAsP/InP Active-Optical Resonator Devices Formed by Reactive Ion Etching," Appl. Phys. Lett., **38**(5), 315–17 (1981a)
Reactive ion etching, $Cl_2/O_2$; Application: InGaAsP/InP grooves and laser facets

COLDREN, L.A., and J.A. Rentschler, "Directional Reactive-ion-etching of InP with $Cl_2$ Containing Gases," J. Vac. Sci. Technol., **19**(2), 225–30 (1981b)
Reactive ion etch; $Cl_2$, $Cl_2/O_2$ (4:1); InP photolithography

COLEMAN, J.J., and F.R. Nash, "Zinc Contamination and Misplaced p–n Junctions in InP-GaInAsP Double-Heterojunction Lasers," Electron. Lett., **14**, 558 (1978)
$HF:HNO_3:H_2O$ (50:1:50) + 5 mg $K(FeCN)_6$; Application: InGaAs/InP cleaved cross-section later delineation

COLLIVER, D.J., Compound Semiconductor Technology, (Artech House, Inc., Dedham, MA, 1976)
$HCl:HNO_3:H_2O$ (2:3:6); InP etch rate = 1 μm/min; non-preferential
$HCl:HNO_3:H_2O$ (2:2:1); InP etch rate = 2 μm/min; non-preferential
$HCl:H_3PO_4$ (2:3); InP bulk etch rate = 2.5 μm/min; no measurable InGaAsP or InGaAs etching after 30 min
$HCl:H_3PO_4$ (2:3); InP bulk etch rate = 2.5 μm/min; no measurable InGaAsP or InGaAs etching after 30 min; Ref. (Colliver, D.J. 1976)
$Br_2:HBr:H_2O$ (1:17:35); InP etch rate = 2 μm/min
$H_2SO_4:H_2O_2:H_2O$ (3:1:1); GaAs etch rate = 3.1 μm/min
$H_2SO_4:H_2O_2:H_2O$ (18:1:1); GaAs etch rate = 2.1 μm/min
$H_2SO_4:H_2O_2:H_2O$ (8:1:1); GaAs etch rate = 2.8 μm/min
$H_2SO_4:H_2O_2:H_2O$ (9:9:2); GaAs etch rate = 8.7 μm/min
$H_2SO_4:H_2O_2$ (1:1); GaAs etch rate = 5.0 μm/min
$NH_4OH:H_2O_2:H_2O$ (1:4:20) GaAs etch rate = 1.8 μm/min
$HNO_3:HF$ (1:3); GaAs layer delineation
$HNO_3:HF:H_2O$ (1:3:4); GaAs layer delineation
$HNO_3:HF:H_2O$ (3:1:5); GaAs layer delineation
$KOH:K_3Fe(CN)_6$ ((120 g KOH + 500 ml $H_2O$):(80 g $K_3Fe(CN)_6$ + 500 ml $H_2O$)); GaAs layer delineation
$H_2O:AgNO_3:CrO_3:HF$ (2 ml:8 mg:1 g:1 ml) {**A–B etch**}; GaAs etch rate = 4 μm/min at 65°C

COLLOT, P., and C. Gaonach, "Electrical Damage in n-GaAs Due to Methane–hydrogen RIE," Semicond. Sci. Technol., **5**, 237–41 (1990)
Reactive ion etch; $CH_4 + H_2$; GaAs n-type; electrical damage due to hydrogen passivation of donors

CONSTANTIN, C., E. Martinet, A. Rudra, K. Leifer, F. Lelarge, G. Biasiol, and E. Kapon, "Orgaometallic chemical vapor deposition of vee-groove InGaAs/GaAs quantum wires incorporated in planar Bragg microcavities," J. Cryst. Growth, **207**, 161 (1999)
$H_2SO_4:H_2O_2:H_2O$ (1:8:80); Application: vee-groove etch of GaAs, quasi (1 1 1)A sidewalls; with $Si_3N_4$ mask

CONSTANTINE, C., C. Barratt, S.J. Pearton, F. Ren, and J.R. Lothian, "Smooth, Low-Bias Plasma Etching of InP in Microwave $Cl_2/CH_4/H_2$ Mixtures," Appl. Phys. Lett., **61**(24), 2899–301 (1992)
ECR etch; $Cl_2/CH_4/H_2$; InP at 150°C for laser mesa fabrication

CONSTANTINE, C., R.J. Shul, C.T. Sullivan, M.B. Snipes, G.B. McClellan, M. Hafickh, C.T. Fuller, J.R. Mileham, and S.J. Pearton, "Etching of GaAs/AlGaAs rib waveguide structures using $BCl_3/Cl_2/N_2/Ar$ electron cyclotron resonance," J. Vac. Sci. Technol., B, **13**(5), 2025 (1995)
ECR etch; non-selective for GaAs AlGaAs; $BCl_3/Cl_2/N_2/Ar$; where $BCl_3$ reduces oxidation effects for AlGaAs and $N_2$ protects from sidewall polymer deposition when using photoresist masks

CONTOLINI, R.J., "The Temperature Dependence of the Etch Rates of GaAs, AlGaAs, InP, and Masking Materials in a Boron Trichloride:Chlorine Plasma," J. Electrochem. Soc., **135**(4), 929–36 (1988)
Reactive ion etch; $BCl_3:Cl_2$; GaAs, AlGaAs, InP; etch rate is temperature dependent

CONTOUR, J.P., J. Massies, A. Saletes, M. Outrequin, F. Simondet, and J.F. Rochetter, "In situ Chemical Etching of GaAs (0 0 1) and InP (0 0 1) Substrates by Gaseous HCl Prior to Molecular-beam Epitaxy Growth," J. Vac. Sci. Technol. B, **5**(3), 730–33 (1987)
Thermochemical vapor etch; HCl; InP and GaAs in situ surface cleaning for MBE growth

CONWAY, K.L., A.G. Dentai, and J.C. Campbell, "Etch Rates for Two Material Selective Etches in the InGaAsP/InP System," J. Appl. Phys., **53**(3), 1836–38 (1982)
$HCl:H_3PO_4$ (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
$HCl:H_3PO_4$ (2:3); InP bulk etch rate = 2.5 μm/min; no measurable InGaAsP or InGaAs etching after 30 min
$KOH:K_3Fe(CN)_6:H_2O$ (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)

COOPER, C.B., M.E. Day, C. Yuen, and M. Salimian, "Reactive Ion Etching of Through-the Wafer via Connections for Contacts to GaAs FET's," J. Electrochem. Soc., **134**(10), 2533–2535 (1987a)
Reactive ion etching, $SiCl_4 + Cl_2$; Application: via holes in GaAs

COOPER, C.B., S. Salimian, and H.F. MacMillan, "Use of Thin AlGaAs and InGaAs stop-etch Layers for Reactive Ion Etch Processing of III–V Compound Semiconductor Devices," Appl. Phys. Lett., **51**, 2225 (1987b)
Reactive ion etch; $SiF_6/SiCl_4$; AlGaAs/GaAs with use of etch stop layers of AlGaAs and InGaAs

COSTA, E.M., B.A. Dedavid, and A. Müller, "Investigations of structural defects by etching of GaSb grown by the liquid encapsulated Czochralski technique," Mater. Sci, Eng. B, **B44**, 208 (1997)
Defect delineation in GaSb:
CP-4 40% diluted in $H_2O$; etch pit delineation only on (1 1 1)A
$Br_2$/methanol (3%); etch pit delineation only on (1 1 1)A
$HCl:HNO_3:H_2O$ (6:1:6); unreproducible etch pit delineation
$HCl:H_2O_2$ (2:1); unreproducible etch pit delineation
$H_2SO_4:H_2O_2$ (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 0); precipitates on (1 1 1)A, (1 0 0), (1 1 0)
$CrO_3$ (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 0); precipitates on (1 1 1)A, (1 1 1)B, (1 0 0), (1 1 0)
$KMnO_4$ (sat.):$HF:CH_3COOH$ (1:1:1); growth striations on (1 1 0) in n-type GaSb
$Ce(SO_4)_2$(0.1 M):$HNO_3:CH_3COOH$ (1:2:2); Growth striations on (1 1 0) in Te-doped GaSb

CREMER, C., and M. Schienle, "RIE Etching of Deep Bragg Grating Filters in GaInAsP/InP," Electron. Lett., **17**(25), 1177–78 (1989)
Reactive ion etch; $CH_4/H_2$; Application: InP and InGaAsP grating with titanium layer mask

CUMMINGS, K.D., L.R. Harriott, G.C. Chi, and F.W. Jr. Ostermayer, "Using Focused Ion Beam Damage Patterns to Photoelectrochemically Etch Features in III–V Materials," Appl. Phys. Lett., **48**(10), 659–61 (1986)

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
$H_2SO_4$ (2 M); Photoelectrochemical etch electrolyte

DALEIDEN, J., K. Eisele, R.E. Sah, K.H. Schmidt, and J.D. Ralston, "Chemical analysis of a $Cl_2$/$BCl_3$/IBr chemically assisted ion-beam etching process for GaAs and InP laser-mirror fabrication under cryo-pumped ultrahigh vacuum conditions," J. Vac. Sci. Technol., B, **13**(5), 2022 (1995)
Chemically assisted ion beam etch; $Cl_2$/$BCl_3$/IBr in a cryo-pumped vacuum system; GaAs and InP

DALEIDEN, J., K. Czotscher, C. Hoffmann, R. Kiefer, S. Klussman, and S. Müller, "Sidewall slope control of chemically assisted ion-beam etched structures in InP-based materials," J. Vac. Sci. Technol., B, **16**(4), 1864 (1998)
Chemically assisted ion beam etching; $BCl_3$/Ar of InGaAsP/InP and AlInGaAsP/InP; control of the sidewall slope by tilting the sample

DALEIDEN, J., R. Kiefer, S. Klußmann, M. Kunzer, C. Manz, M. Wailher, J. Braunstein, and Weimann, "Chemically-assisted ion-beam etching of (AlGa)As/GaAs: lattice damage and removal by in situ $Cl_2$ treatment," Microelctron. Eng., **45**, 9 (1999)
CAIBE damage of AlGaAs/GaAs using $BCl_3$/$Cl_2$; post-etch damage removal by $Cl_2$ flow at 120°C without plasma

DAMBKES, H., U. Konig, and Schwaderer, "InGaAs/InP Heterobipolar Transistors for Integration on Semi-insulating InP Substrates," Electron. Lett., **20**(23), 955–57 (1984)
$H_2SO_4$:$H_2O_2$:$H_2O$ (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)
$H_3PO_4$:HCl (3:1); InP selective etch from InGaAs

DAS NEVES, S., and M.-A. De Paoli, "A Quantitative Study of Chemical Etching of InP," J. Electrochem. Soc., **140**(9), 2599–2602 (1993)
HCl:ethanol; InP; etch rate concentration and temperature dependence; mesa sidewall profiles

D'ASARO, L.A., A.D. Butherus, J.V. DiLorenzo, D.E. Iglesias, and S.H. Wemple, "Plasma-Etched Via Connections to GaAs FET's," GaAs and Related Compounds, 1980 (Inst. Phys. Conf. Ser. No. 56 1981), pp. 267–273
Plasma etched via holes in GaAs with 6% $Cl_2 + 94\%$ $BCl_3$

DAUMANN, W., F. Scheffer, W. Prost, and F.-J. Tegude, "High power InAlAs/InGaAs/InP-HFET grown by MOVPE," InP and Related Material Conference Proceedings, 1997, p. 24
$H_2SO_4$:$H_2O_2$:$H_2O$ (1:1:40); selective InAlAs/InGaAs HFET mesa etch from InP. succinic acid ($C_4H_6O_4$):$H_2O_2$:$NH_3$ (20:4:1); selective InGaAs from InAlAs; InGaAs etch rate = 5 Å/s; InAlAs etch rate = 0.07 Å/s

DAVIES, G.J., R. Heckingbottom, H. Ohno, C.E.C. Wood, and A.R. Calawa, "Arsenic Stabilization of InP Substrates for growth of GaInAs Layers by MBE," Appl. Phys. Lett., **37**(3), 290–92 (1980)

$H_2SO_4$:$H_2O_2$:$H_2O$ (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

DE WOLF, I., M. Van Hove, R.-G. Pereira, M. Van Rossum, H.E. Maes, and H. Münder, "Raman spectroscopy study of damage in $n^+$-GaAs introduced by $H_2$ and $CH_2/H_2$ RIE," Mat. Res. Soc. Symp. Proc., **240**, 355 (1992)

RIE damage study of n-GaAs in $CH_4/H_2$ and $H_2$ plasmas

DEBIEMME-CHOUVY, C., D. Ballutaud, J.C. Pesant, and A. Etcheberry, "X-ray Photoelectron Spectroscopy Study of GaAs Surface Exposed to a RF Hydrocen Plasma," Appl. Phys. Lett., **62**(18), 2254–55 (1993)

$H_2$ plasma damage study; GaAs; X-ray photelectron spectroscopy analysis

DECHIARO, L.F., and C.J. Sandroff, "Improvements in electrostatic Discharge performance of InGaAsP semiconductor lasers by facet passivation," IEEE Trans. Electron Devices, **39**(3), 561 (1992)

$(NH_4)_2S$; Application: InGaAsP laser facet passivation

DECORBY, R.G., R.I. MacDonald, M. Beaudoin, T. Pinnington, T. Tiedje, and F. Gouin, "Elimination of low frequency gain in InAlAs/InGaAs metal–semiconductor–metal photodetectors by silicon nitride passivation," J. Electron. Mater., **26**(12), L25 (1997)

$NH_4OH$:$H_2O$ (1:10); oxide removal from InAlAs; 20 s; prior to deposition of silicon nitride passivation layer

DEMEESTER, P., P. Van Daele, and R. Baets, "Growth Behavior During Non-planar MOVPE," J. Appl. Phys., **63**(7), 2284–90 (1988)

$H_3PO_4$:$H_2O_2$:$H_2O$ (1:1:100); Application: GaAs slow recess etch; showing etch profiles with little anisotropy

$H_2O$:$AgNO_3$:$CrO_3$: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⟩

$H_2SO_4$:$H_2O_2$:$H_2O$ (1:8:11) and (1:8:40); GaAs (1 0 0) photolithography substrate patterning etch profiles

DEMEO, N.L., J.P. Donnelly, F.J. O'Donnell, M.W. Geis, and K.J. O'Connor, "Low Power Ion-beam-assisted Etching of Indium Phosphide," Nuclr. Inst. and Meth. Phys. Res. B, **7/8**, 814–19 (1985)

Ar ion beam assisted $Cl_2$ dry etching of InP; temperatures above 150°C are required to remove reaction products

DESALVO, G.C., C.A. Bozada, J.L. Ebel, D.C. Look, J.P. Barrette, C.L.A. Cerny, R.W. Dettmer, J.K. Gillespie, C.K. Havasy, T.J. Jenkins, K. Nakano, C.I. Pettiford, T.K. Quach, J.S. Sewell, and G.D. Via, "Wet Chemical Digital Etching of GaAs at Room Temperature," J. Electrochem. Soc., **143**(11), 3652–3656 (1996)

$H_2O_2$ (30%); oxidation of GaAs followed by
HCl:$H_2O$ (1:1); oxide removal agent from GaAs
Citric acid (1 M); oxide removal agent from GaAs
$H_3PO_4$:$H_2O$ (1:4); oxide removal agent from GaAs
$H_2SO_4$:$H_2O$ (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)

| Volume ratio of citric acid/H$_2$O$_2$ | Etch rates of layers on GaAs substrate (Å/min) | | |
|---|---|---|---|
| | GaAs | Al$_{0.3}$Ga$_{0.7}$As | In$_{0.2}$Ga$_{0.8}$As |
| 0 | 0 | 0 | 0 |
| 0.5 | 60 | 27 | 346 |
| 1.0 | 69 | 27 | 751 |
| 1.5 | | | 1094 |
| 2.0 | 85 | 24 | 1442 |
| 3.0 | 2169 | 24 | 2318 |
| 4.0 | 2235 | 23 | 2777 |
| 5.0 | 3140 | 27 | 2588 |
| 6.0 | | 30 | |
| 7.0 | 2882 | 89 | 2231 |
| 8.0 | | 2331 | |
| 9.0 | | 2297 | |
| 10.0 | 2513 | 1945 | 1219 |
| 15.0 | 1551 | 1082 | 882 |
| 20.0 | 762 | 918 | 624 |
| 50 | 397 | 512 | 384 |
| | 0 | 0 | 0 |

| Volume ratio of citric acid/H$_2$O$_2$ | Etch rates of layers on InP substrate (Å/min) | | |
|---|---|---|---|
| | In$_{0.53}$Ga$_{0.47}$As | In$_{0.52}$Al$_{0.48}$As | InP |
| 0 | 0 | 0 | 0 |
| 0.2 | 21 | 11 | |
| 0.5 | 1235 | 21 | 12 |
| 1.0 | 1116 | 22 | 11 |
| 2.0 | 1438 | 26 | 9 |
| 5.0 | 1433 | 44 | 5 |
| 7.0 | 1421 | 63 | 3 |
| 10.0 | 1020 | 154 | 4 |
| 15.0 | 1013 | | |
| 20.0 | 665 | 204 | 2 |
| 50 | 303 | 174 | 5 |
| 100 | | 176 | |
| | 0 | 0 | 0 |

DIATEZUA, D.M., Z. Wang, D. Park, Z. Chen, A. Rockett, and H. Morkoc, "$Si_3N_4$ on GaAs by direct electron resonance plasma assisted nitridation of Si layer in Si/GaAs structure," J. Vac. Sci. Technol., B, **16**(2), 507 (1998)
 $Si_3N_4$ surface passivation of GaAs by plasma nitridation of a Si layer

DILORENZO, "An in situ etch for the CVD growth of GaAs: the 'He-etch'," GaAs and Related Compounds, 1975 (Inst. Phys. Conf. Ser. No. 2, 1981) pp. 362–68
 Thermochemical vapor etch using $AsCl_3$/He; GaAs in situ substrate etch for CVD

DIMROTH, F., A.W. Bett, and W. Wettling, "Liquid-phase epitaxy of $Al_xGa_{1-x}As$ and technology for tandem solar cell application," J. Cryst. Growth, **179**, 41 (1997)
 $H_2SO_4$:$H_2O_2$:$H_2O$ (2:1:1); Application: rapid GaAs substrate thinning, 300 μm under continuous swirling at 60°C for $< 15$ s
 citric acid:$H_2O_2$ (2:1); Application: selective removal of GaAs from $Al_{0.26}Ga_{0.74}As$; selectivity of 70:1

DIN, K.-S., and G.-C. Chi, "$CHF_3$ and $NH_3$ additives for reactive ion etching of GaAs using $CCl_2F_2$ and $SiCl_4$," Mat. Res. Soc. Symp. Proc., **240**, 373 (1992a)
 $CHF_3$ and $NH_3$ additives for reactive ion etching of GaAs using $CCl_2F_2$ and $SiCl_4$

DIN, K.-S., and G.-C. Chi, "Investigation of GaAs deep etching by using reactive ion etching technique," Mat. Res. Soc. Symp. Proc., **240**, 367 (1992b)
 Reactive ion etch; $CCl_2F_2$; GaAs pattern etching of deep features comparing metal, $Si_3N_4$ and photoresist masks

DING, L., Q. Mingxin, and K. Zhong, "Properties of Laser-induced Thermochemical Etching in InP," J. Electron. Mater., **17**(1), 29–31 (1988)
 Thermochemical vapor etch; $Cl_2$; InP, Ar laser-induced etching

DOERSCHEL, J., and U. Geissler, "Characterization of extended defects in highly Te-doped $\langle 1\,1\,1 \rangle$ GaSb single crystals grown by the Czochralski technique," J. Cryst. Growth, **121**, 781–89 (1992)
 HF:$HNO_3$:$CH_3COOH$ (2:18:40); GaSb first step prior to defect delineation etch
 $Br_2$/methanol (2%); GaSb(1 1 1)A etch pit defect delineation etch
 HCl:$H_2O_2$; GaSb etch pit defect delineation etch for all other orientations

DONNELLY, V.M., D.L. Flamm, and D.E. Ibbotson, "Plasma Etching of III–V Compounds," J. Vac. Sci. Technol., A, **1**(2), 626–28 (1983)
 Plasma etch; $CCl_4$, $CHCl_3$, $CF_2Cl_2$, $BCl_3$; InP and GaAs review

DONNELLY, V.M., D.L. Flamm, C.W. Tu, and D.E. Ibbotson, "Temperature Dependence of InP and GaAs Etching in a Chlorine Plasma," J. Electrochem. Soc., **129**(11), 2533–37 (1982)
 Plasma etch; $Cl_2$; InP and GaAs; non-volatile reaction by-product $InCl_3$ limits low temperature etching. InP activation energy $= 34.5 \pm 2.8$ kcal/mol; GaAs activation energy $= 10.5 \pm 0.7$ kcal/

mol; InP absolute etch rate = 7 μm/m at 250°C; multilayers of $InCl_3$ deposit on InP and submonolayer of $InCl_3$ on GaAs; etched surface texture depends strongly on etch temperature; InP etching is anisotropic while GaAs is partially ansiotropic; InP etch rate is controlled by volatilization of $InCl_3$ layer from surface; GaAs etch rate is limited by slow chemical reaction

DOUGHTY, G.F., C.L. Dargan, and C.D.W. Wilkinson, "Dry Etching of Indium Phosphide at Room Temperature," SPIE Proc.: Integrated Optical Circuit Engineering, Vol. 578, pp. 82–87 (1985)
Ar ion etch; reactive ion etch using iodine; InP

DOUGHTY, G.F., S. Thoms, V. Law, and C.D.W. Wilkinson, "Dry Etching of Indium Phosphide," Vacuum, **36**(11–12), 803–06 (1986)
Review; dry etching of InP; Ar ion milling, reactive ion etching and ion beam assisted $I_2$ and $Cl_2$ etching; gives comparison of results. Reactive ion etch; $SiCl_4$: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; $CF_3$ and $CH_3I$ give rough surface due to $CH_3I$ polymers on substrate; smooth surface is obtained from 25% $O_2$ in $CH_3I$ with Ti mask; $Cl_2$ ion beam etching for GaAs requires high temperature, above 150°C; smooth etched surface also obtained from $I_2$:Ar at 0.1 mTorr with high Ar + beam of 300–500 V and high flow rate of $I_2$; vertical walls are obtained by 15° titled substrate to beam

DUCROQUET, F., P. Kropfeld, O. Yaradou, and A. Vanoverschelde, "Arrays of ungated GaAs field emitters fabricated by wet or dry etching," J. Vac. Sci. Technol., B, **17**(4), 1553 (1999)
$HCl:H_2O_2:H_2O$ (40:4:1); field emitter tip formation on GaAs by etching through square mask patterns
$HF:H_2O_2:H_2O$ (1:10:21.2);field emitter tip formation on GaAs by etching through square mask patterns
$HF:HNO_3:H_2O$ (1:1:2); field emitter tip formation on GaAs by etching through square mask patterns
$HF:H_2O_2:H_2O$ (1:20:100); field emitter tip formation on GaAs by etching through square mask patterns
$NH_4OH:H_2O_2:H_2O$ (1:1:8)); field emitter tip formation on GaAs by etching through square mask patterns
$H_3PO_4:H_2O_2:H_2O$ (3:1:50); sharpening of dry etched field emitter tips. Reactive ion etch of GaAs field emitter tips using Ar + $SiCl_4$

DUCROQUET, F., P. Kropfeld, O. Yaradou, and A. Vanoverschelde, "Fabrication and emission characteristics of GaAs tip and wedge-shaped field emitter arrays by wet etching," J. Vac. Sci. Technol., B, **16**(2), 787 (1998)
$HCl:H_2O_2:H_2O$ (40:4:1); tip formation on GaAs by etching through square mask patterns
$HF:HNO_3:H_2O$ (1:1:2); tip formation on GaAs by etching through square mask patterns

DUMKE, W.P., J.M. Woodall, and V.L. Rideout, "GaAs–GaAlAs Heterojunction Transistor for High Frequency Operation," Solid-State Electron., **15**, 1339–43 (1972)
HCl; Application: $Al_{0.5}Ga_{0.5}As$ selective etch from GaAs

DUNN, J., and G.B. Stringfellow, "Ag/Al Schottky Contacts on InP," J. Electron. Mater., **17**(2), 181–86 (1988)

KOH:methanol (2.5 g:200 ml); InP surface cleaning study for Schottky contacts

DUPUIS, R.D., D.G. Deppe, C.J. Pinzone, N.D. Gerrard, S. Singh, G.J. Zydzik, J.P. van der Ziel, and C.A. Green, "$In_{0.47}Ga_{0.53}As$–InP heterostructures for vertical cavity surface emitting lasers at 1.65 μm wavelength," J. Cryst. Growth, **107**, 790–95 (1991)

$H_3PO_4$:HCl (3:1); Application: InP selective etch from InGaAs. $H_2SO_4$:$H_2O_2$:$H_2O$ (3:1:1); InGaAs selective etch from InP

DURAN, H.C., W. Patrick, and W. Bächtold, "Atomic force microscopy investigation of dry etched gate recesses for InGaAs/InAlAs-based high-electron-mobility transistors using methane–hydrogen reactive ion etching," J. Vac. Sci. Technol., B, **13**(6), 2386 (1995)

Reactive ion etch; $CH_4$/$H_2$ for gate recess in InGaAs/InAlAs HEMTs; AFM surface study

DURAN, H.C., L. Ren, M.A. Py, O.J. Homan, U. Lott, and W. Bächtold, "High performance InP-based HEMTs with dry etched gate recess for the fabrication of low-noise microwave oscillators," Proc. 11th Int'l Conf. on Indium Phosphide and Related Materials, 319 (1999)

HF (4%) (in isopropanol:$H_2O$ (1:5) as wetting agent); 5 s native oxide removal from InGaAs
Reactive ion etch using $CH_4$(8.3%) of InGaAs/InAlAs/InP for gate recess in HEMTs
$H_3PO_4$:$H_2O_2$:$H_2O$ (1:1:150); gate recess etch in InGaAs/InAlAs/InP HEMTs

DUROSE, K., M.R. Aylett, and J. Haigh, "Production of Etched Features in InP for Integrated Optoelectronic Applications by Laser Direct-write Photochemical Etching," Chemtronics, **3**, 201–05 (1988)

Laser-induced dry etch of InP using UV photolysis of $CH_3I$; direct write patterning contrast is enhanced by presence of surface oxide. Photochemical etching using $CH_3I$ in $H_2$ with laser assisted beam to clean InP and InGaAs; InGaAs etch rate is higher than InP etch rate

DYMENT, J.C., and G.A. Rozgonyi, "Evaluation of a New Polish for Gallium Arsenide Using a Peroxide-alkaline Solution," J. Electrochem. Soc., **188**(8), 1346–50 (1971)

$NH_4OH$:$H_2O_2$ (1:700); GaAs chemi-mechanical polishing solution. $Br_2$/methanol; GaAs chemi-mechanical polishing solution

DZIOBA, S., S. Jatar, T.V. Herak, J.P.D. Cook, J. Marks, T. Jones, and F.R. Shepherd, "High Temperature Operation of InGaAsP/InP Heterostructure Lasers and Integrated Back Facet Monitors Fabricated by Chemically assisted Ion Beam Etching," Appl. Phys. Lett., **62**(20), 2486–88 (1993)

Chemically assisted ion beam etch; Ar/$Cl_2$; Application: InGaAsP/InP laser facets

EBERHARD, F., M. Schauler, E. Deichsel, C. Kirchner, and P. Unger, "Comparison of the etching behavior of a GaAs and GaN in a chemically-assisted ion-beam etching system," Microelectron. Eng., **46**, 323 (1999)

CAIBE of GaN and GaAs using $Cl_2$–Ar; vertical, smooth sidewalls for laser facets

EBBINGHAUS, G., R. Strzoda, T. Scherg, H. Albrecht, R. Penz, and C. Lauterbach, "Two-step MOVPE Growth for Planar InP/InGaAs/InP pin-FET Combinations with Locally Diffused Buffer Layer," J. Cryst. Growth, **107**, 840–44 (1991)

$H_2SO_4$:$H_2O_2$:$H_2O$ (5:1:1); Application: InP(Zn) thinning etch for two step MOVPE regrowth in InGaAs/InP pin-FET

EDDY, C.R., O.J. Glembocki, D. Leonhardt, V.A. Shamamian, R.T. Holm, B.D. Thoms, J.E. Butler, and S.W. Pang, "Gallium Arsenide surface chemistry and surface damage in a chlorine high density plasma etch process," J. Electron. Mater., **26**(11), 1320 (1997)

ECR plasma etch; $Cl_2$/Ar; GaAs; surface damage study

EDDY JR., C.R., D. Leonhardt, S.R. Douglass, V.A. Shamamian, B.D. Thoms, and J.E. Butler, "Characterization of high density $CH_4$/$H_2$/Ar plasmas for compound semiconductor etching," J. Vac. Sci. Technol., A, **17**(3), 780 (1999)

ECR plasma etching, $CH_4$/$H_2$/Ar for compound semiconductor; study of gas species versus process conditions

EDWARDS-SHEA, L., "A Reliable Method for the Etching of vee-grooves in Indium Phosphide," GEC Journal of Research, **3**(1), 55–7 (1985)

HF Buffered, (5N $H_3F$: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)

$H_3PO_4$:HCl (1:1) is preferred vee-grooved etchant for InP with smaller etch rate (0.1 μm/min at 22°C). Optimum etching conditions: 50 s in $H_3PO_4$: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 μm photoresist mask giving an angle of 35°

EDWARDS, N.V., M.D. Bremser, T.W. Weeks, R.S. Kern, R.F. Davis, and D.E. Aspnes, "Real-time assessment of overlayer removal on GaN, AlN, and AlGaN surfaces using spectroscopic elipsometry," Appl. Phys. Lett., **69**(14), 2065 (1996)

Surface treatment of GaN, AlN, and AlGaN to remove air-exposure overlayers; studied by spectroscopic elipsometry

EFTEKHARI, G., "Rh/n-GaAs contacts with and without sulfur passivation," J. Vac. Sci. Technol., B, **14**(6), 3596 (1996)

$(HN_4)_2S$; GaAs surface passivation

EFTEKHARI, G., "Electron trapping in thin oxide on n-InP," J. Vac. Sci. Technol., B, **11**(4), 1317–18 (1993)

$H_2SO_4$:$H_2O_2$:$H_2O$ (5:1:1); Application: InP surface cleaning prior to oxidation; 4 min $HNO_3$; 50 Å anodic oxide growth on InP

EHRLICH, D.J., R.M. Osgood, and T.F. Deutsch, "Laser-Induced Microscopic Etching of GaAs and InP," Appl. Phys. Lett., **36**(8), 698–700 (1980)

Vapor etch; GaAs and InP by ultra-violet photodecomposition of methyl-halides; etch rate $> 10^4$ X the dark reactions

EISELE, K.M., J. Daleiden, and J. Ralston, "Low temperature chemically assisted ion-beam etching processes using $Cl_2$, $CH_3I$, and $IBr_3$ to etch InP optoelectronic devices," J. Vac. Sci. Technol., B, **14**(3), 1780 (1996)
CAIBE for InP optoelectronic devices using $Cl_2$, $CH_3I$ and $IBr_3$

EL JANI, B., J.C. Genet, M. Guittard, and B. Senouci, "In situ Etching of GaAs Using $AsCl_3$ in MOVPE, I," J. Cryst. Growth, **58**, 381 (1982a)
Thermochemical vapor etch; $AsCl_3 + H_2$; GaAs in situ etch for OMVPE. $H_2SO_4$:$H_2O_2$:$H_2O$ (5:1:1); GaAs substrate cleaning for 20 s at 20°C

EL JANI, B., M. Guittard, J.C. Genet, and P. Gilbart, "In situ Etching of GaAs Using $AsCl_3$ in MOVPE, II," J. Cryst. Growth, **60**, 131 (1982b)
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:$H_2O_2$:$H_2O$ (1:1:10); InGaAs etch rate = 1000 Å/min
Tartaric acid:$H_2O_2$:$H_2O$ (1:120); InGaAs etch rate = 700 Å/min
Tartaric acid:$H_2O_2$ (1:1); InGaAs etch rate = 2900 Å/min
HF:$H_2O_2$:$H_2O$ (1:1:10); InGaAs etch rate = 6300Å/min
HF:$H_2O_2$:$H_2O$ (1:1:20); InGaAs etch rate = 2750 Å/min
$H_2SO_4$:$H_2O_2$:$H_2O$ (1:1:10); InGaAs etch rate = 9500 Å/min
$H_2SO_4$:$H_2O_2$:$H_2O$ (1:1:20); InGaAs etch rate = 4500 Å/min
$H_2SO_4$:$H_2O_2$:$H_2O$ (1:1:60); InGaAs etch rate = 700 Å/min
citric acid:$H_2O_2$ (25:1); InGaAs etch rate = 1200 Å/min
citric acid:$H_2O_2$ (25:1); p-InGaAs etch rate = 450 Å/min
citric acid:$H_2O_2$:$H_2O$ (1:1:10); InGaAs etch rate = 700 Å/min
Lactic acid:$H_2O_2$:HF (50:8:2); InGaAs etch rate = 7200 Å/min

ELDER, D.I., "Etching of Indium Phosphide with Buffered Hydrofluoric Acid," Progress report, Naval Ocean Systems Center, San Diego, CA (1987), (1987)
Buffered HF, {$NH_4F$:HF (10:1)}; InP etch rate after 60 min at 20°C is negligible

ELDER, D.I., and A.R. Clawson, "Determination of InGaAs Layer Thicknesses from Etched Steps," J. Mater. Sci. Lett., **3**, 340 (1984)
InGaAs selective etches from InP:
Tartaric acid:$H_2O_2$ (1:1);InGaAs rate = 3000 Å/min; InP etch rate = 6 Å/min; Ref. (Clawson, 1978)
Tartaric acid:$H_2O_2$:$H_2O$ (1:1:10); InGaAs etch rate = 1000 Å/min
Tartaric acid:$H_2O_2$:$H_2O$ (1:1:20); InGaAs etch rate = 600 Å/min
$H_2SO_4$:$H_2O_2$:$H_2O$ (1:1:10); InGaAs etch rate = 9000 Å/min

$H_2SO_4$:$H_2O_2$:$H_2O$ (1:1:20); InGaAs etch rate = 4500 Å/min
$H_2SO_4$:$H_2O_2$:$H_2O$ (1:1:60); InGaAs etch rate = 700 Å/min
HF:$H_2O_2$:$H_2O$ (1:1:10); InGaAs etch rate = 6300 Å/min
HF:$H_2O_2$:$H_2O$ (1:1:20); InGaAs etch rate = 3000 Å/min

ELIAS, P., V. Cambel, S. Hasenöhrl, P. Hudek, and J. Novák, "SEM and AFM characterization of high mesa patterned InP substrates prepared by wet etching," Mater. Sci. Eng. B, **66**, 15 (1999)
$H_3PO_4$:$H_2O_2$:$H_2O$ (1:1:8); Selective etch of InGaAs mask patterns on InP; at 25°C in light, 120 nm InGaAs etches through in ~25 s
$H_3PO_4$:$H_2O_2$:$H_2O$ (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:$H_3PO_4$ (0.5:1); at 25°C in light InP rate is 21 nm/s
HCl:$H_3PO_4$ (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:$H_3PO_4$: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 μm mesas etched in HCl:$H_3PO_4$:lactic acid to reduce surface roughness

ELLIOT, A.G., C.L. Wei, and D.A. Vanderwater, "Temperature Gradients, Dopants, and Dislocation Formation during Low-pressure LEC Growth of GaAs," J. Cryst. Growth, **85**, 59–68 (1987)
KOH molten; Application: GaAs (1 0 0) dislocation etch pit delineation. Sirtl etch, modified; GaAs (1 1 1) dislocation etch pit delineation

ELLIOTT, C.R., and J.C. Regnault, "The Detection of Structural Defects in Indium Phosphide by Electrochemical etching," J. Electrochem. Soc., **128**(1), 112–16 (1981)
Anodization: InP; defect delineation

ELLIOTT, C.R., and J.C. Regnault, "Electrochemical Sectioning and Surface Finishing of GaAs and GaSb," J. Electrochem. Soc., **127**(7), 1557–1562 (1980)
EDTA:$NH_4OH$ (0.2 M ethylene diamine tetraacetic acid disodium salt with ammonium hydroxide for pH control); electrolyte for photoelectrochemical etching of GaAs and GaSb

ERNÉ, B.H., D. Vanmaekelberge, and I.E. Vermier, "The anodic dissolution of InP studied by the optoelectrical impedance method-1. competition between electron injection and hole capture at InP photoanodes," Electrochim. Acta, **38**(17), 2559 (1993)
HCl (1.2 M); electrolyte (pH = 0) for study of anodic dissolution of InP

ETRILLARD, J., S. Blayac, and M. Riet, "A selective low induced damage ICP dry etching process for a self-aligned InP–InGaAs HBT technology," Proc. 11th Int'l Conf. on Indium Phosphide and Related Materials, 369 (1999a)
Inductively coupled plasma etch using $CH_4$/$H_2$/$O_2$ of InGaAs/InP HBTs; conditions for InGaAs selectivity of 30

ETRILLARD, J., J.F. Bresse, C. Gaguet, M. Riet, and J. Mba, "Low damage dry etching of III–V materials for heterojunction bipolar transistor applications using a chlorinated inductively couple plasma," J. Vac. Sci. Technol., A, **17**(4), 1174 (1999b)

Inductively coupled plasma etch of GaAs and InP for HBTs using $SiCl_4$

ETRILLARD, J., F. Héliot, P. Ossart, M. Juhel, G. Patriarche, P. Carcenac, C. Vieu, M. Puech, and Maquin, "Sidewall and surface-induced damage comparison between reactive ion etching and inductive plasma etching of InP using a $CH_4/H_2/O_2$ gas mixture," J. Vac. Sci. Technol., A, **14**(3), 1056 (1996)

Study on InP of etch damage dependence on ion energy using $CH_4/H_2/O_2$; comparing inductively-coupled plasma etch to reactive ion etch

ETRILLARD, J., P. Ossart, G. Patriarche, M. Juhel, J.F. Bresse, and C. Daguet, "Anisotropic etching of InP with low sidewall and surface-induced damage in inductively coupled plasma etching using $SiCl_4$," J. Vac. Sci. Technol., A, **15**(3), 626 (1997)

Inductively coupled plasma etch; $CH_4/H_2$ of InP; study of pattern etching and etch damage

FAKTOR, M.M., and J.L. Stevenson, "The Detection of Structural Defects in GaAs by Electrochemical Etching," J. Electrochem. Soc., **125**(4), 621–629 (1978)

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

FANG, R.Y., D. Bertone, G. Morello, and M. Meliga, "Eaves structures on (1 0 0) InP and InP/InGaAsP/InP heterostructures," J. Electrochem. Soc., **144**(11), 3940 (1997)

Reactive ion etch of $Si_3N_4$ masked InP mesas, followed by wet etch for controlled undercutting of mask in preparation for MOVPE regrowth

$H_3PO_4$:$H_2O$:saturated bromine water (1:15:2); undercut-mesa etch of InP for MOVPE regrowth following RIE etch

$HNO_3$:HBr:$H_2O$ (1:1:10); undercut-mesa etch of InP for MOVPE regrowth following RIE etch

$H_3PO_4$:$H_2O$:saturated bromine water (5:5:2); undercut-mesa etch of InP for MOVPE regrowth following RIE etch

$H_3PO_4$:$H_2O$:saturated bromine water (10:10:1); undercut-mesa etch of InP for MOVPE regrowth following RIE etch

FASTENAU, J., E. Özbay, G. Tuttle, and F. Laabs, "Epitaxial Lift-Off of Thin InAs Layers," J. Electron. Mater., **24**(6), 757–60 (1995)

HF:$H_2O$ (1:20) or (1:40); Selective etch of sacrificial AlSb layer to lift-off an InAs layer from a GaAs substrate

HF:$H_2O_2$:$H_2O$ (2:1:20); Selective etch of GaSb from InAs stop layer

FAUR, M., M. Faur, C. Vargas, and M. Goradia, "EC-V Profiling of InP," 3rd Int'l Conf. on Indium Phosphide and Related Materials, Apr 8–11, 1991a, Cardiff, Wales, UK, (IEEE Catalog no. $91CH_2950$-4) pp. 310–14

ECV profiling; InP; unidentified electrolyte compared with HCl

FAUR, M., M. Faur, D.J. Flodd, D.J. Brinker, C. Goradia, S. Bailey, I. Weinberg, M. Goradia, D.T. Jayne, J. Moulerot, and N. Fatemi, ‘‘Effective First Layer Antireflective Coating on InP Solar Cells Grown by Chemical oxidation,’’ InP and Related Material Conference Proceedings, 1994a, (IEEE cat. no. 94CH 3369-6), paper WP27, pp. 492–95

$o$-$H_3PO_4$:$HNO_3$:$H_2O$ (5:30:1); Application: chemical growth of native oxide on InP for use as solar cell surface coating

FAUR, M., M. Faur, D.J. Flood, M. Goradia, and D.M. Wilt, ‘‘Electrolyte for EC-V Profiling of InP- and GaAs-Based Heterostructures,’’ InP and Related Material Conference Proceedings, 1994b, (IEEE cat. no. 94CH 3369-6), paper WP31, pp. 508–511

$NH_3F_2$:$o$-$H_3PO_4$ (*UNIEL*); Electrolyte for EC-V profiling InP and GaAs

FAUR, M., M. Faur, D.J. Flood, and M. Goadia, ‘‘Electrolyte for electrochemical $C$–$V$ profiling of InP- and GaAs-based structures,’’ Mater. Sci. Eng. B, **28**, 361 (1994c)

Comparison of electrolyte for $C$–$V$ profiling of InP and GaAs materials:
HCl
Tiron
pear etch
EDTA
Ammonium tartarate
FAP

FAUR, M., M. Faur, D.J. Flood, S. Bailey, and M. Goradia, ‘‘Electrolyte for EC-V profiling of III–V multilayer structures,’’ IPRM Proceedings (1996)

0.3 M $N$-$n$-butylpyridinium Chloride ($CgH_{14}ClN$):1 M $NH_3F_2$ (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

FAUR, M., M. Faur, S. Bailey, D. Brinker, M. Goradia, I. Weinberg, and N. Fatemi, ‘‘High Performance Etchant for Thinning p+ InP and its applications to p + n InP Solar Cell Fabrication,’’ The Conference Record of the 22rd IEEE Photovoltaics Specialists Conference 1991b, Las Vegas, NV, (IEEE Cat. No. 91CH$_2$953-8), pp. 241–45

$o$-$H_3PO_4$:$HNO_3$:$H_2O_2$:$H_2O$; InP thinning etch; with concentration dependent etch rates from 5 to 110 nm/min

FAUR, M., M. Faur, M. Ghalla, S. Bailey, G. Mateescu, and V. Voljin, ‘‘High Resolution Etchants and Electrolytes for Accurate Revealing of Surface and Deep Dislocations and Precipitates in InP Structures,’’ The Conference Record of the 23rd IEEE Photovoltaics Specialists Conference 1993, Louisville, KY, (IEEE Cat. No. 93CH3283-9), pp. 747–51

$HF$:$CH_3COOH$:$H_2O_2$
$H_3PO_4$:$HF$ (1:1); electrolytes for photoelectrochemical defect etch pit delineation; compared with chemical defect etchant results from: $HNO_3$:$HBr$ (1:3)
$H_3PO_4$:$HBr$ (1:2) (Huber etch)

FAUST, J.W., ‘‘Etching of III–V Intermetallic Compounds,’’ Compound Semiconductors: Preparation of III–V Compounds; Ed. R.K. Willardson and H.L. Goering (Reinhold, NY, 1962) pp. 445–468

III–V semiconductor etchant review; gives pre-1962 data tables for chemical etchants of InSb, GaSb, AlSb, InAs, GaAs, InP, GaP

FAUST, J.W., “Etching of Metals and Semiconductors,” The Surface Chemistry of Metals and Semiconductors, Ed. H.C. Gatos (John Wiley and Sons, NY, 1959) pp. 151–173, (1959)
Review: general discussion of etch pit dislocation and hillock formation

FAUST, J.W., and A. Sagar, “Effect of Polarity of the III–V Intermetallic Compounds on Etching,” J. Appl. Phys., **31**(2), 331–33 (1960)
(0 0 1)orientation determination; (1 1 1)A planes etch faster than (1 1 1)B planes:
$HF:H_2O_2:H_2O$ (1:1:4); InSb, InAs, GaAs
$HF:HNO_3:H_2O$ (1:1:4);InSb
$HF:HNO_3$ (1:1); InSb
HCl conc.; InAs
$HNO_3:H_2O_2$:tartaric acid (1:1:6); InAs
$HNO_3:HF:CH_3COOH:Br_2$ (75:15:15:0.06); InAs
$HCl:H_2O_2:H_2O$ (1:1:2); GaSb
$HNO_3$:tartaric acid (1:3); GaSb
$HNO_3$:tartaric acid (3:1); GaAs
$HF:HNO_3:H_2O$ (1:1:1); GaSb
$HCl:HNO_3:H_2O$ 1:1:1); GaAs
$H_2O_2$:NaOH (3:1); GaAs

FAY, P., S. Agarwala, C. Scafidi, I. Adesida, C. Caneau, and R. Bhat, “Reactive ion etching-induced damage in InAlAs/InGaAs heterostructure field-effect transistors processed in HBr plasma,” J. Vac. Sci. Technol., B, **12**(6), 3322 (1994)
Reactive ion etching; HBr for gate recess in InGaAs/InAlAs FETs; surface analysis

FEDISON, J.B., T.P. Chow, H. Lu, and I.B. Bhat, “Reactive ion etching of GaN in $BCl_3/N_2$ plasmas,” J. Electrochem. Soc., **144**(8), L221 (1997)
Reactive ion etch; $BCl_3/N_2$ of GaN; nitrogen decreases etch rate of sapphire substrates

FENG, M., L.W. Cook, M.M. Tashima, and G.E. Stillman, “Lattice Constant, Bandgap, Thickness and Surface Morphology of InGaAsP/InP LPE Cooling and Two-Phase Growth Techniques,” J. Electron. Mater., **9**(2), 241–280 (1980)
$Br_2$/methanol; Application: InGaAsP thinning for X-ray lattice parameter profile

FERRANTE, G.A., J.P. Donnelly, and C.A. Armiento, “A Slow Selective Etch for GaInAsP grown on InP,” J. Electrochem. Soc., **130**(5), 1222–24 (1983)
HCl conc.; InP (1 0 0) etch rate = 5.4 μm/min; InP selective etch from InGaAsP. $H_2SO_4:H_2O_2:$-$H_2O$ (1:1:10); InP (1 1 1)B etch rate = 30 Å/min; InP (1 0 0) etch rate is negligible
$H_2SO_4:H_2O_2:H_2O$ (1:1:10); $In_{0.73}Ga_{0.27}As_{0.63}P_{0.37}$ (1 0 0) etch rate = 1000 Å/min
$H_2SO_4:H_2O_2:H_2O$ (1:1:10); $In_{0.83}Ga_{0.17}As_{0.39}P_{0.61}$ (1 0 0) etch rate = 420 Å/min
$H_2SO_4:H_2O_2:H_2O$ (1:1:10); $In_{0.90}Ga_{0.10}As_{0.04}P_{0.96}$ (1 0 0) etch rate = 75 Å/min

FEURPRIER, Y., Ch Cardinaud, and G. Turban, "Influence of the gas mixture on the reactive ion etching of InP in $CH_4$–$H_2$ Plasmas," J. Vac. Sci. Technol., B, **15**(5), 1733 (1997)

Reactive ion etch; $CH_4/H_2$; InP; study of etch mechanism

FEURPRIER, Y., Ch Cardinaud, B. Grolleau, and G. Turban, "Proposal for an etching mechanism of InP in $CH_4$–$H_2$ mixtures based on plasma diagnostics and surface analysis," J. Vac. Sci. Technol., A, **16**(3), 1552 (1998a)

Plasma etching of InP in $CH_4$–$H_2$ mixtures; study of etch mechanism

FEURPRIER, Y., Ch Cardinaud, and G. Turban, "X-ray photoelectron spectroscopy damage characterization of reactively ion etched InP in $CH_4$–$H_2$ plasmas," J. Vac. Sci. Technol., B, **16**(4), 1823 (1998b)

Reactive ion etch; $CH_4/H_2$; of InP; study of surface damage with X-ray photoelectron spectroscopy

FIEDLER, F., A. Schlachetzki, and G. Klein, "Material-Selective Etching of InP and an InGaAsP Alloy," J. Mater. Sci., **17**, 2911–18 (1982)

$HCl:H_2O$ (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

| $H_2SO_4:H_2O_2:H_2O$: | InGaAsP etch rate (μm/min) | InP etch rate (μm/min) |
|---|---|---|
| (3:1:1) 20°C | 0.7 | 0.014 |
| (3:1:1) 30°C | 1.6 | 0.035 |
| (3:1:1) 20°C | 0.6 | 0.012 |
| (3:1:1) 30°C | – | 0.030 |

| $HCl:H_3PO_4$ | InP etch rate (selective from InGaAsP) (μm/min) |
|---|---|
| (1:1) 60°C | 27 |
| (1:4) 60°C | 4.8 |
| (1:6) 60°C | 3.0 |
| (1:1) 20°C | 2 |

FINK, T.H., and R.M. Osgood, "Light-induced Selective Etching of GaAs in AlGaAs/GaAs Heterostructures," J. Electrochem. Soc., **140**(4), L73 (1993a)

$HNO_3:H_2O$ (1:10–100); GaAs and AlGaAs non-selective etch under illumination

$HNO_3:H_2O$ (1:200); GaAs selective etch from AlGaAs under illumination. $HNO_3:H_2O$ (1:300–1000); weak etching for both GaAs and AlGaAs with trench at boundary between illuminated and dark regions

FINK, T.H., and R.M. Osgood, ‘‘Photochemical Etching of GaAs/AlGaAs Multilayer Structures,’’ J. Electrochem. Soc., **140**(9), 2572 (1993b)
$HNO_3$:$H_2O$ (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

FLAMM, D.L., ‘‘Feed Gas Purity and Environmental Concerns in Plasma Etching,’’ Solid State Technol., (Oct (part 1); Nov (part 2)), 49–54, 43–50 (1993)
Plasma etch environmental concerns

FLAMM, D.L., and G.K. Herb, ‘‘Plasma Etch Technology — An Overview,’’ Plasma Etching, D.M. Manos, D.L. Flamm, eds. Ch. 1, p. 1 (Academic Press, San Diego, CA, 1989), Review; Plasma etching

FLEMISH, J.R., and K.A. Jones, ‘‘Selective Wet Etching of GaInP, GaAs, and InP in Solutions of HCl, $CH_3COOH$, and $H_2O_2$,’’ J. Electrochem. Soc., **140**(3), 844–47 (1993)
HCl:$CH_3COOH$:$H_2O_2$ (1:20:$x$); $0 < x < 5$; etch rates for GaAs, InP and InGaP
HCl:$CH_3COOH$:$H_2O_2$ (1:$y$:1); $y > 20$ gives slow etch rates and smooth surfaces
HCl:$CH_3COOH$:$H_2O_2$ (1:40:1); etch rate dependence on the age of the solution

FOAD, M.A., S. Thoms, and C.D.W. Wilkinson, ‘‘New Technique for Dry Etch Damage Assessment of Semiconductors,’’ J. Vac. Sci. Technol., B, **11**(1), 20–25 (1993)
Reactive ion etch; $CH_4$/$H_2$ and $SiCl_4$
Ar and Ne ion beam etching
ECR plasma etching in $CCl_2F_2$/He; GaAs surface conductance measurement assessment of etch damage

FONASH, S.J., ‘‘Advances in Dry Etching Processes — A Review,’’ Solid State Technol., 150–58 (1985)
Review: dry etching processes; classification of dry etching as: physical, chemical, chemical-physical, and photochemical; tabulates the approaches and their characteristics

FORNARI, R., J. Kumar, M. Curti, and G. Zuccalli, ‘‘Growth and Properties of Bulk InP Doubly Doped with Cadmium and Sulfur,’’ J. Cryst. Growth, **96**, 795–801 (1989)
HBr:$HNO_3$ (3:1); Application: InP (1 1 1) dislocation etch pit delineation; for 7 s

FORREST, S.R., R. Kohl, J.C. Panock, J.C. Dewinter, R.E. Nahory, and E. Yanowsky, ‘‘A Long-wavelength, Annular $In_{0.53}Ga_{0.47}As$ p–n Photodetector,’’ IEEE Electron Device Lett., **EDL-3**(12), 415–17 (1982)
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

FOULON, F., M. Green, R.A. Lawes, J. Baker, F.N. Goodall, and G. Arthur, ‘‘Laser projection patterned processing of semiconductors,’’ Appl. Surf. Sci., **54**, 291 (1992a)
Laser-induced projected pattern etching of GaAs in $Cl_2$

FOULON, F., M. Green, F.N. Goodall, and S. De Unamuno, "Laser-Projection-Pattern Etching of GaAs in a Chlorine Atmosphere," J. Appl. Phys., **71**(6), 2898–2907 (1992b)
Thermochemical, laser-induced dry etch of GaAs in $Cl_2$

FOULON, F., and M. Green, "Through-wafer via fabrication in GaAs by excimer laser projection patterned etching," J. Vac. Sci. Technol., B, **11**(5), 1854–58 (1993)
Thermochemical $Cl_2$ etching of GaAs; pulsed laser heating to desorb etch products; photomask pattern etching of vias and recesses

FOURRE, H., F. Diette, and A. Cappy, "Selective wet chemical etching of lattice-matched InGaAs/InAlAs on InP and metamorphic InGaAs/InAlAs on GaAs using succinic acid/hydrogen peroxide solution," J. Vac. Sci. Technol., B, **14**(5), 3400–3402 (1996)
succinic acid:$H_2O_2$ (30:1); selective etch of InGaAs from InAlAs; selectivity is 1030 for layers lattice-matched to InP
succinic acid:$H_2O_2$ (15:2); selective etch of InGaAs from InAlAs; selectivity is 70 for strained layers on GaAs
(erratum in J. Vac. Sci. Technol., B14(6), 3603 (1996)

FRANZ, G., "High-rate etching of GaAs using chlorine atmospheres doped with a Lewis acid," J. Vac. Sci. Technol., A, **16**(3), 1542 (1998)
Capacitance coupled plasma; $BCl_3/Cl_2$ of GaAs; rate enhancement by adding Lewis acid gas ($BCl_3$)

FRANZ, G., C. Hoyler, and J. Kaindl, "Reactive ion etching GaAs and AlAs: Kinetics and process monitoring," J. Vac. Sci. Technol., B, **14**(1), 126 (1996)
Reactive ion etch; $BCl_3$/(Ar, He); study of AlGaAs etching

FRANZ, G., and F. Rinner, "Reactive ion etching of GaN and GaAs: radially uniform processes for rectangular, smooth sidewalls," J. Vac. Sci. Technol., A, **17**(1), 56 (1999)
Reactive ion etch and ECR etch; $BCl_3/Cl_2/CH_4/H_2$/Ar of GaN and GaAs; radially uniform etching

FRANZ G., "Robust Reactive Ion Etching Process for GaAs/AlGaAs/AlAs by Application of Statistical Concepts," J. Electrochem. Soc., **140**(4), 1147–51 (1993)
Reactive ion etch; $BCl_3 + He$; AlGaAs/GaAs; very small etch rate dependence on Al content

FREI, M.R., J.R. Hayes, H.F. Shirokmann, and C. Caneau, "Regrowth of InGaAs/InP p–n Heterojunctions by MOCVD," J. Appl. Phys., **70**(7), 3967 (1991)
$H_2SO_4$:$H_2O_2$:$H_2O$ (5:1:1); InGaAs surface cleaning for OMVPE InP regrowth
$H_2SO_4$:$H_2O_2$:$H_2O$ (1:8:100); InGaAs/InP mesa p–n junction surface treatment to reduce excess surface recombination
HBr:$CH_3COOH$:$K_2Cr_2O_7$ (1:1:1); InP and InGaAs mesa etch, equal rates for both

FRICKE, K., H.L. Hartnagel, W.Y. Lee, and Schüßler, "AlGaAs/GaAs/AlGaAs DHBT's for High Temperature Stable Circuits," IEEE Electron Device Lett., **15**(3), 88–90 (1994)
$NH_4OH$:$H_2O_2$ (1:170); Application:? selective etch from?

$H_3PO_4$:$H_2O_2$:$CH_3OH$ (28:16:84); Application: AlGaAs mesa etch
$NH_4OH$:$H_2O_2$:$H_2O$ (2:0.7:100); Application: $Al_{0.42}Ga_{0.58}As$ selective etch from GaAs

FRIGERI, C., "Recent developments in the study of bulk GaAs properties by electron microscopy," J. Cryst. Growth, **126**, 91–102 (1993)
HF:$CrO_3$:$H_2O$; diluted Sirtl-like (DSL) photoetching; GaAs; identification of etch features with transmission electron microscopy

FRIGERI, C., and J.L. Weyher, "Combined use of EBIC and DSL photoetching for the quantitative assessment of defect properties in LEC GaAs," J. Cryst. Growth, **103**, 268 (1990)
$CrO_3$:HF:$H_2O$ (DSL, diluted Sirtl-like with light photoetch); defect delineation in GaAs; comparison to EBIC images

FRIGERI, C., and J.L. Weyher, "Electron-beam-induced Current and Photoetching Investigations of Dislocations and Impurity Atmospheres in n-type LEC GaAs," J. Appl. Phys., **65**, 4646 (1989)
HF:$CrO_3$ (1:5) diluted with $H_2O$ (1:1) {DSL; diluted Sirtl-like etch with light}; GaAs photoetch, 30 s for etch pit delineation of dislocations

FRIGERI, C., J.L. Weyher, and P. Gall, "Microdefects in Si-doped HB GaAs Crystals Investigated by TEM, DSL Photoetching and Laser Scattering Tomography," Microsc. Semicond. Mater. 1991 (Inst. Phys Conf. Ser. No. 117) pp
$CrO_3$:HF:$H_2O$; diluted Sirtl-like (DSL) photoetching; Application: GaAs defect delineation

FRITZCHE, D., E. Kuphal, and R. Aulback, "Fast Response InP/InGaAsP Heterojunction Phototransistors," Electron. Lett., **17**(5), 178–80 (1981)
$H_3PO_4$:HCl (1:1); Application: InP selective etch from InGaAsP
$H_2SO_4$:$H_2O_2$:$H_2O$ (3:1:1); InGaAsP selective etch from InP

FRONIUS, H., A. Fischer, and K. Ploog, "Elimination of GaAs Oval Defects and High-throughput Fabrication of Selectively Doped AlGaAs/GaAs Heterostructures by MBE," J. Cryst. Growth, **81**, 169–74 (1987)
NaOCl; GaAs etch-polish to remove surface polish damage
$H_2SO_4$:$H_2O_2$:$H_2O$ (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

FUJII, K., K. Shimoyama, H. Miyata, Y. Inoue, N. Hosoi, and H. Gotoh, "Model for in situ etching and selective epitaxy of $Al_xGa_{1-x}As$ with HCl gas by metalorganic vapor phase epitaxy," J. Cryst. Growth, **145**, 277 (1994)
Thermochemical etch of AlGaAs with HCl; in situ MOVPE

FUJISAKI, Y., "Non-stoichiometry Fluctuations Along Striations in Undoped Semi-insulating GaAs," J. Cryst. Growth, **126**, 77–84 (1993)

$H_2SO_4$:$H_2O_2$:$H_2O$ (10:1:1); GaAs striation pattern delineation in semi-insulating LEC material; 20–30 min at 10°C under illumination

FULLER, C.S., and H.W. Allison, "A Polishing Etchant for III–V Semiconductors," J. Electrochem. Soc., **109**, 880 (1962)
$Br_2$/methanol; GaAs and GaP
$I_2$/methanol; InSb
$Cl_2$/methanol

FULLOWAN, T.R., S.J. Pearton, R.F. Kopf, F. Ren, Y.K. Chen, P.R. Smith, M.A. Chin, and J. Lothian, "Dry etch self-aligned AlInAs/InGaAs heterojunction bipolar transistors," Mat. Res. Soc. Symp. Proc., **240**, 285 (1992a)
ECR plasma etch; $CH_4$/$H_2$/Ar; Application to self-aligned InAlAs/InGaAs HBT

FULLOWAN, T.R., F. Ren, S.J. Pearton, G.E. Mahoney, and R.L. Kostelak, "Anisotropic reactive ion etching of submicron W features in $CF_4$ or $SF_6$ plasmas," Mat. Res. Soc. Symp. Proc., **240**, 315 (1992)
Reactive ion etch; $CF_6$, $SF_6$; selective removal of tungsten from III–V semiconductors using a titanium etch mask

FURUHATA, N., H. Miyamoto, A. Okamoto, and K. Ohata, "Chemical Dry Etching of GaAs and InP by $Cl_2$ Using a New Ultrahigh-vacuum Dry-etching Molecular-beam-epitaxy System," J. Appl. Phys., **65**(1), 168–71 (1989)
Thermochemical vapor etch; $Cl_2$; GaAs and InP in situ vacuum technique for MBE substrate cleaning

FURUHATA, N., H. Miyamoto, A. Okamoto, and K. Ohata, "$Cl_2$ Chemical Dry Etching of GaAs Under High Vacuum Conditions — Crystallographic Etching and Its Mechanism," J. Cryst. Growth, **19**(2), 201–08 (1990)
Thermochemical vapor etch; $Cl_2$; GaAs under high vacuum conditions; temperature range: 100–700°C; surface and profile characteristics of $SiO_2$-masked patterns

FURUHATA, N., and Y. Shiraishi, "Improvement in electrical properties at an n-GaAs/n-GaAs regrown interface using ammonium sulfide treatment," Jpn. J. Appl. Phys. Pt. 1, **37**(1), 10 (1998)
$(NH_4)_2S_x$; GaAs surface treatment for MBE regrowth

FURUYA, K., L.A. Coldren, B.I. Miller, and J.A. Rentschler, "Crystallographic Facets Chemically Etched in InGaAsP/InP for Integrated Optics," Electron. Lett., **17**(17), 582–83 (1981)
HCl:$HNO_3$ (1:2); equal etch rate on InP and InGaAsP = 0.16 μm/s

FUYUKI, T., S. Moriuchi, and H. Matsunami, "Plasma Anodic Oxidation of InP," Jpn. J. Appl. Phys. Pt. 1, **22**(10), 1574–76 (1983)
Plasma anodic oxidation; InP

GAMMEL, J.C., H. Ohno, and J.M. Ballantyne, "High-Speed Photoconductive Detectors Using GaInAs," IEEE J. Quantum Electron., **QE-17**(2), 269–74 (1981)
$H_3PO_4$:$H_2O_2$:$H_2O$ (1:1:8); Application: InGaAs notch etch for FET; etch rate = 0.47 μm/min

GANNON, J.J., and C.J. Nuese, "A Chemical Etchant for the Selective Removal of GaAs Through $SiO_2$ Masks," J. Electrochem. Soc., **121**(9), 1215–19 (1974)
$NH_4OH$:$H_2O_2$:$H_2O$ (20:7:973); GaAs (1 1 1)B etch rate = 0.2 μm/min; GaAs (1 0 0) etch rate = 0.12 μm/min; GaAs (1 1 1)A etch rate = 0.037 μm/min; shows much less $SiO_2$ mask undercutting than with NaOH:$H_2O_2$ etchant

GAO, L.J., G.W. Anderson, F. Esposto, P.R. Norton, B.F. Mason, Z.-H. Lu, and M.J. Graham, "Surface topography and composition of InP(1 0 0) after various sulfur passivation treatments," J. Vac. Sci. Technol., B, **B13**(5), 2053 (1995)
S passivation of InP in $S_2Cl_2$, $(NH_4)_2S$, and sulfide-containing $Br_2$:methanol solutions

GATOS, H.C., M.C. Finn, and M.C. Lavine, "Antimony Edge Dislocations in InSb," J. Appl. Phys., **32**, 1174–75 (1961)
$H_2O_2$: [HF + $H_2O$ + 0.4% butylthiobutane] (1:1); InSb {1 1 1}Sb dislocation delineation

GATOS, H.C., and M.C. Lavine, "Characteristics of the {1 1 1} Surfaces of the III–V Intermetallic Compounds," J. Electrochem. Soc., **107**(5), 427–33 (1960a)
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)
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Reactive ion etch; $CCl_2F_2$, $SiCl_4$, $BCl_3$, $CF_4$ and mixtures with Ar; GaAs via hole fabrication characteristics

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Relationship of semiconductor etching to the Fermi level for electrochemical and photochemical techniques; GaP, GaAs

GERISCHER, H., Metal and Semiconductor Electrode Processes,“ The Surface Chemistry of Metals and Semiconductors," Ed. H.C. Gatos (John Wiley and Sons, NY, 1959), pp. 177–204 (1959)
Review of electrochemical behavior of semiconductor electrodes

GERISCHER, H., Solar Photoelectrolysis with Semiconductor Electrodes,"Topics in Applied Physics," Vol. 31; Solar Energy Conversion, Ed. B.O. Seraphim (Springer, Berlin, 1979) pp. 115–172

Treatise on photochemical behavior of semiconductors; discusses thermodynamics and kinetics of photodecomposition and function of electrolyte junction solar cells

GERMANN, R., A. Forchel, M. Bresch, and H.P. Meier, "Energy Dependence and Depth Distribution of Dry Etching-induced Damage in III/V Semiconductor Heterostructures," J. Vac. Sci. Technol. B, **7**(6), 1475–78 (1989a)

Ar ion milling; energy dependence and damage depth distribution; GaAs/AlGaAs; uses degradation of a single quantum well to assess damage depth

GERMANN, R., A. Forchel, and F. Scholz, "High Resolution Luminescence Depth Profiling of Ion Etched Multiquantum Well Structures," J. Luminescence, **40/41**, 733–34 (1988)

Ion milling etch; $Ar + O_2$; InGaAs/InP quantum well structure profiling by photoluminescence at different depths

Ion milling etch; $Ar:O_2$ (3:1 flow ratio); etching conditions: 500 eV ion energy, 0.25–0.50 mA/cm$^2$ current density, 1.33E−4 mbar; normal incident ion beam is used to etch InP/InGaAs MQW structures; smooth InP surface is obtained; InP and InGaAs etch rates at 300 eV and 0.25 mA/cm$^2$ are 20 and 11.5 nm/min, respectively; this etching method is used as step etching for QW in high resolution depth profile study

GERMANN, R., A. Forchel, and D. Grutzmacher, "Optical Depth Profiling of Ion Beam Etching-induced Damage in InGaAs/InP Heterostructures," Appl. Phys. Lett., **55**(21), 2196–98 (1989b)

Ion beam etch; $Ar + O_2$; InGaAs/InP; induced damage is assessed from photoluminescence of a single quantum well

Reactive ion etch; $Ar:O_2$ (9:1) from 175 to 1200 eV with constant current density of 0.12 mA/cm$^2$; Application: InGaAs/InP heterostructures; etch rate for InP = 4.5 nm/m at 175 eV and 27.8 nm/min at 1200 eV; $Ar + O_2$ mixture causes damage to InP barrier layer

GHANBARI, R.A., M. Burkhardt, D.A. Antoniuadis, and H.I. Smith, "Comparative Mobility Degradation in Modulation-doped GaAs Devices After e-beam and X-ray Irradiation," J. Vac. Sci. Technol., B, **10**(6), 2890–92 (1992)

$NH_4OH:H_2O_2:H_2O$ (5:3:80); Application: GaAs/AlGaAs for 6 s; photolithography isolation of Hall bars

GINOUDI, A., E.C. Paloura, G. Kostandinidis, G. Kiriadis, Ph. Maurel, J.C. Garcia, and A. Chriatou, "low-temperature dc characteristics of S- and Si-doped $Ga_{0.51}In_{0.49}P$/GaAs high electron mobility transistors grown by metalorganic molecular beam epitaxy," Appl. Phys. Lett., **60**(25), 3162 (1992)

$NH_4OH:H_2O_2:H_2O$; Application: selective removal of GaAs from InGaP

$HBr:Br_2:H_2O$ (5:0.1:100); Application: non-selective mesa etch for InGaP/GaAs; etch rate 0.6 μm/min for both materials

GLANG, R., and L.V. Gregor, "Generation of patterns in thin films," Chapter 7, Handbook of Thin Films, Ed. L.I. Maissel and R. Glang (McGraw-Hill Book Co., N.Y., 1970)

Ceric sulfate (saturated solution):$HNO_3$ (9:1); chromium etchant from semiconductor surface; etch rate ~800 Å/min

$I_2$:KI:$H_2O$ (100 g:400 g:400 ml); gold etchant from semiconductor surface. NaOH (20%); Al etchant; 60–90°C

GLOERSEN, P.G., "Ion-beam Etching," J. Vac. Sci. Technol., **12**(1), 28–35 (1975)
Ar ion sputtering; GaAs etch rate = 650 Å/s; etch profiles

GODINES, J.A., F. de Anda, A. Canales, L. Baños, and D. Rios-Jara, "A Chemical Etching Solution for the Determination of the Crystallographic Orientation of GaSb by Optical Reflectograms," J. Electrochem. Soc., **141**(8), 2220–22 (1994)
HCl conc.:CuCl (1.0N); GaSb surface etching to determine crystal orientation

GOMES, W.P., and H.H. Goossens, "Electrochemistry of III–V compound semiconductors: dissolution kinetics and etching," Advances in Electrochemical Science and Engineering, Vol. 3, Chapter 1, Ed. H. Gerischer and C.W. Tobias (VCH Weinhem, 1994)
Review; electrochemistry of III–V semiconductors

GONG, X.Y., T. Yamaguchi, H. Kan, T. Makino, T. Iida, T. Kato, M. Aoyama, Y. Suzuki, N. Sanada, Y. Fukuda, and M. Kumagawa, "Influence of sulfidization treatment on the performance of mid-infrared InAsPSb/InAs detectors," Jpn. J. Appl. Phys. Pt. 1, **37**(1), 55 (1998)
$(NH_4)_2S_x$ passivation of InAs/InAsPSb photodetectors

GOTTSCHO, R.A., G. Smolinsky, and R.H. Burton, "Carbon Tetrachloride Plasma Etching of GaAs and InP: A Kinetic Study Utilizing Non-perturbative Optical Techniques," J. Appl. Phys., **53**(8), 5908–19 (1982)
Plasma etch; $CCl_4$; 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 $CCl_4$

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:
$H_3PO_4$:$H_2O_2$ (1:1); GaP (1 0 0), 15 min under illumination
$H_3PO_4$:$H_2O_2$ (1:1); $GaAs_{0.2}P_{0.8}$ (1 0 0) 10 min under illumination
$H_3PO_4$:$H_2O_2$ (10:1); $GaAs_{0.6}P_{0.4}$ (1 0 0) 15 min under illumination
$H_3PO_4$:$H_2O_2$ (10:1); GaAs (1 0 0) 3 min under illumination
$H_3PO_4$:$H_2O_2$ (10:1); $Ga_{0.98}In_{0.02}As$ (1 0 0) 3 min under illumination
$H_3PO_4$:$H_2O_2$ (10:1); AlGaAs (1 0 0) 3 min under illumination
A–B etch; with A = 40 ml $H_2O$: 40 g $CrO_3$; B = 40 ml $H_2O$: 0.3 g $AgNO_3$; A:B (3:1); GaP 15 min at boiling; etch pits show 1-to-1 correlation with $H_3PO_4$:$H_2O_2$ photoetch

GOTTSCHALCH, V., W. Heinig, E. Butter, H. Rosin, and G. Freydank, "$H_3PO_4$ Etching of (0 0 1)-faces of InP, GaInP, GaP and GaAsP," Kristall. und Technik., **14**, 563 (1979b)
$H_3PO_4$; (1 0 0): InP, GaInP, GaP, GaAsP

GOTTSCHALCH, V., R. Srnanek, and G. Wagner, ''Detection of Lattice Defects in InP and (InGa)As Using Selective Photoetching,'' J. Mater. Sci. Lett., **1**, 358–63 (1982)
$H_3PO_4$:$H_2O_2$ (1:1); InP and InGaAs lattice defect delineation with preferential photoetching
$H_2O_2$ (30%); InGaAs treatment leaves 8–10 Å $In_2O_3$ and $Ga_2O_3$

GREBEL, H., B. Ishandear, and K.G. Sheppard, ''Photochemical Etching of n-InP in a Thin-film Cell,'' Appl. Phys. Lett., **55**(25), 2655–57 (1989)
HCl:$HNO_3$:$H_2O$ (1:3:$x$); InP photoetching through thin electrolyte layer; etch rate is dependent on $x$

GREEN, D.L., E.L. Hu, P.M. Petroff, V. Liberman, M. Nooney, and R. Martin, ''Characterization of Low Energy Ion-Induced Damage Using the Multiple Quantum Well Probe Technique with an Intervening Superlattice,'' J. Vac. Sci. Technol., B, **11**(6), 2249–2253 (1993a)
Ar ion beam etch, surface damage study using characteristics of a GaAs/AlGaAs superlattice quantum well structure

GREEN, D.L., J.A. Skidmore, D.G. Lishan, E.L. Hu, and P.M. Petroff, ''Calibration of the Multiple Quantum Well Probe Technique for Dry-Etch-Induced Damage Analysis,'' Appl. Phys. Lett., **62**(11), 1253–55 (1993b)
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:$H_2O$ (1:3); oxide removal; from AlGaAs/GaAs

GREEN, L.I., ''A New Defect-revealing Etchant for GaAs,'' J. Appl. Phys., **48**(9), 3739–41 (1977)
$NH_4OH$:$H_2O$ electrochemical etch with $pH = 10.6–13.4$; GaAs delineation of striations, dislocations and twins

GREEN, R.T., D.K. Walker, and C.M. Wolfe, ''An Improved Method for the Electrochemical Profiling of Indium Phosphide,'' J. Electrochem. Soc., **133**(11), 2278–83 (1986)
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)

GREENBERG, D.R., J.A. del Alamo, and R. Bhat, ''A Recessed-Gate InAlAs/$n^+$-InP HFET with an InP Etch-Stop Layer,'' IEEE Electron Device Lett., **13**(3), 137–39 (1992)
$H_2SO_4$:$H_2O_2$:$H_2O$ (1:10:220); selective etch of InGaAs layer with InP etch-stop layer for HFET

GREENE, P.D., ''Preferential Photoelectrochemical Dissolution of n-GaAs in Fe(III)-based Etches,'' GaAs and Related Compounds, 1976 (Inst. Phys. Conf. Ser. No. 33a 1977), pp. 141–49
Ferric sulfate(non-ahydrate):EDTA(disodium salt of ethylenediaminetetracetic acid):$H_2O$ (5 g:3 g:100 ml); GaAs photoelectrochemical p–n junction delineation

GRÉUS, CH, A. Forchel, J. Straka, and M. Emmerling, "High Quantum Efficiency InGaAs/GaAs Quantum Wires Defined by Selective Wet Etching," J. Vac. Sci. Technol., B, **9**(6), 2882–85 (1991)

$H_2O_2$ buffered with $NH_4OH$ (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

GROBER, L.H., M. Hong, R.D. Grober, J.P. Mannaerts, and R.S. Freund, "Etch Rate and Thickness Measurements of Layered GaAs, AlAs and AlGaAs Structures Using a Laser Reflectance Technique," Mat. Res. Symp. Proc.(Symp. on Compound Semiconductor Epitaxy), **340**, 227–32 (1994)

ECR etch, rate monitoring with laser reflectance; GaAs, AlAs, AlGaAs in situ measurement

GRUNDBACHER, R., H. Chang, M. Hannan, and I. Adesida, "Fabrication of Parallel Quantum Wires in GaAs/AlGaAs Heterostructures Using AlAs Etch Stop Layers," J. Vac. Sci. Technol., B, **11**(6), 2254–57 (1993)

Citric acid:$H_2O_2$ (3:1); GaAs selective etch from AlAs stop etch layer

HCl dilute; AlAs etch stop layer removal from GaAs

GUEL, G., E.A. Armour, S.Z. Sun, S.T. Srinivansan, K.J. Malloy, and S.D. Hersee, "Reduction of Deep Levels in MOCVD-regrown $Al_xGa_{1-x}As$ Interfaces by $(NH_4)_2S$ Passivation and in situ HCl etching," J. Electron. Mater., **21**(11), 1051–56 (1992)

Thermochemical vapor etch; HCl/$H_2$/$AsH_3$; Application: GaAs and AlGaAs in situ etch in OMVPE reactor at 550°C

$NH_4OH$:$H_2O_2$:$H_2O$ (1:1:400); AlGaAs surface cleaning 15 s etch prior to loading for AlGaAs regrowth

GUIVARC'H, A., H. L'Haridon, G. Pelous, G. Hollinger, and P. Pertosa, "Chemical cleaning of InP surfaces: oxide composition and electrical properties," J. Appl. Phys., **55**(4), 1139 (1984)

$Br_2$:HBr:$H_2O$ (1:17:35); 90 s InP wafer etch after $Br_2$/methanol chemical–mechanical polishing

InP surface oxide (XPS) and Schottky contact study following chemical treatment in:

NaOH:$H_2O$ (1 M:0.8 M); 20 min at 80°C, pH = 9.6

$NH_4OH$:$H_2O_2$:$H_2O$ (5:1:100); 80°C for 1, 5, 20, and 80 min; pH = 11 $H_2O_2$ at 80°C; pH = 4.4

HF (49%)

$H_2SO_4$:$H_2O_2$:$H_2O$ (3:1:1); pH = 2

$Br_2$:Methanol (1:100)

$Br_2$:HBr:$H_2O$ (1:17:35); pH = 0

$Br_2$:HBr:$H_2O$ (0.3:10:100); pH = 0.2

GUO, Q.X., O. Kato, and A. Yoshida, "Chemical Etching of Indium Nitride," J. Electrochem. Soc., **139**(7), 2008–09 (1992)

InN wet chemical etching study; no etch in acid:$H_2O_2$ solutions; KOH:$H_2O$ (33 wt.% solution); InN etch rate at 50°C = 220 Å/min. NaOH:$H_2O$ (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 $AsCl_3$ 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 $SiO_2$-patterned GaAs using $AsCl_3$ in a CBE reactor

HABIBI, S., M. Totsuka, J. Tanaka, T. Kinoshita, S. Matsumoto, and S. Iida, “Dry Photochemical Selective Etching of InGaAs/InAlAs in HBr Gas Using a 172 nm Excimer Lamp,” J. Vac. Sci. Technol., B, **13**(2), 247–52 (1995a)

Photochemical etch in HBr gas; selective etch of InGaAs from InAlAs; selectivity of ∼1 0 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 $H_2S$,” J. Vac. Sci. Technol., B, **13**(4), 1466 (1995b)

HBr photochemical dry etch; selectively removes InGaAs from InAlAs. $H_2S$:$N_2$ (1:9) photochemical gas sulfidization of $In_{0.52}Al_{0.48}As$

HAGBERG, M., B. Jonsson, and Larsson, “Investigation of Chemically Assisted Ion Beam Etching for the Fabrication of Vertical, Ultrahigh Quality Facets in GaAs,” J. Vac. Sci. Technol., B, **12**(2), 555–66 (1994)

Ion beam etch, chemically assisted; $Cl_2$; GaAs vertical facets

HAHN, L., K.-C. Wong, and E.A. Ogryzlo, “The Etching of Gallium Arsenide with Iodine Monochloride,” J. Electrochem. Soc., **140**(1), 226–29 (1993)

ICl thermochemical vapor etch; GaAs etch rate study in 100–300°C temperature range

HAHN, Y.B., D.C. Hays, S.M. Donovan, C.R. Abernathy, J. Han, R.J. Shul, H. Cho, K.B. Jung, and S.J. Pearton, “Effect of additive noble gases in chlorine-based inductively coupled plasma etching of GaN, InN, and AlN,” J. Vac. Sci. Technol., A, **17**(3), 768 (1999a)

Inductively coupled plasma etching; $Cl_2$/Xe, $Cl_2$/Ar, and $Cl_2$/He of InN, GaN, and AlN; study of etch characteristics

HAHN, Y.B., J.W. Lee, G.A. Vawter, R.J. Shul, C.R. Abernathy, D.C. Hays, E.S. Lambers, and S.J. Pearton, “Reactive ion beam etching of GaAs and related compounds in an inductively coupled plasma of $Cl_2$–Ar mixture,” J. Vac. Sci. Technol., B, **17**(2), 366 (1999b)

RIE inductively coupled plasma etch of GaAs, GaP, AlGaAs, GaSb in $Cl_2$–Ar mixtures

HAISTY, R.W., “Photoetching and Plating of Gallium Arsenide,” J. Electrochem. Soc., **108**, 790–94 (1961)

Photoetching of n-GaAs in KCl, KOH, and HCl electrolytes

HAJKOVA, E., and R. Fremunt, “Effective Chemical Polishing of n-type GaP Surfaces,” Phys. Status Solidi A, **10**, K35–K37 (1972)

$HNO_3$:HCl:$H_2SO_4$:$H_2O$ (1:2:2:2); GaP {1 1 1}B, 5 min to remove mechanical polish damage. etch rate is dependent on carrier concentration

HAKIMI, R., and M.-C. Amann, “Reduction of 1/f carrier noise in InGaAsP/InP heterostructures by sulfur passivation of facets,” Semicond. Sci. Technol., **12**, 778 (1997)

$Na_2S$:isopropanol (saturated solution); sulfur passivation of InGaAsP/InP laser diodes; reduced surface recombination

HALES, M.C., J.R. Knight, and C.W. Williams, "Epitaxial InP and InAsP," GaAs and Related Compounds, 1970 (Inst. Phys. Conf. Ser. No. 9 1971), p. 50

KOH: $K_3Fe(CN)_6$:$H_2O$ (6 g:4 g:50 ml); Application: InP cleaved cross-section layer delineation; ~5 min at 20°C

HALL, R.N., and J.H. Racette, "Diffusion and Solubility of Copper in Extrinsic and Intrinsic Germanium, Silicon, and Gallium Arsenide," J. Appl. Phys., **35**(2), 379 (1964)

KCN (20%) solution; Application: GaAs, Si, Ge; cleaning of metallic ions from surface prior diffusion

HAMAMATSU, A., C. Kaneshiro, T. Sato, H. Fujikura, and H. Hasegawa, "Subnano-scale selective etching and nano-scale pore array formation on InP (0 0 1) surfaces by a wet electrochemical process," Proc. 11th Int'l Conf. on Indium Phosphide and Related Materials, 503 (1999)

HCl (1 M); electrolyte for photo-anodic etching and pulsed avalanche etching of InP (0 0 1); formation of pore arrays

HAMISCH, Y., R. Steffen, J. Oshinowo, and A. Forchel, "Selective Order–Disorder Transition in GaInP/AlGaInP: A New Approach for the Definition of Buried Quantum Wires," J. Vac. Sci. Technol., B, **10**(6), 2864–67 (1992)

KI:$I_2$:$H_2O$; Application: removal Au implantation mask from InGaP; etch rate = 150 Å/s

HAN, B.Y., C.Y. Cha, and J.H. Weaver, "Layer-by-layer etching of GaAs (1 1 0) with halogenation and pulsed-laser irradiation," J. Vac. Sci. Technol., A, **16**(2), 490 (1998)

Layer by layer etch of GaAs (1 1 0) by $Cl_2$ exposure followed by laser photodesorption

HAN, I.K., E.K. Kim, J.I. Lee, S.H. Kim, K.N. Kang, Y. Kim, H. Lim, and H.L. Park, "Stability of sulfur-treated InP surface studied by photoluminescence and X-ray photoelectron spectroscopy," J. Appl. Phys., **81**(10), 6986 (1997)

Sulfur passivation of InP; anodization in $(NH_4)_2S_x$ solution; study of surface stability

HANISH, C.K., J.W. Grizzle, H.-H. Chen, L.I. Kamlet, S. Thomas III, F.L. Terry Jr, and S.W. Pang, "Modeling and algorithm development for automated optical endpointing of a HBT emitter etch," J. Electron. Mater., **26**(12), 1401 (1997)

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

HANSON, A.W., S.A. Stockman, and G.E. Stillman, "Comparison of $In_{0.5}Ga_{0.5}P$/GaAs single- and double-heterojunction transistors with a carbon-doped base," IEEE Electron Device Lett., **14**(1), 25 (1993)

$H_2SO_4$:$H_2O_2$:$H_2O$ (1:8:200); Application: selective etch of GaAs from InGaP
HCl:$H_3PO_4$ (1:3); Application: selective etch of InGaP from GaAs

HARA, A., R. Nakamura, and H. Ikoma, "Niridization of GaAs using helicon-wave excited and inductively coupled nitrogen plasma," J. Vac. Sci. Technol., B, **16**(1), 183 (1998)

Nitridization of GaAs in plasmas of $N_2 + O_2$ with pretreatment in $O_2$ + Ar plasma

HARRIOT, L.R., H. Temkin, R.A. Hamm, J. Weiner, and M.B. Panish, "A Focused Ion Beam Vacuum Lithography Process Compatible with Gas Source Molecular Beam Epitaxy," J. Vac. Sci. Technol. B, **7**(6), 1467–70 (1989)

Ar ion etching; $Cl_2$ assisted; Application: InP substrate patterning by etch of a Ga ion beam direct-write damage pattern

HARRIS, D., P.A. Kohl, and J. Winnick, "Photoelectrochemical Etching of InAs," J. Electrochem. Soc., **141**(5), 1274–77 (1994)

$H_2SO_4$ (0.2 M); electrolyte for photo-selective etch of n-InAs
HCl (0.2 M); electrolyte for photoelectrochemical etch of InAs

HASHEMI, M.M., Y. Li, K. Kiziloglu, M. Wassermeier, P.M. Petroff, and U.K. Mishra, "Direct-current and Radio-frequency Characterization of Submicron Striped-channel Field Effect Transistor Structures Using Focused Ion Beam and Electron-beam Lithography.," J. Vac. Sci. Technol., B, **10**(6), 2945–48 (1992)

$H_3PO_4$:$H_2O_2$:$H_2O$ (3:1:50); Application: GaAs MESFET mesas

HATATE, H., M. Hashimoto, H. Shirakawa, Y. Fujiwara, Y. Takeda, H. Nakano, H. Tatsuta, and O. Tsuji, "Fabrication of InP submicron pillars for two-dimensional photonic crystal by reactive ion etching," Jpn. J. Appl. Phys., Pt. 1, **37**(12b), 7172 (1998)

ICP and ECR etching of InP submicron pillars using $SiCl_4$/Ar

HAYES, T.R., U.K. Chakrabarti, W.C. Dautremont-Smith, H.S. Luftman, F.A. Baiocchi, and P.M. Thomas, "Physical and Electrical Damage to InP and InGaAsP Surfaces Resulting from $CH_4/H_2$ Reactive Ion Etching, (Electron. Materials Conf. Abstract)," J. Electron. Mater., **18**(4), 60–1 (1989a)

Reactive ion etch; $CH_4 + H_2$; InP and InGaAsP; near-surface properties are modified. phosphorous depletion rate depends on $CH_4/H_2$ ratio; morphology and electrical damage (Ohmic contacts) caused by etching; layer of damage ~150 Å; great $H_2$ passivation near Zn-acceptor for p-InP but not for p-InGaAsP

HAYES, T.R., M.A. Dreisbach, P.M. Thomas, W.C. Dautremont-Smith, and L.A. Heimbrook, "Reactive Ion Etching of InP Using $CH_4/H_2$ Mixtures: Mechanisms of Etching and Anisotropy," J. Vac. Sci. Technol., B, **7**(5), 1130–39 (1989b)

Reactive ion etch; $CH_4/H_2$; InP etch kinetics

HAYNES, R.W., G.M. Metze, V.G. Kreismanis, and L.F. Eastman, "Laser-Photoinduced Etching of Semiconductors and Metals," Appl. Phys. Lett., **37**(4), 344–346 (1980)

$Br_2$:KBr:$H_2O$ (1:10:89); n-GaAs photoetchant for maskless laser-induced patterning
$I_2$:KI:$H_2O$ (0.1:10:90); n-GaAs photoetchant for maskless laser-induced patterning

HE, L., Z.Q. Shi, and W.A. Anderson, "Photoreflectance Study of Plasma Etching Effect on InP," 3rd Int'l Conf. on Indium Phosphide and Related Materials, 8–11 April 1991, Cardiff, Wales, UK), IEEE Catalog no. 91CH$_2$950-4) pp. 531–34

Plasma etch; $CF_4$; InP surface damage study by photoreflectance

HE, Y., B.W. Liang, N.C. Tien, and C.W. Tu, "Selective Chemical Etching of InP over InAlAs," J. Electrochem. Soc., **139**(7), 2046–48 (1992)

$HCl:H_3PO_4:CH_3COOH$ (1:1:2); InP selective etch from InAlAs; selectivity $> 85$; InP etch rate $= 3000$ Å/min

$HCl:H_3PO_4:CH_3COOH$ (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

HEIMANN, R.B., "Principles of Chemical Etching — The Art and Science of Etching Crystals," Crystals: Growth, Properties and Applications, Vol. 8: Silicon Chemical Etching (Springer-Verlag, Berlin, Heidelburg, 1982),"

Review: silicon defect etch pit delineation

HEMENWAY, B.R., J.E. Bowers, and B.I. Miller, "Anisotropic Undercutting in (1 0 0) Indium Phosphide," Electron. Lett., **19**(24), 1049–51 (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 $Cl_2/O_2$ which leaves the pattern with an initial 75° wall angle

HENRY, L., C. Vaudry, and P. Granjoux, "Novel Process for Integration of Optoelectronic Devices Using Reactive Ion Etching without Chlorinated Gas," Electron. Lett., **23**(24), 1253–54 (1987)

Reactive ion etch; $CH_4 + Ar + H_2$; InP, GaAs, InGaAs, AlGaAs and InGaAsP; $Si_3N_4$ 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 $Si_3N_4$; Application: InGaAs junction FET; $Al_{0.3}Ga_{0.7}As$ etch rate is less than other III–V compounds etch rate

HERSHENSON, L., and K. Zanis, "Grain Boundary Etching in InP," J. Appl. Phys., **51**, 3663 (1980)

$HCl:HNO_3:HF$ (5:3:4); InP grain boundary delineation; no effect on first-order twins

HIDA, H., Y. Tsukada, Y. Ogawa, H. Toyoshima, M. Fujii, K. Shibahara, M. Kohno, and T. Nozaki, "High-speed and Large Noise Margin Tolerance Electrooptical Logic Gates with LDD Structure DMTs Fabricated Using Selective RIE Technology," IEEE Trans. Electron Devices, **36**, 2223 (1989)

Reactive ion etch; $CCl_4$/He; Application: AlGaAs selective etch from GaAs with selectivity $> 1000$

HIGUCHI, K., H. Uchiyama, T. Shiota, M. Kudo, and T. Mishima, "Selective wet-etching of InGaAs on InAlAs using adipic acid and its application to InAlAs/InGaAs HEMTs," Semicond. Sci. Technol., **12**, 475 (1997)

Adipic acid:$NH_4OH:H_2O_2$ (1 g adipic acid in 5 ml $H_2O$; $NH_4OH$ to adjust pH over the range 5.3–7.0: $H_2O_2$ added in the range of volume ratios of 0.013–0.12); InGaAs removal from InAlAs; selectivity up to 250

HIKOSAKA, K., T. Mimura, and K. Joshin, “Selective Dry Etching of AlGaAs–GaAs Heterojunction,” Jpn. J. Appl. Phys., **20**(11), L847–L850 (1981)

Reactive ion etch; $CCl_2F_2 + He$; GaAs selective etch from $Ga_{0.7}Al_{0.3}As$; gives etch rate selectivity dependence on gas pressures and concentrations

HILL, D.G., K.L. Lear, and J.S. Harris, “Two Selective Etching Solutions for GaAs on InGaAs and GaAs/AlGaAs on InGaAs,” J. Electrochem. Soc., **137**(9), 2912–14 (1990)

$H_2O_2$:$NH_4OH$ (250:1), pH $= 7.3$; GaAs selective etch from InGaAs, selectivity $> 50$; attacks photoresists; $SiO_2$ photolithographic mask defined by buffered HF etch

$K_3Fe(CN)_6$:$K_4Fe(CN)_6 \cdot 3H_2O$ (14.8 g:19.0 g:200 ml $H_2O$:buffered with 3 ml HCl:$H_2O$ {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 $> 8$

$H_3PO_4$:$H_2O$ (1:4); GaAs oxide removal prior to etching and InGaAs oxide removal following the above etch

HILTON, K.P., and J. Woodward, “Via Holes for GaAs MMICs Fabricated Using Reactive Ion Etching,” Electron. Lett., **21**, 962–963 (1985)

Reactive ion etch, $CCl_2F_2$; Application: via hole formation in GaAs

HIPWOOD, L.G., and P.N. Wood, “Dry Etching of Through Substrate Via Holes for GaAs MMIC’s,” J. Vac. Sci. Technol., B, **3**(1), 395–397 (1985)

Reactive ion etch; $CCl_2F_2$; Application; via holes in GaAs

HIRANO, R., T. Kanazawa, and S. Katsura, “Microdefects in InP Crystals Grown by the Liquid-Encapsulation Czochralski Method,” J. Cryst. Growth, **134**, 81–89 (1993)

$H_3PO_4$:HBr (2:1) (Huber etch); Application: InP defect delineation etch; 2 min at room temperature

$CrO_3$:$AgNO_3$:$H_2O$:HF (1 g:8 mg:2 ml:1 ml) (A–B etch); Application: InP defect delineation etch; 60 min at 60°C

HIRAO, M., A. Doi, S. Tsuji, M. Nakamura, and K. Aiki, “Fabrication and Characterization of Narrow Stripe InGaAsP/InP Buried Heterostructure Lasers,” J. Appl. Phys., **51**(8), 4539–40 (1980a)

$Br_2$/methanol; Application: InGaAsP stripe etch for BH laser fabrication

HIRAO, M., S. Tsuji, K. Mizuishi, A. Doi, and M. Nakamura, “Long Wavelength InGaAsP/InP Lasers for Optical Fiber Communication Systems,” J. Optical Commun., **1**(1), 10–14 (1980b)

$Br_2$/methanol; Application: InGaAsP stripe etch for BH laser fabrication

HIRATA, K., O. Mikami, and T. Saitoh, “Direct Transfer of Resist Grating Patterns onto InP by Reactive-ion Etching Using $CCl_4/O_2$,” J. Vac. Sci. Technol. B, **2**(1), 45–48 (1984)

Reactive ion etch; $CCl_4$:$O_2$; 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 $O_2$ concentration up to 50% but then decreases when $O_2$ is higher than 50% while etch rate for photoresist increases with $O_2$ concentration; in $CCl_4 + O_2$, $O_2$ reacts with carbon to produce $CO_2$ 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

HIROTA, Y., "Schottky Characteristics of GaAs Surface Cleaned by Ultrasonic Running Deionized Water Treatment," Appl. Phys. Lett., **63**(14), 1936–38 (1993)
$NH_4OH:H_2O_2:H_2O$ (1:1:20); Application: GaAs; for removal of surface damage after annealing, prior to Schottky contact

HIROTA, Y., Y. Homma, and K. Sugii, "Clean and damage-free GaAs surfaces prepared by ultrasonic running deionized water treatment," Appl. Surf. Sci., **60/61**, 619 (1992)
$H_2O$; GaAs (0 0 1) surfaces treated with ultrasonic running deionized water show complete removal of arsenic and gallium oxides following etch in $H_2SO_4$ or $NH_4OH$

HIROTA, Y., T. Ogino, Y. Watanabe, and M. Oshima, "Thermal Effects on GaAs(0 0 1) Surface Prepared by Deoxygenated and Deionized Water Treatment," J. Vac. Sci. Technol., A, **13**(3), 1676–80 (1995)
$NH_4OH:H_2O_2:H_2O$ (1:1:20); GaAs surface treatment to remove damage, 2 min at room temperature
$H_2O$ (deoxygenated, deionized); GaAs treatment for oxide-free surface

HIROTA, Y., K. Sugii, and Y. Homma, "Cleaning effects of running deionized water on a GaAs surface," J. Electrochem. Soc., **138**(3), 799 (1991)
$H_2O$; dissolution of oxides from GaAs

HOBSON, W.S., Y.K. Chen, and M.C. Wu, "InGaAs/AlGaAs Ridge Waveguide Lasers Utilizing an InGaP Etch-stop Layer," Semicond. Sci. Technol., **71**, 425–27 (1992)
$H_2SO_4:H_2O_2:H_2O$ (1:1:10); Application: InGaAs/AlGaAs MQW laser using 30 Å InGaP etch stop layer

HOFFMANN, H.J., and J.M. Woodall, "Photo-enhanced Etching of n-Si," Appl. Phys. A, **33**, 243–45 (1989)
$HF:H_2O$ (1:10); Si photoetch, rate increase of 1000X under illumination; Si etch rate = 26 Å/s

HOFFMANN, H.J., J.M. Woodall, and T.I. Chappell, "Voltage-controlled Photoetching of GaAs," Appl. Phys. Lett., **38**(7), 564–66 (1981)
1 M KOH aqueous solution; GaAs n-type voltage-controlled photoetching at 26°C; self-limiting to thickness of the depletion layer for FETs

HÖKELEK, E., and G.Y. Robinson, "Schottky Contacts on Chemically Etched p- and n-type InP," Appl. Phys. Lett., **40**(5), 426–28 (1982)
Iodic acid:$H_2O$ (10% wt. solution); InP surface preparation AES study for Schottky contacts

HOLLAN, L., J.C. Tranchart, and R. Memming, "Interpretation of Selective Etching of III–V Compounds on the Basis of Semiconductor Electrochemistry," J. Electrochem. Soc., **126**(5), 855–59 (1979)
Electrochemical etch study on GaAs; redox processes and photoeffects on III–V etchant selectivity

HOLLINGER, G., E. Bergignat, J. Joseph, and Y. Robach, "On the Nature of Oxides on InP Surfaces," J. Vac. Sci. Technol. A, **3**(6), 2082–88 (1985)

XPS study of InP surface oxides following chemical treatment:
$NaOH:H_2O_2$ (1 M:0 > 8 M)
$Br_2:HBr:H_2O$ (1:17:35)
$HNO_3$
Wet chemical etch; $Br_2:CH_3OH$ and HF are used for InP surface treatment before oxidation study; chemicals for oxidation study include: $NaOH:H_2O_2$ (1 M:0.8 M) for 20 min at 80°C; $Br_2:HBr:H_2O$ (1:17:35) for 30 s and $HNO_3$ (40%) under strong illumination

HOLLINGER, G., J. Joseph, Y. Robach, E. Bergignat, B. Commere, P. Viktorovitch, and M. Froment, "On the chemistry of passivated oxide–InP interfaces," J. Vac. Sci. Technol., B, **5**(4), 1108 (1987)

Anodization: InP; study of surface passivation

HOLMES, A.L., M.R. Islam, R.V. Chelakara, F.J. Ciuba, and R.D. DuPuis, "High-Reflectivity Visible-Wavelength Semiconductor-Native Oxide Bragg Reflectors (EMC abstract)," J. Electron. Mater., **24**(7), A11 (1995)

$H_2SO_4:H_2O_2:H_2O$ (1:8:80); Application: selective removal of GaAs from InAlP stop layer; 1 min
$HCl:H_2O$ (1:1); Application: selective removal of InAlP layer form GaAs; 20 s

HOLMES, D.E., and G.S. Kamath, "Growth Characteristics of LPE InSb and InGaSb," J. Electron. Mater., **9**, 95 (1980)

$NH_4OH:H_2O_2$ (1:1); Application: InAs and InSb substrate cleaning; used boiling to remove organic residues
Lactic acid:$HNO_3$:HF (50:8:2); InSb surface cleaning for LPE; no carbon contamination

HOLONYAK, N., B.A. Vojak, R.M. Kolbas, R.D. Dupuis, and P.D. Dapkus, "Bevel Cross Sectioning of Ultra-thin (~100Å) III–V Semiconducting Layers," Solid-State Electron., **22**, 431–33 (1979)

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

HOLSTRA, P.G., B.J. Robinson, D.A. Thompson, and S.A. McMaster, "Etching of InP surface oxide with atomic hydrogen produced by electron cyclotron resonance," J. Vac. Sci. Technol., A, **13**(4), 2146 (1995)

ECR hydrogen plasma surface oxide removal from InP

HOMMEL, J., F. Schneider, M. Moser, C. Geng, F. Scholz, and H. Schweizer, "Nearly damage-free dry etching of AlGaInP/GaInP by electron cyclotron resonance technique," Microelectron. Eng., **23**, 349 (1994)

ECR etch; $CCl_2F_2$/Ar; AlGaInP/GaInP low damage

HONG, J., H. Cho, T. Maeda, C.R. Abernathy, S.J. Pearton, R.J. Shul, and W.S. Hobson, "New plasma chemistries for dry etching of InGaAlP alloys: $BI_3$ and $BBr_3$," J. Vac. Sci. Technol., B, **16**(5), 2690 (1998a)

Inductively coupled plasma (ICP) etch of InGaAlP using $BI_3$ and $BBr_3$ with or without Ar; AlInP acts as etch stop for InGaP and AlGaP

HONG, J., E.S. Lambers, C.R. Abernathy, S.J. Pearton, R.J. Shul, and W.S. Hobson, "Inductively coupled plasma etching of InGaP, AlInP, and AlGaP in $Cl_2$ and $BCl_3$ chemistries," J. Electron. Mater., **27**(3), 132 (1998b)

Inductively coupled plasma etching in $Cl_2$ and $BCl_3$ of InGaP, InAlP and AlGaP; study of etch behavior

HONG, J., J.W. Lee, E.S. Lambers, C.R. Abernathy, S.J. Pearton, C. Constantine, and W.S. Hobson, "Comparison of ICl and IBr plasma chemistries for etching of InGasAlP alloys," J. Electrochem. Soc., **143**(11), 3656 (1996a)

ECR etch; ICl and IBr; comparison for etching InGaAlP

HONG, J., J.W. Lee, C.R. Abernathy, S.J. Pearton, C. Constantine, W.S. Hobson, and F. Ren, "Comparison of ECR plasma chemistries for etching of InGaP and AlGaP," J. Electron. Mater., **26**(11), 1303 (1997)

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

HONG, J., J.W. Lee, C.R. Abernathy, E.S. Lambers, S.J. Pearton, R.J. Shul, and W.S. Hobson, "Comparison of plasma chemistries for inductively coupled plasma etching of InGaAlP alloys," J. Vac. Sci. Technol., B, **16**(3), 1497 (1998c)

ICP etch study of InGaP, AlInP and AlGaP using $CH_4$/$H_2$/Ar and $Cl_2$/Ar

HONG, J., J.W. Lee, E.S. Lambers, C.R. Abernathy, C.J. Santana, W.S. Hobson, and F. Ren, "Dry etching of InGaAlP alloys in $Cl_2$/Ar high ion density plasmas," J. Electron. Mater., **25**(9), 1428 (1996b)

ECR etch; $Cl_2$/Ar; high etch rate conditions for InGaP and AlInP

HONG, J., J.W. Lee, C.J. Santana, C.R. Abernathy, S.J. Pearton, W.S. Hobson, and F. Ren, "Plasma etching of InGaP, AlInP and AlGaP in $BCl_3$ environments," Mater. Sci. Eng. B, **B41**, 247 (1996c)

ECR plasma etch; $BCl_3$/Ar; of InGaP, AlInP and AlGaP; comparison to RIE

HONG, M., R.S. Freund, K.D. Choquette, H.S. Luftman, J.P. Mannaerts, and R.C. Wetzel, "Removal of GaAs Surface Contaminants Using $H_2$ Electron Cyclotron Resonance Plasma Treatment Followed by $Cl_2$ Chemical Etching," Appl. Phys. Lett., **62**(21), 1658–60 (1993)

ECR etch; $H_2$; GaAs surface cleaning followed by:
$Cl_2$ thermochemical etch; 1–2 min at 350–400°C

HONG, M., J.P. Mannaerts, L.H. Grober, F.A. Theil, and R.S. Freund, "AlGaAs Surface Reconstruction After $Cl_2$ Chemical Etch and Ultra High Vacuum Anneal (Symp. on Compound Semiconductor Epitaxy)," Mat. Res. Soc. Symp. Proc., **340**, 213–19 (1994)

$Cl_2$ etch of AlGaAs; in situ high vacuum; surface reconstruction and anneal

HOOLE, A.C.F., and A.N. Broers, "Etch-rate Characterization of Irradiated $SiO_2$ and its Application in the Fabrication of a T-gate Structure," J. Vac. Sci. Technol., B, **10**(6), 2855–59 (1992)

$HF:HNO_3:H_2O$ (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

$KOH:H_2O$ (5 g:20 ml); Si anisotropic etch at 65°C, stops at {1 1 1} planes

HORIIKE, Y., N. Hayasaka, M. Sekine, T. Arikado, M. Nakase, and H. Okano, "Excimer-Laser Etching on Silicon," Appl. Phys. A, **44**, 313–322 (1987)

Laser-induced photoetching of Si in $Cl_2$ and $NF_3$ gases

HORST, S.C., S. Agarwala, O. King, J.L. Fitz, and S.D. Smith, "GaAs/AlGaAs ridge lasers with etched mirrors formed by an inductively coupled plasma reactor," Appl. Phys. Lett., **71**(11), 1444 (1997)

Inductively coupled plasma etch; $BCl_3/Cl_2$; etched mirrors for ridge lasers

HOU, D.T.C., M.F. Yan, J.D. Wynn, and D.P. Wilt, "Preferential etching of InGaAsP/InP using low temperature bromine/methanol for planar buried heterostructure lasers," J. Electrochem. Soc., **136**(6), 1828 (1989)

$Br_2$/methanol (1%); InGaAsP/InP mesa etch; temperature dependence of etch rate; for $T < -58°C$ there is no undercutting of $SiO_2$ masks

HOU, D.T.C., and M.F. Yan, "Wafer Stage Staining Technique for Detection of Zn Out-diffusion in InGaAsP/InP Lasers," J. Electrochem. Soc., **137**(10), 3270–71 (1990)

$KOH:Fe(CN)_6:H_2O$ (6 g:4 g:50 ml); Application: p–n junction photochemical delineation for Zn diffusion assessment in InGaAsP/InP structures

HOU, X., X. Chen, Z. Li, X. Ding, and X. Wang, "Passivation of GaAs surface by sulfur glow discharge," Appl. Phys. Lett., **69**(10), 1429 (1996)

Sulfur passivation of GaAs surface using a sulfur glow discharge plasma

HOULET, L., A. Rhallabi, and G. Turban, "Microscopic modeling of InP etching in $CH_4$–$H_2$ plasma," J. Vac. Sci. Technol., A, **17**(5), 2598 (1999)

Reactive ion etch of InP in $CH_4/H_2$; reaction modeling

HOUSTON, P.A., C. Blaauw, A. Margittai, M.M. Svilans, N. Puetz, D.J. Day, F.R. Shepherd, and A.J. Springthorpe, "Double-heterojunction Bipolar Transistors in InP/GaInAs Grown by MOCVD," Electron. Lett., **23**, 931 (1987)

$H_3PO_4:HCl$ (4:6); Application: InP selective etch from InGaAs

$H_2SO_4:H_2O_2:H_2O$ (3:5:50) InGaAs selective etch from InP

HRYNIEWICZ, J.V., Y.J. Chen, S.H. Hsu, C.-H. Lee, and Porkolab, "Ultrahigh vacuum chemically assisted ion beam etching with a three grid ion source," J. Vac. Sci. Technol., A, **15**(3), 616 (1997)

CAIBE; $Ar/Cl_2$ of AlGaAs/GaAs in ultrahigh vacuum to eliminate aluminum oxide problems

HSIEH, H.F., C.C. Yeh, and H.C. Shih, "The Dependence of the Etching Properties of Illuminated InAs, GaP and other III–V Semiconductors in Concentrated HCl Solutions on the Formation of Chloro Complexes," J. Electrochem. Soc., **140**(2), 463–67 (1993)
HCl; photochemical; InAs and GaP etch characteristics under illumination; reaction kinetics dependence on semiconductor band structure

HSIEH, H.F., C.C. Yeh, and H.C. Shih, "The Etching Kinetics of Illuminated n-GaP in Nitric Acid," J. Electrochem. Soc., **139**(2), 380–85 (1992)
$HNO_3$; GaP oxidation/etching under illumination; chemical kinetics

HSIEH, J.J., J.A. Rossi, and J.P. Donnelly, "Room-Temperature CW Operation of GaInAsP/InP Double-Heterostructure Diode Lasers Emitting at 1.1 μm," Appl. Phys. Lett., **28**(12), 709–11 (1976)
KOH: $K_3Fe(CN)_6$:$H_2O$; Application: InGaAsP/InP cleaved cross-section layer delineation; ~5 s at 20°C

HU, E.L., and C.-H. Chen, "Dry etch damage in III–V semiconductors," Microelectron. Eng., **35**, 23 (1997a)
Reactive ion etching; modeling of ion-induced damage in III–V semiconductors

HU, E., C.-H. Chen, and D.L. Green, "Low-energy ion damage in semiconductors: A progress report," J. Vac. Sci. Technol., B, **14**(6), 3632 (1996a)
1. Etch damage using low energy ions on semiconductors

HU, E.L., and L.A. Coldren, "Recent developments in reactive plasma etching of III–V compound semiconductors," SPIE Proc., Advanced Processing of Semiconductor Devices, **797**, 98 (1987)
Review; plasma etching of III–Vs

HU, E.L., and R.E. Howard, "Reactive Ion Etching of GaAs and InP Using $CCl_2F_2/Ar/O_2$," Appl. Phys. Lett., **37**(11), 1022–24 (1980)
Reactive ion etch; $CCl_2F_2/Ar/O_2$; InP and GaAs

HU, E.L., D.G. Yu, C.-H. Chen, B.P. Keller, A.L. Holmes Jr., and S.P. DenBaars, "Ion damage propagation in dry etched InP-based structures," InP and Related Material Conference Proceedings, 1996b, p. 107
Reactive ion etch of InP using $CH_4/H_2/Ar$; damage study
Thermochemical etch of InP using Cl; damage study
Cl-assisted RIE of InP; damage study

HU, M.H., J.Z. Huang, R. Scarmozzino, M. Levy, and R.M. Osgood J., "A low-loss and compact waveguide Y-branch using refractive-index tapering," IEEE Photon. Technol. Lett., **9**(2), 203 (1997)
$HNO_3$:HCl:$H_2O$ (1:4:50); GaAs photoinduced etching to taper the thickness by varying pattern of the UV intensity

HU, Y.Z., J. Joseph, and E.A. Irene, "Electron Cyclotron Resonance Plasma Oxidation Studies of InP," J. Vac. Sci. Technol., B, **12**(2), 540–46 (1994)
ECR plasma oxidation study of InP

HU, Y.Z., M. Li, E.A. Irene, M. Rowe, and H.C. Casey Jr., "Electron Cyclotron Resonance Plasma Process for InP Passivation," Appl. Phys. Lett., **63**(8), 1113–15 (1993)
ECR plasma oxidation; InP surface passivation
HF:methanol (1:10); Application: InP native oxide removal; 2 min ultrasonic

HUANG, R.-T., C.-L. Jiang, A. Applebaum, D. Renner, and S.W. Zehr, "Selective Growth of InP on Patterned, Non-planar InP Substrates by Low-pressure Organometallic Vapor Phase Epitaxy," J. Electron. Mater., **19**(11), 1313–17 (1990)
$HBr:HNO_3:H_2O$; Application: InP mesa stripe using an InGaAsP interface layer to control the sidewall shape for reproducible height and width

HUBER, A., and N.T. Linh, "Revelation Metallographique des Defaults Cristalline dans InP," J. Cryst. Growth, **29**, 80–84 (1975)
$H_3PO_4:HBr$ (2:1) {Huber etch}; InP dislocation etch pit delineation
A–B etch; InP dislocation etch pit delineation
$HCl:HNO_3:H_2O$ (1:3:6)
$HCl:HNO_3:Br_2$ (10:20:0.25); comparison

HUE, X., B. Boudart, and Y. Crosnier, "Gate recessing optimization of $GaAs/Al_{0.22}Ga_{0.78}/As$ heterojunction field effect transistor using citric acid/hydrogen peroxide/ammoniun hydroxide for power applications," J. Vac. Sci. Technol., B, **16**(5), 2675 (1998)
Citric acid:$H_2O_2:NH_4OH$; 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
$H_2SO_4:H_2O$ (1:8); GaAs deoxidation for 1 min

HUH, C., S.J. Park, S. Ahn, J.Y. Han, K.J. Cho, and J.M. Seo, "Sychrotron radiation photoemission spectroscopy studies of the thermal nitridization of GaAs(1 0 0) with ammonia," J. Vac. Sci. Technol., B, **16**(1), 192 (1998)
Thermochemical nitridization of GaAs in $NH_3$; synchrotron photoemission spectroscopy study

HUO, D.T.C., J.D. Wynn, S.G. Napholtz, and D.P. Wilt, "Controlled Undercutting of vee-groove Channels for InP by Photoresist Etch Mask," J. Electrochem. Soc., **135**(5), 1231–34 (1988a)
$HCl:H_3PO_4$ (5:1); InP; vee-groove etchant with photoresist mask; undercut rate is modified by heating substrate

HUO, D.T.C., J.D. Wynn, M.F. Yan, and D.P. Wilt, "InP Etch Pit Morphologies Revealed by Novel HCl-based Etchants," J. Electrochem. Soc., **136**(6), 1804–06 (1989a)
$HBr:H_2O_2:HCl:H_2O$ (20:2:20:20): InP (1 1 1) and (1 0 0) dislocation etch pit delineation; etch pit shape and formation depend on $H_2O_2$ and water concentration; shelf time of this etchant is about 12 h

HUO, D.T.C., J.D. Wynn, S.G. Napholtz, F.R. Lenzo, and D.P. Wilt, "A Novel Etch Mask Process for the Etching of (0 1 1) Oriented Facet vee-grooves in InP(1 0 0) Wafers," J. Electrochem. Soc., **134**(11), 2850–56 (1987)

$HCl:H_3PO_4$ (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

HUO, D.T.C., J.D. Wynn, S.G. Naphotty, and D.P. Witt, "Preferential Etching of InP Through Photoresist Masks," J. Electrochem. Soc., **135**(9), 2334–38 (1988b)

InP (1 0 0) photoresist undercut study; etch profiles:
$H_3PO_4:HCl:H_2O_2$ (1:5:0.1–1)
$H_3PO_4:HCl:HF$ (1:5:0.1–1); (HF causes bad undercut)
$H_3PO_4:HCl:HBr$ (1:5:0.1–1)
$H_3PO_4:HCl$ (1:5)

HUO, D.T.C., M.F. Yan, J.D. Wynn, and D.P. Wilt, "Chemical etching of (0 0 1) InP by $HBr–H_2O_2–H_2O–HCl$ Solution," J. Electrochem. Soc., **136**(10), 3094–97 (1989b)

$HBr:H_2O_2:H_2O:HCl$ (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

HUO, D.T.C., M.F. Yan, J.D. Wynn, and D.P. Wilt, "Effects of Mask Imperfections on InP Etching Profiles," J. Electrochem. Soc., **137**(1), 239–42 (1990)

$HCl:H_3PO_4$ (5:1); InP vee-groove etch $\langle 1\ 1\ 0 \rangle$ direction; no undercut
$HBr:H_3PO_4$:1N $K_2Cr_2O_7$ (2:1:1); InP vee-groove etch for $\langle \underline{1}\ 1\ 0 \rangle$ direction; attacks photoresist; undercuts

HUO, D.T.C., M.F. Yan, J.D. Wynn, and D.P. Wilt, "Modified Photoresist Etch Mask Process for InP Channeled Substrate Lasers," J. Electrochem. Soc., **136**(3), 772–75 (1989c)

$HCl:H_3PO_4$ (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

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)

$HP_3O_4:HCl:H_2O$ (1:1:1); InP (1 0 0) vee-groove etch; does not erode photoresist
$HP_3O_4:HCl:HBr$ (1:1:1); InP (1 0 0) vee-groove etch; does not erode photoresist

HUO, D.T., M.F. Yan, J.D. Wynn, and D.P. Wilt, "Preferential Etching of InGaAsP/InP Using Low Temperature Bromine/methanol for Planar Buried Heterostructure Lasers," J. Electrochem. Soc., **136**(6), 1828–30 (1989e)

$Br_2$/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
$KOH:K_3Fe(CN)6:H_2O$ (6 g:4 g:50 g): InGaAsP/InP layer delineation

HUR, K.Y., and R.C. Compton, "Fabrication of Overpass Microstructures in GaAs Using Isotropic Reactive Ion Etching," J. Vac. Sci. Technol., B, **10**(6), 2486–87 (1992)
Reactive ion etching; $Cl_2/BCl_3/Ar$ and $BCl_3/Ar$; Application: GaAs free standing airbridge contacts

HUR, K.Y., B.J. Guerin, and T.E. Kazior, "Reactive Ion Etching of InP Via Holes," J. Vac. Sci. Technol., B, **12**(3), 1410–12 (1994a)
Reactive ion etch; $Cl_2/HBr/BCl_3/Ar$; InP via holes

HUR, K.Y., T.P. McKenna, and T.E. Kazior, "Electron Beam Sublimation Deposited and Lift-off Carbon Mask for InP Reactive Ion Etching," J. Vac. Sci. Technol., B, **12**(5), 3046–47 (1994b)
Reactive ion etch; $Cl_2:HBr:BCl_3:Ar$; Application: using lift-off carbon masks for etching deep features on InP

HURWITZ, C.E., and J.J. Hseih, "GaInAsP/InP Avalanche Photodiodes," Appl. Phys. Lett., **32**(8), 487–89 (1978)
$Br_2$/methanol; Application: InGaAsP/InP non-selective mesa etch

HURWITZ, C.E., J.A. Rossi, J.J. Hsieh, and C.M. Wolfe, "Integrated GaAs–AlGaAs Double-Heterostructure Lasers," Appl. Phys. Lett., **27**, 241 (1975)
$H_2SO_4:H_2O_2:H_2O$ (1:8:1); Application: GaAs etch

HYDER, S.B., R.R. Saxena, S.H. Chiao, and R. Yeats, "Vapor-Phase Epitaxial Growth of InGaAs Lattice-matched to (1 0 0) InP for Photodiode Applications," Appl. Phys. Lett., **35**(10), 787–89 (1979)
$KOH:K_3Fe(CN)_6:H_2O$ (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
$H_2SO_4:H_2O_2:H_2O$ (4:1:1); InP surface cleaning
$Br_2:HBr:H_2O$ (1:17:300); InP surface treatment following $H_2SO_4:H_2O_2:H_2O$ (4:1:1) for 2–4 min; etch rate = 0.8 μm/min

IBBOTSON, D.E., D.L. Flamm, and V.M. Donnelly, "Crystallographic Etching of GaAs with Bromine and Chlorine Plasmas," J. Appl. Phys., **54**(10), 5974–81 (1983)
Plasma etch; $Cl_2$ and $Br_2$; GaAs (1 0 0); development of {1 1 0}, {1 0 0}, and {1 1 1}A facets

IBER, H., S. Mo, E. Peiner, G. Vollrath, A. Schlacetzki, and F. Fiedler, "Characterization of surface damage dry-etched InP," Semicond. Sci. Technol., **12**, 755 (1997)
Reactive ion beam etch; $N_2/O_2$ of InP; characterization of surface damage

ICHIKAWA, S., Y. Suzuki, N. Sanada, N. Utsumi, T. Yamaguchi, X.Y. Gong, and Y. Fukuda, "A $(NH_4)_2S_x$-treated InSb(0 0 1) surface studied by using X-ray photoelectron spectroscopy, low-energy electron diffraction, and inverse phototemission spectroscopy," J. Vac. Sci. Technol., A, **17**(2), 421 (1999)
$(NH_4)_2S_x$ sulfidation study of InSb surfaces

IGA, K., T. Kambayashi, K. Wakao, K. Moriki, and C. Kitahara, ‘‘GaInAsP/InP DH Lasers and Related Fabricating Techniques for Integration,’’ IEEE J. Quantum Electron., **QE-15**(8), 707–10 (1979a)

$HCl:CH_3COOH:H_2O_2$ (1:2:1) {KKI etch}; Application: InGaAsP/InP (1 0 0) non-selective etch; shows etch profiles

IGA, K., T. Kambayashi, K. Wakao, and Y. Sakamoto, ‘‘GaInAsP/InP Facet Lasers with Chemically Etched End Mirrors,’’ Jpn. J. Appl. Phys., **18**(10), 2035–36 (1979b)

$HCl:CH_3COOH:H_2O_2$ (1:2:1) {KKI etch}; Application: InGaAsP/InP (1 0 0) non-selective mesa etch

IGA, K., T. Kambayashi, K. Wakao, C. Kitahara, and K. Moriki, ‘‘GaInAsP/InP D. H. Planar LEDs,’’ IEEE Trans. Electron Devices, **ED-26**, 1227 (1979c)

$HCl:CH_3COOH:H_2O_2$ (1:2:1) {KKI etch}; Application: InGaAsP/InP (1 0 0) non-selective mesa etch

$H_2SO_4:H_2O_2:H_2O$ (3:1:1); InP substrate cleaning for LPE

IGA, K., and B.I. Miller, ‘‘Chemically Etched Mirror GaInAsP/InP Lasers; Review,’’ IEEE J. Quantum Electron., **QE-18**(1), 22–29 (1982)

$HCl:CH_3COOH:H_2O_2$ (1:2:1) {KKI etch}; Application: InGaASP/InP non-selective groove etch at 15°C for laser mirror

IGA, K., and B.I. Miller, ‘‘CW Operation of GaInAsP/InP Laser with Chemically Etched Mirror,’’ Electron. Lett., **16**(22), 830–32 (1980a)

$HCl:CH_3COOH:H_2O_2$ (1:2:1) {KKI etch}; Application: InGaASP/InP non-selective groove etch at 15°C for laser mirror

Buffered HF [$NH_4F:HF$ (10:1)]; InGaAsP oxide removal

IGA, K., and B.I. Miller, ‘‘GaInAsP/InP Laser with Monolithically Integrated Monitoring Detector,’’ Electron. Lett., **16**, 342–43 (1980b)

$HCl:CH_3COOH:H_2O_2$ (1:2:1) {KKI etch}; Application: InGaAsP/InP non-selective groove etch at 15°C for laser mirror

Iga, K., M.A. Pollack, B.I. Miller, and R.J. Martin, ‘‘GaInAsP/InP DH Lasers with a Chemically Etched Facet,’’ IEEE J. Quantum Electron., **QE-16**(10), 1044–46 (1980c)

$HCl:CH_3COOH:H_2O_2$ (1:2:1) {KKI etch}; Application: InGaASP/InP non-selective groove etch for laser mirror

$HCl:H_2O$ (4:1); InP (1 0 0) orientation determination

IIDA, S., and K. Ito, ‘‘Selective Etching of GaAs Crystal in $H_2SO_4$–$H_2O_2$–$H_2O$ System,’’ J. Electrochem. Soc., **118**(5), 768–71 (1971)

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:

$H_2SO_4:H_2O_2:H_2O$ (1:4:0); GaAs (1 0 0) etch rate = 10 μm/min at 20°C

$H_2SO_4$:$H_2O_2$:$H_2O$ (1:1:1); GaAs (1 0 0) etch rate = 8.8 μm/min at 20°C
$H_2SO_4$:$H_2O_2$:$H_2O$ (5:1:1); GaAs (1 0 0) etch rate = 1.4 μm/min at 20°C
$H_2SO_4$:$H_2O_2$:$H_2O$ (5:1:20); GaAs (1 0 0) etch rate = 0.60 μm/min at 20°C
$H_2SO_4$:$H_2O_2$:$H_2O$ (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:
$H_2SO_4$:$H_2O_2$:$H_2O$ (1:8:1); GaAs (1 0 0) etch rate = 8.8 μm/min at 20°C
$H_2SO_4$:$H_2O_2$:$H_2O$ (8:1:1); GaAs (1 0 0) etch rate = 1.3 μm/min at 20°C

IIZUKA, T., “Etching Studies of Impurity Precipitates in Pulled GaP Crystals,” J. Electrochem. Soc., **118**(7), 1190–1194 (1971)
$H_2O$:$AgNO_3$:$CrO_3$:HF (10 ml:40 mg:5 g:8 ml) {A–B etch}; GaP defect delineation; 50 min at 75°C
$H_2O$:$AgNO_3$:$HNO_3$:HF (8 ml:10 mg:6 ml:4 ml) {RC etch}; GaP defect delineation; 3 min at 60°C

IKOSSI-ANASTASIOU, K., S.C. Binari, G. Kelner, J.B. Boos, C.S. Ktono, J. Mittereder, and G.L. Griffin, “Wet chemical etching with Lactic Acid solutions for InP-Based semiconductor Devices,” J. Electrochem. Soc., **142**(10), 3558 (1995)
Lactic acid ($CH_3CHOHCOOH$):Iodic acid ($HIO_3$):$H_2O$ (1.5:1:2); InP etch rate of 2 A/s; specular surfaces; diffusion limited, isotropic etch
HCl:$H_3PO_4$:$CH_3COOH$ (1:1:$x$, with $0 < x < 6$); study of InP etch rate, surface finish and photoresist undercut
HCl:$H_3PO_4$:lactic acid (1:1:$x$, with $0 < x < 6$); study of InP etch rate, surface finish and photoresist undercut. Smoother InP surfaces

ILS, P., M. Michel, A. Forchel, I. Gyuro, M. Klenk, and E. Zielinski, “Fabrication and Optical Properties of InGaAs/InP Quantum Wires and Dots with Strong Lateral Quantixation Effects,” J. Vac. Sci. Technol., B, **11**(6), 2584–87 (1993)
HBr:$HNO_3$:$H_2O$ (1:1:4); Application: InP/InGaAs pattern etch with Au mask for quantum wires; etch rate 100–200 Å/min at 33°C
KI:$I_2$:$H_2O$; Au mask removal from InP

IMAI, H., H. Ishikawa, T. Tanahashi, and K.I. Hori, “InGaAsP/InP Separated Multiclad Layer Stripe Geometry Laser Emitting at 1.5 μm Wavelength,” IEEE J. Quantum Electron., **QE-19**(6), 1063–67 (1983)
HCl:$H_3PO_4$ (1:1); Application: InGaAsP ($\lambda = 0.997$ μm) stripe etch
$H_2SO_4$:$H_2O_2$:$H_2O$ (3:1:1); InGaAsP ($\lambda = 1.52$ μm) stripe etch

IMAI, H., H. Ishikawa, and K. Hori, “vee-grooved-substrate Buried Heterostructure InGaAsP/InP Laser Diode,” Fujitsu Sci. Tech. J., **18**(4), 541–61 (1982)
HCl:$HNO_3$; Application: InGaAsP/InP photolithography groove etch profiles for vee-groove laser
HCl:$H_3PO_4$
$Br_2$/methanol

IMAI, Y., and K. Ohwada, “Application of reactive-ion-beam etching to recessed-gate GaAs metal–semiconductor field-effect transistors,” J. Vac. Sci. Technol., B, **5**, 88 (1987)

Application of reactive-ion-beam etching to recessed-gate GaAs metal–semiconductor field-effect transistors

INADA, T., S. Taka, and K. Kadama, "Ion Bombarded-enhanced Etching of Indium Phosphide," J. Electrochem. Soc., **131**(6), 1401–03 (1984)
$HF:H_2O$ (1:1); InP etch rate enhanced by Mg ion bombardment damage for maskless patterning

INAMURA, E., Y. Miyamoto, S. Tamura, T. Takasugi, and K. Furuya, "Wet Chemical Etching for Ultrafine Periodic Structure: Rectangular InP Corrugation of 70 nm Pitch and 100 nm Depth," Jpn. J. Appl. Phys., **28**(10), 2193–96 (1989)
$HBr:H_3PO_4:H_2O$ (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
$HCl:H_3PO_4:H_2O$ (3:1:1); InP etch at 0°C, material selective from InGaAs; shows sidewall deformation for nanometer geometries. $HCl:CH_3COOH$ (1:4); InP material selective etch from InGaAs; gives near vertical sidewalls for nanometer geometries

INAMURA, E., Y. Miyamoto, S. Tamura, T. Takasugi, and K. Furuya, "Wet Chemical Etching for Ultrafine Periodic Structure: Rectangular InP Corrugation of 70 nm Pitch and 100 nm Depth," Jpn. J. Appl. Phys., **28**(10), 2193–96 (1989)
$HBr:H_3PO_4:H_2O$ (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
$HCl:H_3PO_4:H_2O$ (3:1:1); InP etch at 0°C, material selective from InGaAs; shows sidewall deformation for nanometer geometries
$HCl:CH_3COOH$ (1:4); InP material selective etch from InGaAs; gives near vertical sidewalls for nanometer geometries

Ishibashi, T., "InP MESFET with InGaAs/InP Heterostructure Contacts," Electron. Lett., **17**(16), 215–16 (1981)
HCl:propylene glycol (1:2); Application: InP selective etch from InGaAs mask layer
$H_2SO_4:H_2O_2:H_2O$ (4:1:1); InGaAs selective etch from InP

Ishikawa, H., H. Imai, T. Tanahashi, Y. Nishitani, M. Takusagawa, and K. Takahei, "vee-grooved Substrate Buried Heterostructure InGaAsP/InP Laser," Electron. Lett., **17**(13), 465–67 (1981)
$HCl:H_3PO_4$ (3:1); Application: InP vee-groove etch for laser fabrication

Ishikawa, H., H. Imai, I. Umebu, K. Hori, and M. Takusagawa, "vee-grooved Substrate Buried Heterostructure InGaAsP/InP Laser by One-step Epitaxy," J. Appl. Phys., **53**(4), 2851–53 (1982)
$HCl:H_3PO_4$ (3:1); Application: InP vee-groove etch for laser fabrication

Ishikawa, J., T. Ito, Y. Oh-iso, M. Yamamoto, N. Shin-ichi, Takahashi, and S. Kurita, "Lasing Characteristics of 0.8 μm InGaAsP/GaAs Lasers Fabricated by Wet Chemical Etching," J. Appl. Phys., **65**(10), 3767–72 (1989)
$Br_2$/methanol (0.05%) and $H_2SO_4:H_2O_2:H_2O$ (3:1:1); Application: InGaAsP/GaAs etched mirror lasers

Itaya, Y., T. Matsuoka, K. Kuriowa, and T. Ikegami, "Longitudinal Mode Behaviors of 1.5 μm Range GaInAsP/InP Distributed Feedback Lasers," IEEE J. Quantum Electron., **QE-20**(3), 230–35 (1984)

$K_2Cr_2O_7$:HBr:$CH_3COOH$ (3:1:1); Application: InGaAsP tilted laser facet etch

Saturated $Br_2$ water:HBr:$H_2O$; InGaAsP/InP laser surface grating etch

Itaya, Y., Y. Suematsu, S. Katayama, K. Kishino, and S. Arai, "Low Threshold Current Density GaInAsP/InP Lasers," Jpn. J. Appl. Phys., **18**(9), 1795–1805 (1979)

KOH:$K_3Fe(CN)_6$:$H_2O$; Application: InGaAsP/InP cleaved cross-section layer delineation

Itaya, Y., T. Tanbun-ek, K. Kishino, S. Arai, and Y. Suematsu, "1.6 μm Wavelength Buried Heterostructure GaInAsP/InP Lasers," Jpn. J. Appl. Phys., **19**(3), L141–L144 (1980)

$Br_2$/methanol (0.1%); Application: InGaAsP stripe etch with $SiO_2$ mask for BH laser

Ito, H., and T. Ishibashi, "Selective and non-selective chemical etching of InGa(As)P/GaAs heterostructures," J. Electrochem. Soc., **142**(10), 3383 (1995)

HCl:$H_2O$ ($m$:1, with $0.6 < m < 1.5$); rate dependence for $In_{0.5}Ga_{0.5}P$, InGaAsP and GaAs

HCl:$H_2SO_4$:$H_2O_2$:$H_2O$ ($m$:1:10:2000, with $0.6 < m < 1.5$); rate dependence and selectivity for $In_{0.5}Ga_{0.5}P$, InGaAsP and GaAs

Ito, N., T. Uesugi, S. Sakai, M. Umeno, and S. Hattori, "InGaAsP/InP Wavelength Division Solar Cells, Proc. 2nd Photovoltaic Science and Engineering Conf., Tokyo, 1980," Jpn. J. Appl. Phys. Suppl. 20–2, p. 121 (1980)

Anodization; InGaAsP/InP anodize/strip thinning of InP

Itoh, K., K. Asaki, M. Inoue, and I. Teramoto, "Embedded Stripe GaAs-GaAlAs Double-heterostructure Lasers with Polycrystalline GaAsP Layers: II: Lasers with Etched Mirrors," IEEE J. Quantum Electron., **QE-13**(8), 628–31 (1977)

NaOH:$H_2O_2$:$NH_4OH$ (5:1:1); Application: GaAs/AlGaAs laser mirror etch

$H_2SO_4$:$H_2O_2$:$H_2O$; comparison profiles

Ives, N.A., G.W. Stupian, and M.S. Keung, "Unpinning of the Fermi level on GaAs by flowing water," Appl. Phys. Lett., **50**(2), 256 (1987)

$H_2O$; photochemical reaction on GaAs to unpin the Fermi level

Iyer, R., B. Bollig, and D.L. Lile, "Preparation and characterization of polysulfide treated InP MIS structures," InP and Related Material Conference Proceedings, 1991a, p. 621

$(NH_4)_2S_x$; 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

Iyer, R., and D.L. Lile, "Downstream Plasma Activated Etching of III–V Compound Semiconductors, (Electron. Mater. Conf. Abstract)," J. Electron. Mater., **18**(4), 60 (1989)

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

Iyer, R., and D.L. Lile, "Role of polysulfides in the passivation of the InP surface," Appl. Phys. Lett., **59**(4), 437 (1991b)

$(NH_4)_2S_x$; 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

Jackson, N.F., "Pulsed Anodic Etching of III–V Semiconductors for Carrier Concentration Profiling," Semicond. Sci. Technol., **7**, 686–90 (1992)

Electrochemical *C–V* profiling; III–V semiconductor carrier concentrations

Janiak, K., and U. Niggebrügge, "Investigation of macroscopic uniformity during $CH_4/H_2$ reactive ion etching of InP and improvement using a guard ring," Proc., 1996 Indium Phosphide and Related Materials Conference, p. 111 (1996)

Reactive ion etch of InP using $CH_4/H_2$; uniformity study

Jenkins, P., and G.A. Landis, "Surface Etching for Light Trapping in Encapsulated InP Solar Cells," 3rd Int'l Conf. on Indium Phosphide and Related Materials, Apr 8–11, 1991, Cardiff, Wales, UK, IEEE Catalog no. 91CH2950-4, pp. 164–67

HCl conc.; InP; Application: low angle groove etch to reduce optical reflection in solar cells

Jeong, Y.-H., K.-H. Choi, and S.-K. Jo, "Sulfide Treated GaAs MISFET's with Gate Insulator of Photo-CVD Grown $P_3N_5$ Film," IEEE Electron Device Lett., **15**(7), 251–53 (1994)

$NH_4OH:H_2O$ (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

Jin, Y., C. Takahashi, K. Nishimura, T. Ono, and S. Matsuo, "0.1 μm WSiN-gate fabrication of GaAs metal–semiconductor field effect transistors using electron cyclotron resonance ion stream etching with $SF_6$–$CF_4$–$SiF_4$–$O_2$," J. Vac. Sci. Technol., B, **15**(6), 2639 (1997)

Electron cyclotron resonance ion stream etching of GaAs with $SF_6$–$CF_4$–$SiF_4$–$O_2$ for WSiN-gate FETs

Jones, A.M., J.J. Coleman, B. Lent, A.H. Moore, and Bonner. W. A., "Lasers on a low-composition InGaAs substrate by selective-area MOCVD," IEEE Photon. Technol. Lett., **10**(4), 489 (1998)

$H_2SO_4:H_2O$ (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

Jönsson, J., K. Deppert, and L. Samuelson, ‘‘Real-time monitoring of the reaction of $H_2S$ on GaAs,’’ J. Appl. Phys., **74**(10), 6146 (1993)
Sulfur passivation of GaAs from $H_2S$; study of reaction behavior

Juang, C., J.K. Hsu, I.S. Yen, and H.S. Shian, ‘‘Photoluminescence of $CF_4/O_2$ Reactive Ion Etched InGaAs Surfaces,’’ J. Appl. Phys., **72**, 684 (1992)
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:$H_2O_2$ (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

Juang, Y.Z., Y.K. Su, S.C. Shei, and B.C. Fang, ‘‘Comparing Reactive Ion Etching of III–V Compounds in $Cl_2/BCl_3/Ar$ and $CCl_2F_2/BCl_3/Ar$ Discharges,’’ J. Vac. Sci. Technol., A, **12**(1), 75–82 (1994)
Reactive ion etch; comparison of $Cl_2/BCl_3/Ar$ and $CCl_2F_2/BCl_3/Ar$ for III–V compounds
$NH_4OH$:$H_2O_2$:$H_2O$ (1:1:50); GaAs substrate cleaning prior to RIE

Juang, Y.Z., Y.K. Su, S.J. Chang, D.F. Huang, and S.C. Chang, ‘‘Reactive ion etching for AlGaInP/GaInP laser structures,’’ J. Vac. Sci. Technol., A, **16**(4), 2031 (1998)
RIE using $BCl_3/Ar$ from GaAs, GaInP, AlGaInP, and AlInP; selective removal of GaAs from InGaP; selective removal of InGaP from AlInP

Kadoya, Y., T. Yoshida, H. Noge, and H. Sakaki, ‘‘Ultraclean etching of GaAs by HCl gas and in situ overgrowth by molecular beam epitaxy,’’ J. Appl. Phys., **83**(1), 567 (1998)
Thermochemical etch; HCl in situ GaAs etch for MBE AlGaAs overgrowth

Kagadei, V.A., and D.I. Proskurovsky, ‘‘In Situ cleaning of GaAs and $Al_xGa_{1-x}As$ surfaces and production of Ohmic contacts using an atomic hydrogen source based on a reflected arc discharge,’’ J. Vac. Sci. Technol., A, **17**(4), 1488 (1999)
Monoethanolamine solution with $NH_4OH$:$H_2O$ (1:5); treatment of GaAs prior to Ohmic contact metallization
$H_2SO_4$ (10%); oxide removal from GaAs
Atomic hydrogen; in situ cleaning of GaAs prior to Ohmic contact metallization

Kahaian, D.J., S. Thomas III, and S.W. Pang, ‘‘In Situ Monitoring of GaAs Etched with a $Cl_2/Ar$ Discharge in an Electron Cyclotron Resonance Source,’’ J. Vac. Sci. Technol., B, **13**(2), 253–57 (1995)
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. Ramachadran, 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

Kallstenius, T., "Sample preparation of InGaAsP/InP-based lasers for plan view transmission electron microscopy using selective chemical thinning," J. Electrochem. Soc., 146(2), 758 (1999a)
HF conc.; removal of Ti from InGaAs
$C_4H_6O_6$:$H_2O$:$H_2O_2$ (5:5:1); selective etch of InGaAs layer from InP; 8 min for 3000 Å
$CH_3COOH$:HCl (1:1); selective InP removal from InGaAsP; etch rate ~1 μm/min
For fresh solution; rate decreases after 30 min
Etch mask, transparent low melting point was (Gatan Inc., USA)

Kallstenius, T., U. Smith, and B. Stoltz, "Studies of internal structure in InGaAsP/InP-based lasers using atomic force microscopy in combination with selective etching," J. Electrochem. Soc., **146**(2), 749 (1999b)
$K_3[Fe(CN)_6]$ (10 g): KOH (15 g): $H_2O$ (270 ml); photochemical dopant selective n-InP from p-InP; smooth surfaces

Kamada, M., and H. Ishikawa, "Effects of III–V Ratio on Electronic and Optical Properties of GaInAs Layers Grown by MOCVD," J. Cryst. Growth, **94**, 849 (1989)
$H_3PO_4$:$H_2O_2$:$H_2O$ (3:1:50); InGaAs thinning, etch rate = 10 Å/s at 20°C; for differential Hall measurements
$H_2SO_4$:$H_2O_2$:$H_2O$ (5:1:1); InP substrate cleaning prior to OMVPE growth; 3 min at 60°C

Kambayashi, T., C. Kitahara, and K. Iga, "Chemical Etching of InP and GaInAsP for Fabricating Laser Diode and Integrated Optical Circuits," Jpn. J. Appl. Phys., **19**(1), 79–85 (1980)
HCl:$CH_3COOH$:$H_2O_2$ (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:$CH_3COOH$:$H_2O_2$ (1:1:1) {KKI-111 etch}; InP etch rate = 1.1 μm/min at 25°C $H_3PO_4$:HCl:$H_2O_2$; and
$HNO_3$:HCl:$H_2O_2$; comparison of surface smoothness
HCl:$H_2O$ (4:1); InP (1 0 0) orientation determination

Kaminov, I.P., R.E. Nahory, M.A. Pollack, L.W. Stuly, and J.C. DeWinter, "Single-mode C. W. Ridge-waveguide Laser Emitting at 1.55 μm," Electron. Lett., **15**, 763–64 (1979)
HCl:$H_3PO_4$; Application: InP selective etch from InGaAsP stop layer for laser fabrication

Kaminska, E., A. Piotrowska, A. Kaminska, and M. Klimkiewicz, "Etching Procedures for GaP Surfaces," Surf. Technol., **12**, 205–15 (1981)
$Br_2$/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:$K_3Fe(CN)_6$ (1:5); GaP etch rate at 21°C = 0.2 μm/min
KOH:$K_3Fe(CN)_6$ (2:1); GaP etch rate at 21°C = 0.3 μm/min
KOH:$K_3Fe(CN)_6$:$H_2O$ (3:1:60); GaP etch rate at 21°C = 0.03 μm/min

$HCl:HNO_3$ (3:1); GaP etch rate at 30°C = 2 μm/min
$HCl:HNO_3$ (3:1); GaP etch rate at boiling = 6 μm/min
$HCl:HNO_3:H_2O$ (2:1:2); GaP etch rate at 60°C = 1 μm/min
$HCl:HNO_3:H_2O$ (1:1:2); GaP etch rate at 60°C = 0.45 μm/min
$HCl:HNO_3:CH_3COOH$ (3:1:5); GaP etch rate at 21°C = 1.15 μm/min
$HCl:HNO_3:CH_3COOH$ (1:1:1); GaP etch rate at 21°C = 1.2 μm/min fresh solution
$HCl:HNO_3:CH_3COOH$ (1:1:1); GaP etch rate at 21°C = 0.25 μm/min, 30 min stabilized solution
$HCl:HNO_3:CH_3COOH:HClO_4$ (1:3:2:3); GaP etch rate at 21°C = 6 μm/min from fresh solution
$HCl:HNO_3:CH_3COOH:HClO_4$ (1:3:2:3); GaP etch rate at 21°C = 0.6 μm/min from 30 min stabilized solution
$HCl:HNO_3:CH_3COOH:HClO_4$ (1:6:1:1); GaP etch rate at 21°C = 1.8 μm/min
$HCl:HNO_3:H_2SO_4:H_2O$ (2:1:2:2); GaP etch rate at 30°C = 1.2 μm/min
$HCl:HNO_3:H_2SO_4:H_2O$ (2:1:2:2); GaP etch rate at 50°C = 3.2 μm/min

KAMIYA, Y., S. Shimomura, and T. Itoh, "The Electrical Characteristics of Boron-implanted InP," J. Electrochem. Soc., **133**(4), 780–84 (1986)
$H_2SO_4:H_2O_2:H_2O$ (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
Anodization of InP for successive anodization/stripping thickness profile van der Pauw measurements using *N*-methylacetomide electrolyte

KAMIYAMA, S., Y. Mori, Y. Takahashi, and K. Ohnaka, "Improvement of catastrophic optical damage level of AlGaInP visible laser diodes by sulfur treatment," Appl. Phys. Lett., **58**(23), 2595 (1991)
$(NH_4)_2S_x$; Application: surface passivation of AlGaInP laser mirror facets

KANBE, H., N. Susa, H. Nakagome, and H. Ando, "InGaAs Avalanche Photodiode with InP p–n Junction," Electron. Lett., **16**(5), 163–65 (1980)
$H_2SO_4:H_2O_2:H_2O$ (10:1:1); Application: InGaAs mesa etch for photodiode fabrication
$Br_2$/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)
$Br_2$/methanol (5%); Application: InP substrate cleaning for VPE

KANESHIRO, C., and T. Okumura, "Nanoscale etching of GaAs surfaces in electrolyte solutions by hole injection from a scanning tunneling microscope tip," J. Vac. Sci. Technol., B, **15**(5), 1595 (1997)
$H_2SO_4:H_2O_2:H_2O$ (5:1:1); GaAs native oxide removal, 2 min
$NiSO_4$ (0.8 M) with pH adjusted to 2–3 with $H_2SO_4$, $H_2O$ diluted; nanoscale photoelectrochemical etch of GaAs with STM

KANESHIRO, C., T. Sato, and H. Hasegawa, "Highly controllable electrochemical etching of InP studied by voltammetry and scanning probe analysis," Proc. 10th Int'l Conf. on Indium Phosphide and Related Materials, 191 (1998)

HCl dilute ($pH = 1.0$); electrolyte for electrochemical etching of InP; study of reaction using voltammetry, XPS and STM

KANG, M.-G., and H.-H. Park, "Effect of prepared GaAs surface on the sulfidation with $(NH_4)_2S_x$ solution," J. Vac. Sci. Technol., A, **17**(1), 88 (1999)

$(NH_4)_2S_x$ sulfidation of GaAs XPS study

KANG, M.-G., S.-H. Sa, H.-H. Park, K.-S. Suh, and J.-L. Lee, "Sulfidation mechanism of precleaned GaAs surface using $(NH_4)_2S_x$ solution," Mater. Sci. Eng. B, **B46**, 65 (1997)

$(NH_4)_2S_x$ solution; sulfur passivation of GaAs; 10 min at 60°C; XPS study of surface bonding states

KANO, H., and K. Sugiyama, "Operation Characteristics of Buried-Stripe GaInAsP/InP Lasers made by Melt-back Method," J. Appl. Phys., **50**(12), 7935–38 (1979)

In–As metal solution; Application: LPE melt back in situ cleaning of mesa stripe prior to regrowth of InP encapsulant layers

$Br_2$/methanol; InGaAsP/InP stripe etch

KAO, H.-C., L.-S. Lai, and Y.-J. Chan, "Reactive ion etching of $CHF_3 + BCl_3$ for ternary $In_xAl_{1-x}As$ and $In_xGa_{1-x}As$ ($x = 0.18, 0.3, 0.52$) compounds using various In contents," J. Vac. Sci. Technol., B, **16**(1), 253 (1998)

Reactive ion etch; $CHF_3 + BCl_3$; rate dependence on ternary composition for InAlAs and InGaAs

KAPILA, A., V. Malhotra, L.H. Camnitz, K.L. Seaward, and D. Mars, "Passivation of GaAs Surfaces and AlGaAs/GaAs Heterojunction Bipolar Transistors Using Sulfide Solutions and $SiN_x$ Overlayer," J. Vac. Sci. Technol., B, **13**(1), 10–14 (1995)

$(NH_4)S_x$ (10 ml solution with added 1 g sulfur and 2 g phosphorus pentasulfide); GaAs surface passivation, followed by deposition of $SiN_x$ overlayer

KAPON, E., M.C. Tamargo, and D.M. Hwang, "Molecular Beam Epitaxy of GaAs/AlGaAs Superlattice Heterostructures on non-planar substrates," Appl. Phys. Lett., **50**(6), 347–49 (1987)

$H_2SO_4$:$H_2O_2$:$H_2O$ (1:8:40); Application; GaAs (1 0 0) photolithography [0 1 1] channel etch

$H_2SO_4$:$H_2O_2$:$H_2O$ (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)

$Br_2$:methanol (0.1%); InP vee-groove etch, first step; exposes {1 1 1}A sidewalls but leaves surface defects

$H_2SO_4$:$H_2O_2$:$H_2O$ (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

$Br_2$:methanol (0.1%); third step of InP vee-groove etch; reduces the radius of the vee after $H_2SO_4$:$H_2O_2$:$H_2O$ etch

KASUKAWA, A., M. Iwase, Y. Hiratani, and N. Matsumoto, “New Fabrication Method for 1.3 μm GaInAsP/InP Buried Crecent Lasers Using a Reactive Ion Beam Etching Technique,” Appl. Phys. Lett., **51**(22), 1774–76 (1987)

Reactive ion etch; $Cl_2$; Application: InGaAsP/InP buried crescent laser; photoresist mask; etched width is smaller than with wet chemical etch

KATAYAMA, M., M. Aono, H. Oigawa, Y. Nannichi, H. Sugahara, and M. Oshima, “Surface structure of InAs (0 0 1) treated with $(NH_4)_2S_x$ solution,” Jpn. J. Appl. Phys. Pt. 2, **30**(5A), L786 (1991)

$(NH_4)_2S_x$; InAs; study of surface structure; S replaces outer most As atoms; all S desorbs above 500°C

KATSURA, S., Y. Sugiyama, O. Oda, and M. Tacano, “Aging-Free InP Substrates Ready for Molecular Beam Epitaxial Growth of InAlAs/InGaAs Heterostructures,” Appl. Phys. Lett., **62**(16), 1910–12 (1993)

$H_2SO_4$:$H_2O_2$:$H_2O$ (7:1:1); InP surface preparation etch for flat, damage-free surface

KATZSCHNER, W., U. Niggelbrugge, R. Löffler, and H. Schröter-Janssen, “Reactive Ion Beam Etching of InP with $N_2$ and $N_2/O_2$ Mixtures,” Appl. Phys. Lett., **48**(3), 230–32 (1980)

Reactive ion etch; $N_2$, $N_2/O_2$; InP and InGaAsP etch profiles

KATZSCHNER, W., Löffler R. Steckenborn, and N. Grote, “Ion Beam Milling of InP with an Ar/$O_2$-gas mixture,” Appl. Phys. Lett., **44**(3), 352–54 (1984)

Ion beam milling; $Ar + O_2$; InP

KAWANISHI, H., Y. Suematsu, K. Utaka, Y. Itaya, and S. Arai, “GaInAsP/InP Injection Laser Partially Loaded with First-Order Distributed Bragg Reflector,” IEEE J. Quantum Electron., **QE-15**(8), 701–6 (1979)

HCl; InP selective etch from InGaAsP

$H_2SO_4$:$H_2O_2$:$H_2O$; InGaAsP first-order grating etch for laser

KAZIOR, T. E., and B. I. Patel, “Selective gate recessing of GaAs/AlGaAs/InGaAs pseudomorphic HEMT structures using $BCl_3$ plasmas,” Mat. Res. Soc. Sump. Proc., **240**, 329 (1992)

Reactive ion etch; $BCl_3$; selective removal of GaAs from AlGaAs or InGaAs

KEAVNEY, C.J., and H.J. Smith, “A 3.8 μm Period Sawtooth Grating in InP by Anisotropic Etching,” J. Electrochem. Soc., **131**(2), 452–53 (1984)

HBr (9n); Application: InP photolithography grating at −15°C; (1 1 1)A facets

HCl:$H_2O_2$ (1:1); InP (1 0 0) orientation determination

KELLY, J.J., J.E.A.M. van den Meerakker, P.H.L. Notten, and R.P. Tyberg, “Wet-Chemical Etching of III–V Semiconductors,” Philips Tech. Rev., **44**(3), 61–74 (1988)

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: $K_3Fe(CN)_6$ at pH = 14; p+ GaAs($10^{20}$ $cm^{-3}$) selective etch from p-GaAs($10^{18}$ $cm^{-3}$)

HCl conc.;InP selective etch from InGaAsP
$Ce^{4+}$:$H_2SO_4$ solution; InGaAsP selective etch from InP
$Br_2$:KBr solution; GaAs groove etch profile dependence on temperature

KEMPJ, B., "Carbon Monoxide/Hafnium: a Very Promising Etch-Gas Mask Combination for Ion Beam Etching of III–V Compounds," GaAs and Related Compounds, 1992 (Inst. Phys. Conf. Ser. No. 129 1993), pp. 591–96
Ion beam etching, CO; Use of hafnium mask for GaAs and InP patterning

KENEFICK, K., "Selective Etching Characteristics of Peroxide/Ammonium-hydroxide Solutions for GaAs/$Al_{0.16}Ga_{0.84}As$," J. Electrochem. Soc., **129**(10), 2380–82 (1982)
$H_2O_2$ with $NH_4OH$ added to adjust pH from 7.2 to 8.6; GaAs selective etch from $Al_{0.16}Ga_{0.84}As$ 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

KERN, W., "Handbook of Semiconductor Wafer Cleaning Techniques," TK7871.85KERN, W., and C.A. Deckert, "Chemical Etching," Thin Film Processes, Ed. J. Vossen and W. Kern (Academic Press, NY, 1978b) pp. 401–96
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

KESAN, V.P., P.G. May, F.K. LeGoues, and S.S. Iyer, "Si/SiGe Heterostructures Grown on SOI substrates by MBE for Integrated Optoelectronics," J. Cryst. Growth, **111**, 936–42 (1991)
HF:0.15 M $K_2Cr_2O_7$ (2:1) {Secco etch}; Application: Si wafer defect delineation

KETTERSON, A.A., E. Andideh, I. Adesida, T.L. Brock, J. Baillargeon, J. Laskar, K.Y. Cheng, and J. Kolodzey, "Selective Reactive Ion Etching for Short-Gate-Length GaAs/AlGaAs/InGaAs Pseudomorphic Modulation-Doped Field Effect Transistors," J. Vac. Sci. Technol. B, **7**(6), 1493–96 (1989)
Reactive ion etch; $SiCl_4 + SiF_4$; Application: GaAs selective etch from AlGaAs for MODFET processing

KHAN, F. A., L. Zhou, A.T. Ping, and I. Adesida, "Inductively coupled plasma reactive ion etching of $Al_xGa_{1-x}N$ for application in laser facet formation," J. Vac. Sci. Technol., B, **17**(6), 2750 (1999)
CAIBE of GaN and GaAs using $Cl_2$–Ar; vertical, smooth sidewalls for laser facets

KHARA, R., J. Brown, M. Hu, D. Pierson, M. Melendes, and C. Constantine, "$CH_4/H_2/Ar/Cl_2$ Electron Cyclotron Resonance Plasma Etching of Via Holes for InP-based Microwave Devices," J. Vac. Sci. Technol., B, **12**(5), 2947–51 (1994)
ECR plasma etch; $CH_4/H_2/Ar/Cl_2$; InP via holes

KHARE, R., E.L. Hu, D. Reynolds, and S.J. Allen, "Photoelectrochemical Etching of High Aspect Ratio Submillimeter Waveguide Filters from n + GaAs Wafers," Appl. Phys. Lett., **61**(24), 2890–92 (1992)

$HCl:HNO_3:H_2O$ (4:1:50); GaAs photoelectrochemical electrolyte for high aspect ratio features

KHARE, R., and E. L. Hu, "Dopant Selective Photoelectrochemical Etching of GaAs Homostructures," J. Electrochem. Soc., **138**(5), 1516–19 (1991)

$HCl:H_2O$ (1:20); GaAs n-type selective photoetch from GaAs p-type, selectivity $> 15{,}000$
GaAs n-type selective etch from GaAs semi-insulating, selectivity $\sim 30$

KHARE, R., E.L. Hu, J.J. Brown, and M.A. Melendes, "Micromachining in III–V Semiconductors Using Wet Photoelectrochemical Etching," J. Vac. Sci. Technol., B, **11**(6), 2497–2501 (1993a)

$HCl:H_2O$ (1:20); electrolyte for photoelectrochemical etching of GaAs and InP; etch rates and profiles for via hole fabrication are given

KHARE, R., D.B. Young, G.L. Snider, and E.L. Hu, "Effect of Band Structure on Etch-Stop Layers in the Photoelectrochemical Etching of GaAs/AlGaAs Semiconductor Structures," Appl. Phys. Lett., **62**(15), 1809–11 (1993b)

Photoelectrochemical dopant selective and bandgap selective etch; $HCl:H_2O$ (1:20) electrolyte; GaAs/AlGaAs structures; dependence on band structure

KHOUKH, A., S.K. Krawczyk, and R. Olier, "Chemomechanical Polishing and Etching of GaAs:In and GaAs in Aqueous Solutions of NaOCl," J. Electrochem. Soc., **134**(7), 1859–62 (1987)

$NaOCl:H_2O$; GaAs chemomechanical polishing

KIBBLER, A.E., S.R. Kurtz, and J.M. Olson, "Carbon-Doping and Etching of MOCVD-grown GaAs, InP and Related Ternaries Using $CCl_4$," J. Cryst. Growth, (1990)

Thermochemical vapor etch; $CCl_4$; InP in situ etch for OMVPE

KICIN, S., J. Novák, M. Kucera, S. Hasenörl, P. Eliás, I. Vávra, and P. Hudek, "Preparation of stair-step grooves by wet etching of AlAs/GaAs heterostructures and MOCVD growth of QWR," Mater. Sci. Eng. B, **B65**, 106 (1999)

$Br_2$/methanol; $Br_2$/ethylene glycol $H_3PO_4:H_2O_2:H_2O$; Application: first step stairstep groove etchant for AlAs/GaAs multilayer structures for quantum wire MOCVD growth. citric acid:$H_2O_2$; Application: second step stairstep groove etchant for shaping grooves in AlAs/GaAs multilayer structures for quantum wire MOCVD growth

KIM, H.-S., Y.-H. Lee, G.-Y. Yeom, J.-W. Lee, and T.-I. Kim, "Effects of inductively coupled plasma conditions on the etch properties of GaN and Ohmic contact formations," Mater. Sci. Eng. B, **B50**, 82 (1997)

Inductively coupled plasma etch; $Cl_2/H_2$; GaN etch characteristics; effect of surface stoichiometery on Ohmic contact

KIM, H.S., G.Y. Yeom, J.W. Lee, and T.I. Kim, "Characteristics of inductively coupled $Cl_2/BCl_3$ plasmas during GaN etching," J. Vac. Sci. Technol., A, **17**(4), 2214 (1999)
Inductively couple plasma etch of GaN using $Cl_2/BCl_3$

KIM, J.-H., S.C. Choi, J.Y. Choi, K.S. Kim, G.M. Yang, C.-H. Hong, K. Y. Lim, and H.J. Lee, "Effects if initial cleaning treatment of a sapphire substrate surface on the GaN epilayer," Jpn. J. Appl. Phys., Pt. 1, **38**(5a), 2721 (1999)
$H_2SO_4:H_3PO_4$ (3:1); sapphire substrate cleaning: 140°C for 10 min
$H_2$ thermal cleaning of sapphire substrate, in situ MOVPE; 1070°C

KIM, J.K., J.-L. Lee, J.W. Lee, Y.J. Park, and T. Kim, "Effect of surface treatment by $(NH_4)_2S_x$ solution on the reduction of Ohmic contact resistivity of p-type GaN," J. Vac. Sci. Technol., B, **17**(2), 497 (1999)
$HCl:HNO_3$ (3:1); 10 min in boiling aqua regia to remove surface oxide from p-type GaN prior to $(NH_4)_2S_x$ surface treatment for Pd low resistivity Ohmic contact
$(NH_4)_2S_x$; 10 min treatment of p-type GaN surface for Pd low resistivity Ohmic contact

KIM, J.-H., D.H. Lim, and G.M. Yang, "Selective etching of AlGaAs/GaAs structures using the solutions of citric acid/$H_2O_2$ and de-ionized $H_2O$/buffered oxide etch," J. Vac. Sci. Technol., B, **16**(2), 558 (1998)
citric acid:$H_2O_2$ (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
$H_2O$:buffered HF (40:1) where buffered HF is $NH_4F$ (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

KIM, J.S., J.B. Yoo, D.H. Jang, D.K. Oh, and Y.T. Lee, "Effects of Pressure and Temperature on Epitaxial Growth of InP on Non-planar Substrates Using OMVPE," J. Electron. Mater., **21**(3), 251–56 (1992)
$H_3PO_4:H_2O_2$ (5:1); Application: InGaAs selective etch from InP; pattern for OMVPE overgrowth
$H_2SO_4:H_2O$ (1:5); InP surface cleaning for photoresist ash removal following $O_2$ plasma prior to InP regrowth
$KOH:K_3Fe(CN)6:H_2O$; InP cleaved cross-section layer delineation

KIM, M.-S., C. Lee, S.K. Park, W.C. Choi, E.K. Kim, S.-I. Kim, B.S. Ahn, and S.-K Min, "Laser-induced direct etching of GaAs using chlorofluorocarbon (CFC) alternative gases," J. Electron. Mater., **26**(5), 436 (1997)
laser-induced thermochemical, maskless etch using $CHClF_2$ and $C_2H_2F_4$ on GaAs

KIM, T. G., S.-M. Hwang, E.K. Kim, S.-K. Min, J.-I. Jeon, S.-J. Leem, J. Jeong, and J.-H Park, "Fabrication of vee-grooved inner stripe GaAs–AlGaAs quantum-wire lasers," IEEE Photon Technol. Lett., **9**(3), 274 (1997)
$H_2SO_4:H_2O_2:H_2O$ (1:8:40); Application: GaAs vee-groove etch; 90 min for 1.2 μm wide stripe with (1 1 1)A sidewalls

KIMURA, T., T. Kimura, E. Ishimura, F. Uesugi, M. Tsugami, K. Mizuguchi, and T. Murotani, "Improvement of InP Crystal Quality Grown on GaAs Substrates and Device Applications," J. Cryst. Growth, **107**, 827–31 (1991)

$H_3PO_4$:HBr (2:1) {Huber etch}; Application: InP dislocation etch pit delineation

KING, S.W., J.P. Barnak, M.D. Bremser, K.M. Tracy, C. Ronning, R.F. Davis, and R.J. Nemanich, "Cleaning of AlN and GaN surfaces," J. Appl. Phys., **84**(9), 5248 (1998)

Wet chemical cleaning; study for AlN and GaN

HF(buffered, 7 $NH_4F$:1 HF): $H_2O$ (10:1); surface oxide removal from AlN and GaN

HCl:$H_2O$ (1:1); surface oxide removal from AlN and GaN

Thermal desorption of oxygen and carbon from AlN and GaN surfaces in UHV

KISHINO, K., Y. Suematsu, Y. Takahishi, T. Tanbun-ek, and Y. Itaya, "Fabrication and Lasing Properties of Mesa Substrate Buried Heterostructure GaInAsP/InP Lasers at 1.3 μm Wavelength," IEEE J. Quantum Electron., **QE-16**(2), 160–64 (1980)

HCl:$H_2O$ (4:1); Application: InP mesa etch for BH laser

KITANO, T., S. Izumi, H. Minami, T. Ishikawa, K. Sato, T. Sonoda, and M. Otsubo, "Selective wet etching for highly uniform GaAs/$Al_{0.15}Ga_{0.85}As$ heterostructure field effect transistors," J. Vac. Sci. Technol., B, **B15**(1), 167 (1997)

citric acid:$NH_4OH$:$H_2O_2$ (citric acid pH adjusted to 6.5 with $NH_4OH$; citric acid:$H_2O_2$ 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

KIZUKI, H., N. Hayafuji, N. Fujii, N. Kaneno, K. Mizuguchi, T. Murotani, and S. Mitsui, "Selective Area Epitaxy of GaAs/AlGaAs by in situ HCl Gas Etching and Subsequent MOCVD Growth.," GaAs and Related Compounds, 1992 (Inst. Phys. Conf. Ser. No. 129 1993a), pp. 603–608

Thermochemical etch, HCl $+$ $AsH_3$; GaAs/AlGaAs in situ etch at 750°C prior to MOVPE regrowth of GaAs

KIZUKI, H., N. Hayafuji, N. Fujii, N. Kaneno, Y. Mihashi, and T. Murotani, "Selective Metalorganic Chemical Vapor Deposition Growth of GaAs on AlGaAs Combined with in situ HCl Gas Etching," J. Cryst. Growth, **134**, 35–42 (1993b)

Thermochemical vapor etch; HCl; in situ etch for GaAs MOCVD regrowth on AlGaAs; optimization of $AsH_3$ flow rate to minimize dislocation density in regrowth

KIZUKI, H., M. Miyashita, Y. Kajikawa, and Y. Mihashi, "Time-resolved photoluminescence study on a hetero interface formed by direct regrowth of GaAs on an AlGaAs surface prepared by an in situ HCl gas etching process," Jpn. J. Appl. Phys. Pt. 1, **36**(10), 6290 (1997)

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)

KLINGER, R.E., and J.E. Greene, "Reactive Ion Etching of GaAs in $CCl_2F_2$," Appl. Phys. Lett., **38**(8), 620–22 (1981)

Reactive ion etch; $CCl_2F_2$ and $CCl_2F_2$/Ar; GaAs

KLINGER, R.E., and J.E. Greene, ‘‘Reactive Ion Etching of GaAs in $CCl_{4-x}F_x$ ($x = 0$, 2, 4) and Mixed $CCl_{4-x}F_x$/Ar Discharges,’’ J. Appl. Phys., **54**(3), 1595–1604 (1983)
Reactive ion etch; $CCl_{4-x}F_x$/Ar; GaAs

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)
$HCl:H_3PO_4$ (5:1); InP masked with Ti or InGaAs for groove etch; no undercutting with InGaAs; dependence of profile shapes on etch time

KNEISSL, M., D. Hofstetter, D.P. Bour, R. Donaldson, J. Walker, and N.M. Johnson, ‘‘Dry-etching and characterization of mirrors on III-nitride diodes from chemically assisted ion beam etching,’’ J. Cryst. Growth, **189**, 846 (1998)
Chemically assisted ion beam etching (CAIBE); $Cl_2$ in Ar; Application: mirror facet etch in InGaN/AlGaN laser diodes

KO, K.K., E.W. Berg, and S.W. Pang, ‘‘Effects of etch-induced damage on the electrical characteristics of in-plane gated quantum wire transistors,’’ J. Vac. Sci. Technol., B, **14**(6), 3663 (1996)
ECR ion etch; $Cl_2$/Ar of GaAs/AlGaAs quantum wire transitors; passivation of damage with $Cl_2$ plasma

KO, K.K., H.C. Davis, H.C. Sun, Y. Lam, W.-Q. Li, T. Brock, M.J. Rooks, S.W. Pang, and P.K. Bhattacharya, ‘‘Effects of Processing Induced Fluctuations on the Optical Properties of InGaAs/AlGaAs Quantum Boxes Created by Dry Etching and Epitaxial Regrowth,’’ GaAs and Related Compounds, 1992 (Inst. Phys. Conf. Ser. No. 129 1993), pp. 567–72
ECR plasma etch, $Cl_2/N_2$; Application: quantum box patterning in InGaAs/AlGaAs using Ni mask
$NH_4OH:H_2O_2:H_2O$ (4:1:2000); 30 Å surface etch following dry etch of InGaAs/AlGaAs
$HCl:H_2O$ (1:1); Ni mask removal from InGaAs/AlGaAs structure

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; $Cl_2$/Ar for etched mirrors in waveguides of $In_{0.20}Ga_{0.80}As$/GaAs

KO, K. K., and S.W. Pang, ‘‘Controllable Layer-by Layer Etching of III–V Compound Semiconductors with an Electron Cyclotron Resonance Source,’’ J. Vac. Sci. Technol., B, **11**(6), 2275–79 (1993)
ECR plasma etching $Cl_2$ surface reaction followed by Ar to desorb non-volatile $GaCl_3$; GaAs, InGaAs, AlGaAs and InP

KO, K.K., and S.W. Pang, ‘‘High aspect ratio deep via holes in InP etched using $Cl_2$/Ar plasma,’’ J. Electrochem. Soc., **142**(11), 3945 (1995b)
ECR etch of deep via holes in InP using $Cl_2$/Ar; etch rate comparison for InP, GaAs, InGaAs, GaAlAs, AlInAs, $SiO_2$, Ti and Ni

KO, K.K., and S.W. Pang, “Surface Damage on GaAs Etched Using a Multipolar Electron Cyclotron Resonance Source,” J. Electrochem. Soc., **141**(1), 255–58 (1994)
ECR etch surface damage study; GaAs

KOBAYASHI, M., K. Wakao, S. Nakamura, A. Jia, A. Yoshikawa, M. Shimotomai, Y. Kato, and K. Takahashi, “Homoepitaxy of ZnSe on the citric acid etched (1 0 0) ZnSe surface,” J. Cryst. Growth, **201/202**, 474 (1999)
citric acid (100 g in 100 ml $H_2O$):$H_2O_2$ (30%) (3:1); surface cleaning of ZnSe (1 0 0) substrates; etch rate 400 Å/min
$CS_2$; rinse of ZnSe surface to remove residual Se

KOBAYASHI, T., K. Taira, F. Nakamura, and H. Kawai, “Band lineup for a GaInP/GaAs heterojunction measured by a high-gain Npn heterojunction bipolar transistor grown by metalorganic chemical deposition,” J. Appl. Phys., **65**(12), 4898 (1989)
$H_3PO_4$:$H_2O_2$:$H_2O$ (3:1:50); Application: selective etch of GaAs from InGaP
HCl:$H_2O$ (3:2); Application: selective etch of InGaP from GaAs

KOCH, S.M., S.J. Rosner, R. Hull, G.W. Yoffe, and J.S. Harris, “The Growth of GaAs on Si by MBE,” J. Cryst. Growth, **81**, 205–13 (1987)
HF:$HNO_3$:$CH_3COOH$ (8:2:1); Application: Si substrate cleaning for GaAs MBE growth

KOCH, T.L., P.J. Corvini, and W.T. Tsang, “Anisotropically Etched Deep Gratings for InP/InGaAsP Optical devices,” J. Appl. Phys., **62**(8), 3461–63 (1987)
HBr:$HNO_3$:$H_2O$ (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 $Al_{0.3}Ga_{0.7}As$/GaSb diodes grown by MBE,” Solid-State Electron., **37**(8), 1567 (1994)
$CH_3COOH$:$HNO_3$:HF (40:18:2); GaSb mesa etch; room temperature for 40 s
$Br_2$:methanol (2%); GaSb mesa etch; room temperature 1 min
$CH_3COOH$:$HNO_3$:HF (40:18:2), followed by HCl:$HNO_3$ (30:1) at 5°C for 10 s; GaSb mesa etch for oxygen-free, low p–n junction leakage

KOHL, P.A., and F.W. Ostermayer, “Photochemical Methods for III–V Compound Semiconductor Device Processing,” Ann. Rev. Mater. Sci., **19**, 379–99 (1989)
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

KOHMOTO, S., Y. Nambu, and K. Asakawa, “Reduced non-radiative recombination in etched/regrown AlGaAs/GaAs structures fabricated by in situ processing,” J. Vac. Sci. Technol., B, **14**(6), 3646 (1996)
$Cl_2$ reactive ion beam etch; AlGaAs/GaAs in situ etch prior to AlGaAs regrowth by MBE

KOHMOTO, S., N. Takado, Y. Sugimoto, M. Ozaki, M. Sugimoto, and K. asakawa, "In Situ Electron Beam Patterning for GaAs Using Electron-Cyclotron-Resonance Plasma-Formed Oxide Mask and $Cl_2$ Gas Etching," Appl. Phys. Lett., **61**(4), 445–46 (1992)
ECR etch; $Cl_2$; Oxide mask with e-beam patterning; GaAs

KOHN, E., "A Correlation Between Etch Characteristics of GaAs Etch Solutions Containing $H_2O_2$ and Surface Film Characteristics," J. Electrochem. Soc., **127**(2), 505–08 (1980)
GaAs etch rate study shows proportional dependence on $H_2O_2$ concentration; low etch rates are surface reaction limited and show flat bottomed profiles; high etch rates are $H_2O_2$-diffusion limited and show enhanced etching at mask edges: $NaOH:H_2O_2:H_2O$ (2:$x$:100), $1 < x < 10$; $NH_4OH:H_2O_2:H_2O$ (1:1:$x$), $16 < x < 50$; $H_2SO_4:H_2O_2:H_2O$ ($x$:1:1), $10 < x < 250$; citric acid:$H_2O_2:H_2O$ (50:$x$:50); $1 < x < 10$; $H_3PO_4:H_2O_2:H_2O$ (1:1:$x$), $18 < x < 50$

KOLLAKOWSKI, ST, Ch Lemm, A. Strittmater, E.H. Böttcher, and D. Bimberg, "Buried InAlAs–InP waveguides: etching, overgrowth, and characterization," IEEE Photon. Technol. Lett., **10**(1), 114 (1998)
Reactive ion etch; $CH_4/H_2/Ar$ of InP/InGaAlAs/InGaAs heterostructure detectors. Reactive ion etch; $CHF_3/O_2$; removal of $SiN_x$ mask from InP
$C_6H_8O_7$(citric acid):$H_2O_2:H_2O$; 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
$H_2SO_4$; 1 min cleaning step for InP/InGaAlAs/InGaAs heterostructure detectors prior to sulfide passivation in preparation for MOCVD regrowth step
$(NH_4)_2S_x$ (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

KONAGAI, M., M. Sugimoto, and K. Takahashi, "High Efficiency GaAs Thin Film Solar Cells by Peeled Film Technology," J. Cryst. Growth, **45**, 277–80 (1978)
HF; $Ga_{0.3}Al_{0.7}As$ selective etch from GaAs; Application: removal of GaAs solar cell layers from the substrate

KONDO, N., Y. Nanishi, and M. Fujimoto, "Hydrogen ECR Plasma Surface Cleaning Using AlGaAs Substrates," GaAs and Related Compounds, 1992 (Inst. Phys. Conf. Ser. No. 129 1993), pp. 585–90
ECR plasma etch, $H_2$; AlGaAs substrate in situ cleaning for GaAs MBE growth

KÖNIG, H., S. Rennon, J.P. Reithmaier, and A. Foschel, "Complex coupled 1.55 μm DFB-lasers based on focused ion beam enhanced wet chemical etching and quantum well intermixing," Proc. 11th Int'l Conf. on Indium Phosphide and Related Materials, p. 29 (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

KONKAR, A., R. Heitz, T.R. Ramachandran, P. Chen, and A. Madhukar, "Fabrication of strained InAs island ensembles on non-planar patterned GaAs(1 0 0) substrates," J. Vac. Sci. Technol., B, **16**(3), 1334 (1998)

$H_2SO_4$:$H_2O_2$:$H_2O$ (8:1:40); Application: mesa etch for {1 1 1}A sidewalls on GaAs [1,−1,0] stripe patterns
$HF$:$H_2O_2$:$H_2O$ (1:9:5); Application: mesa etch for concave sidewalls of ~70° near mesa top on GaAs ⟨1 0 0⟩ stripe patterns

KOPF, R.F., R.A. Hamm, R.J. Malik, R.W. Ryan, M. Geva, J. Burm, and A. Tate, "ECR plasma etch fabrication of C-doped base InGaAs/InP DHBT structures: A comparison of $CH_4/H_2/Ar$ versus $BCl_3/N_2$ plasma etch chemistries," J. Electron. Mater., **27**(2), 69 (1998)
ECR plasma etch of InGaAs/InP; comparison of $CH_4/H_2/Ar$ and $BCl_3/N_2$

KOPF, R.F., R.A. Hamm, Y.-C. Wang, R.W. Ryan, A. Tate, M.A. Melendes, R. Pullela, and Y.-K / Thevin, J. Chen, "Dry-etch fabrication of reduced area InGaAs/InP DHBT devices for high speed circuit applications," Electron. Mater., **29**(2), 222 (2000)
ECR etching of InGaAs/InP using $BCl_3 + N_2$; end point monitoring using optical emission spectroscopy

KOREN, G., and J.E. Hurst, "248 nm Laser Etching of GaAs in Chlorine and Ozone Gas Environments," Appl. Phys. A, **45**, 301–304 (1988)
Laser-induced etching of GaAs in $Cl_2$ and $O_3$ gases

KOSUGI, T., H. Iwase, and K. Gamo, "Characteristics of Ion Beam Assisted Etching of GaAs: Surface Stoichiometry," J. Vac. Sci. Technol., B, **11**(6), 2214–18 (1993)
Focused Ga ion beam etching of GaAs in $Cl_2$; Auger surface study

KOSZI, L.A., and D.L. Rode, "{3 3 2} Ga Habit Planes Formed on GaAs During $Br_2$:$CH_3OH$ Etching," J. Electrochem. Soc., **122**(12), 1676–80 (1975)
$Br_2$: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

KOTANI, T., S. Komiya, S. Nakai, and Y. Yamaoka, "Etching Characteristics of Defects in the InGaAsP–InP LPE Layers," J. Electrochem. Soc., **127**(10), 2273 (1980)
HF:HBr (5:1) and (10:1); InP dislocation etch pit delineation study. A–B etch comparison

KOZAWA, T., T. Kachi, T. Ohwaki, Y. Taga, N. Koide, and M. Koike, "Dislocation etch pits in GaN epitaxial layers grown on sapphire substrates," J. Electrochem. Soc., **143**(1), L17 (1996)
KOH molten; GaN dislocation etch pit delineation; 10 min at 360°C

KRAWCZYK, S.K., M. Garriques, and H. Bouredoucen, "Study of InP Surface Treatments by Scanning Photoluminescence Microscopy," J. Appl. Phys., **60**(1), 392–95 (1986)
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

KUHN-KUHNENFELD, F., “A Polishing Dislocation Etch for GaP and GaAs,” GaAs and Related Compounds, 1976 (Inst. Phys. Conf. Ser. No. 33a 1977), pp. 158–60
$H_2SO_4$:$H_2O_2$:HF (3:2:2); heats spontaneously to 90°C
$H_2SO_4$:$H_2O_2$:HF (1:4:1); $H_2SO_4$:$H_2O_2$: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

KUHN-KUHNENFELD, F., “Selective Photoetching of GaAs,” J. Electrochem. Soc., **119**(8), 1063–68 (1972)
$H_2SO_4$:$H_2O_2$:$H_2O$ (3:1:1); GaAs selective n- from p-photoetching

KUIKEN, H.K., “Etching through a slit,” Proc. Royal Soc. London A, **396**, 95 (1984)
Modeling of masked pattern etching

KUIKEN, H.K., J.J. Kelly, and P.H.L. Notten, “Etch Profiles at Resist Edges; I. Mathematical Models for Diffusion-controlled Cases,” J. Electrochem. Soc., **133**(6), 1217–26 (1986)
Modeling of profiles for photolithographic etching using diffusion limited etchants

KUO, C.-W., Y.-.K Su, and H. Kuan, “$BCl_3$/Ar plasma-induced surface damage in GaInP/InGaAs/GaInP quantum-well high-electron-mobility transistors,” Jpn. J. Appl. Phys. Pt. 2, **37**(6B), L706 (1998a)
Reactive ion etch; $BCl_3$/Ar of GaInP/InGaAs/GaInP; surface damage in HEMTs

KUO, C.W., Y.K. Su, H.H. Lin, and C.Y. Chin, “$BCl_3$/Ar reactive ion etching for gate recessing of GaInP/InGaAs/GaAs pseudomorphic high electron mobility transistors,” J. Vac. Sci. Technol., B, **16**(6), 3003 (1998b)
Reactive ion etch; $BCl_3 + Ar(6:4)$; selective etch of GaAs from InGaP for gate recess of FETs

KUO, J.M., and Y.K. Chen, “Novel GaAs Heterojunction Bipolar Transistors Using $In_{0.5}Al_{0.5}P$ as Emitter,” IEEE Electron Device Lett., **15**(1), 13–15 (1994)
HCl:$H_2O$ (1:10); Application: $In_{0.5}Al_{0.5}P$ selective etch from GaAs

KURODA, S., N. Harada, K. Hikosaka, and M. Abe, “Highly Uniform N-InAlAs/InGaAs HEMT’s on a 3-in InP Substrate Using Photochemical Selective Dry Recess Etching,” IEEE Electron Device Lett., **13**(2), 105–07 (1992)
Photochemical dry etch; $CH_3Br$ with a low pressure mercury lamp; InGaAs selective etch from InAlAs; selectivity of 25

KURTH, E., A. Reif, V. Gottschalch, J. Finster, and E. Butter, “Chemical Etching and Polishing of InP,” Cryst. Res. Technol., **23**(1), 117–26 (1988)
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

$H_2SO_4$:$H_2O_2$:$H_2O$; discusses time dependence of secondary reaction products after initial mixing of the etchant

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
2/pre-etch with $(NH_4)_2S_2O_8$:$H_2SO_4$:$H_2O$ (15:73:15) at RT for 1 min
3/rinse with methanol
4/$Br_2$: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

KÜSTERS, A.M., A. Kohl, R. Müller, V. Sommer, and K. Heime, "Double-Heterojunction Lattice-Matched and Pseudomorphic InGaAs HEMT with d-Doped InP Supply Layers and p-InP Barrier Enhancement Layer Grown By LP-MOVPE," IEEE Electron Device Lett., **14**(1), 36–39 (1993)

HCl:$CH_3COOH$:$H_2O$ (6:4:1); Application: InGaAs/InP mesa etch at 8°C

$H_3PO_4$:$H_2O_2$:$H_2O$ (1:1:40); Application: InGaAs selective etch from InP for HEMT gate recess at 20°C

KWOK, R.W.M., G. Jin, B.K.L. So, K.C. Hui, L. Huang, W.M. Lau, C.C. Hsu, and D. Landheer, "Sulfide-assisted Reordering at the Surface and $SiN_x$/InP Interface," J. Vac. Sci. Technol., A, **13**(3), 652–657 (1995)

HF:$H_2O$ (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

LABANDA, J.G.C., S.A. Barnett, and L. Hultman, "Effects of glancing-angle ion bombardment on GaAs(0 0 1)," J. Vac. Sci. Technol., B, **13**(6), 2260 (1995)

Glancing-angle Ar ion beam, low damage sputtering to clean GaAs surfaces for MBE growth

LAI, L.S., H.C. Kao, and Y.J. Chan, "Low damage and selective gate recess RIE etching of InAlAs/InGaAs HEMTs using fluorine and chlorine gas mixtures," Proc. 10th Int'l Conf. on Indium Phosphide and Related Materials, p. 179 (1998)

Reactive ion etch of InAlAs/InGaAs using mixtures $CHF_3 + BCl_3$ and $CF_4/BCl_3$; selective removal of InGaAs from AlGaAs

LAMONTAGNE, B., J. Stapleton, P. Chow-Chong, M. Bucanan, J. Fraser, J. Phillips, and M. Davies, "InP etching using chemically assisted ion beam etching ($Cl_2$/Ar) formation of $InCl_x$ clusters under high concentration of chlorine," J. Electrochem. Soc., **146**(5), 1918 (1999)

CAIBE etch of InP using $Cl_2$/Ar; roughness from $InCl_x$ clusters

LANDHEER, D., K. Rajesh, J.E. Hulse, G.I. Sproule, J. McCaffrey, T. Quance, and M.J. Graham, "Characterization of GaAs(1 1 0) nitrided by an electron-cyclotron resonance plasma source using $N_2$," J. Electrochem. Soc., **147**(2), 731 (2000)

ECR nitridization of GaAs using $N_2$ plasma; formation of As–N bonds for $SiN_x$ deposition

LAU, W.S., E.F. Chor, S.P. Kek, W.H. Abdul Aziz, H.C. LIM, C.H. Heng, and R. Zhao, “The development of a highly selective $KI/I_2/H_2O/H_2SO_4$ etchant for the selective etching of $Al_{0.3}Ga_{0.7}As$ over GaAs,” Jpn. J. Appl. Phys. Pt. 1, **36**(6A), 3770 (1997)
KI:$I_2$:$H_2O$ (27.8 g:16.25 g:25 ml) with pH adjusted by adding an equal amount of $H_2SO_4$(diluted with $H_2O$ 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

LAU, W.M., R.N.S. Sodhi, B.J. Flinn, K.H. Tan, and G.M. Bancroft, “Photoemission Study of Sputter-etched InP Surfaces,” Appl. Phys. Lett., **51**(3), 177–79 (1987)
Ar ion sputter etching of InP; surface study

LAUTERBACH, CH, H. Albrecht, M. Beschorner, R. Gessner, and M. Schier, “Self-Aligned Gate Recess Technology for the Fabrication of InAlAs/InGaAs HEMT Structures, Using InAlAs as an Etch-Stop Layer,” 3rd Int’l Conf. on Indium Phosphide and Related Materials, Apr 8–11, 1991, Cardiff, Wales, UK, (IEEE Catalog no. 91CH2950-4) pp. 610–13
Reactive ion etch; $CH_4/H_2$; Application: InGaAs selective etch from InAlAs stop layer

LAW, H.D., “Anodic Oxidation of InGaAsP,” Appl. Phys. Lett., **37**(1), 68–70 (1980)
Anodization; InGaAsP in 0.1 M ammonium phosphate dibasic solution electrolyte

LAW, V.J., S.G. Ingram, and G.A.C. Jones, “ECR/Magnetic Mirror Coupled Plasma Etching of GaAs Using $CH_4$:$H_2$:Ar,” Semicond. Sci. Technol., **6**, 945–47 (1991a)
ECR plasma etch; $CH_4 + H_2 + Ar$; GaAs

LAW, V.J., S.G. Ingram, M. Tewordt, and G.A.C. Jones, “Reactive Ion Etching of GaAs Using $CH_4$: in He, Ne and Ar,” Semicond. Sci. Technol., **6**, 411–13 (1991b)
RF plasma etch, $CH_4$ in He, Ne and Ar; GaAs

LAW, V.J., and G.A.C. Jones, “Chloromethane-based Reactive Ion Etching of GaAs and InP,” Semicond. Sci. Technol., **7**, 281–83 (1992)
Reactive ion etch; $ClCH_3$ with $H_2$, He, $O_2$, Ne or Ar; GaAs and InP; GaAs and InP etch selectivity depend on gas combinations

LAW, V.J., G.A.C. Jones, and M. Tewordt, “Propane: hydrogen MORIE of GaAs,” Semicond. Sci. Technol., **5**, 1001–03 (1990a)
RF plasma etch $C_3H_8 + H_2$; GaAs; greater etch rates than with $CH_4 + H_2$

LAW, V.J., G.A.C. Jones, D.A. Ritchie, D.C. Peacock, and J.E.F. Frost, “Selective Metalorganic Reactive Ion Etching of Molecular-beam Epitaxy GaAs/$Al_xGa_{1-x}As$,” J. Vac. Sci. Technol. B, **7**(6), 1479–82 (1989)
Reactive ion etch; $CH_4 + H_2$; Application: GaAs selective etch from AlGaAs

LAW, V.J., G.A.C. Jones, and M. Tewordt, “Substrate Temperature Dependence of GaAs Etch Rates in $CH_4$: $H_2$ MORIE,” Semicond. Sci. Technol., **5**, 281–83 (1990b)
RF plasma etch; $CH_4 + H_2$; GaAs; etch rate dependence on temperature and $CH_4$ concentration

LAW, V.J., M. Tewordt, D.C. Clary, and G.A.C. Jones, "300 kHz Pulse Plasma Etching of GaAs Using a Mixture of $ClCH_3$ and $H_2$," J. Vac. Sci. Technol., B, **11**(6), 2262–65 (1993)
300 kHz Pulse Plasma Etching of GaAs Using a Mixture of $ClCH_3$ and $H_2$

LECROSSNIER, D., L. Henry, A. Le Corre, and C. Vaudry, "GaInAs Junction FET Fully Dry Etched by Metal Organic Reactive Ion Etching Technique," Electron. Lett., **23**, 1254–55 (1987)
Reactive ion etch; $CH_4/H_2/Ar$; Application: InGaAs FET gate etch

LEE, B.-T., T.R. Hayes, P.M. Thomas, R. Pawelek, and P.F. Sciortino, "$SiO_2$ Mask Erosion and Sidewall Composition During $CH_4/H_2$ Reactive Ion Etching of InGaAs/InP," Appl. Phys. Lett., **63**(23), 3170–72 (1993)
Reactive ion etch; $CH_4/H_2$, $SiO_2$ mask erosion and sidewall residues; InGaAsP/InP

LEE, B.-T., D.-K. Kim, J.-H. Ahn, and D.-G. Oh, "Investigation of surface oxide films on InP mesa sidewalls and flat surfaces reactive ion etched using $CH_4/H_2$ chemistry," Proc. 1996 Indium Phosphide and Related Materials Conference, p. 416 (1996)
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

LEE, B.-T., J.-S. Park, D.-K. Kim, and J.-H. Ahn, "Characterization of heavy deposits on InP mesa sidewalls reactive ion etched using $CH_4/H_2$," Semicond. Sci. Technol., **14**, 345 (1999)
Reactive ion etch of InP mesas using $CH_4/H_2$; characterization of mesa sidewall deposits

LEE, C., M. Takai, T. Yada, K. Kato, and S. Namba, "Laser-Induced Trench Etching of GaAs in Aqueous KOH Solution," Appl. Phys. A, **51**, 340–343 (1990)
Maskless laser-induced etching of GaAs in KOH

LEE, H.G., R.J. Fischer, G.J. Zydzik, and A.Y. Cho, "Dry Etching of GaAs and AlGaAs by $Cl_2$ in Molecular Beam Epitaxy," J. Vac. Sci. Technol., B, **11**(3), 989–91 (1993)
Thermochemical etch; $Cl_2$; GaAs and AlGaAs in situ MBE; at 350°C; etched surfaces suitable for layer regrowth

LEE, H., and J.S. Harris, "Iron nitride mask and reactive ion etching of GaN films," J. Electron. Mater., **27**(4), 185 (1998)
RIE plasma etch of patterned GaN; $CHF_3/Ar$, $C_2ClF_5/Ar$, $C_2ClF_5/Ar/O_2$, $SiCl_4$
$CHCl_3$; sputtered iron nitride (Fe–8% N) mask is resistant to Cl-based ion etch and easily removed
$H_2SO_4{:}H_2O_2{:}H_2O$ (1:1:10); removal of iron nitride pattern mask from GaN

LEE, H., D.B. Oberman, Harris Jr., and J. S., "Reactive Ion Etching of GaN Using $CHF_3/Ar$ and $C_2ClF_5/Ar$ Plasmas (EMC abstract)," J. Electron. Mater., **24**(7), A32 (1995a)
RIE etch; $CHF_3/Ar$ and $C_2ClF_5/Ar$; GaN

LEE, H., D.B. Oberman, and Jr J.S. Harris, "Reactive ion etching of gallium nitride films," J. Electron. Mater., **25**(5), 835 (1996)
Reactive ion etching of GaN films; $CHF_3/Ar$ and $C_2ClF_5/Ar$; study

LEE, H.J., M.S. Tse, Prasad K. Radhakrishnan, J. Weng, S.F. Yoon, X. Zhou, H.S. Tan, S.K. Ting, and Y.C. Leong, ‘‘Selective wet etching of a GaAs/$Al_xGa_{1-x}As$ heterostructure with citric acid–hydrogen peroxide solutions for pseudomorphic GaAs/$Al_xGa_{1-x}As$/$InyGa_{1-y}As$ heterojunction field effect transistor fabrication,’’ Mater. Sci Eng. B, **35**, 230 (1995b)
citric acid:$H_2O_2$ (4:1); etches GaAs selectivity from $Al_xGa_{1-x}As$; selectivity $\sim$110

LEE, J.W., C.R. Abernathy, S.J. Pearton, F. Ren, W.S. Hobson, R.J. Shul, C. Constantine, C. Barrat, ‘‘Inductively coupled plasma etch damage in GaAs and InP Schottky diodes,’’ J. Electrochem. Soc., **144**(4), 1417 (1997a)
Inductively couple plasma etch (ICP); Ar; of GaAs and InP; etch damage comparison to ECR etch

LEE, J.W., R.V. Crockett, and S.J. Pearton, ‘‘Comparison of masking materials for high microwave power $CH_4/H_2/Ar$ etching of III–V semiconductors,’’ J. Vac. Sci. Technol., B, **14**(3), 1752 (1996a)
ECR plasma etch; $CH_4/H_2/Ar$; comparison of masking materials($SiN_x$, W, photoresist) for pattern etching of GaAs

LEE, J.W., D. Hays, C.R. Abernathy, S.J. Pearton, W.S. Hobson, and C. Constantine, ‘‘Inductively coupled Ar plasma damage in AlGaAs,’’ J. Electrochem. Soc., **144**(9), L245 (1997b)
ICP etch using Ar, damage of AlGaAs

LEE, J.W., J. Hong, E.S. Lambers, C.R. Abernathy, S.J. Pearton, W.S. Hobson, and F. Ren, ‘‘$Cl_2$-based dry etching of GaAs, AlGaAs, and GaP,’’ J. Electrochem. Soc., **143**(6), 2010 (1996b)
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

LEE, J.W., J. Hong, E.S. Lambers, C.R. Abernathy, and S.J. Pearton, ‘‘Comparison of dry etching of III–V semiconductors on ICl/Ar and IBr/Ar Electron cyclotron resonance plasmas,’’ J. Electron. Mater., **26**(11), 1314 (1997c)
ECR plasma etch; ICl/Ar and IBr/Ar; InP, InGaAs, InSb, GaAs, GaSb, AlGaAs; study of etch rates and morphologies

LEE, J.W., J. Hong, E.S. Lambers, C.R. Abernathy, and S.J. Pearton, ‘‘Dry etching of III–V semiconductors in IBr/Ar cyclotron resonance plasmas,’’ J. Electron. Mater., **26**(5), 429 (1997d)
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

LEE, J.W., J. Hong, E.S. Lambers, and S.J. Pearton, ‘‘ICl plasma etching of III–V semiconductors,’’ J. Vac. Sci. Technol., B, **15**(3), 652 (1997e)
ECR plasma etch; ICl/Ar; etch study on GaAs, GaSb, InP, and InSb

LEE, J.W., K.N. Lee, R.R. Stradtmann, C.R. Abernathy, S.J. Pearton, W.S. Hobson, and F. Ren, ‘‘Damage investigation in AlGaAS and InGaP exposed to high ion density Ar and $SF_6$ plasmas,’’ J. Vac. Sci. Technol., A, **15**(3), 890 (1997f)
ECR plasma etch of AlGaAs and InGaP in Ar and $SF_6$; study of surface damage

LEE, J.W., S.J. Pearton, C.J. Santana, J.R. Mileham, E.S. Lambers, C.R. Abernathy, F. Ren, and W.S. Hobson, "High ion density plasma etching of InGaP, AlInP, and AlGaP in $CH_4/H_2/Ar$," J. Electrochem. Soc., **143**(3), 1093 (1996c)

ECR high power plasma etch; $CH_4/H_2/Ar$; of InGaP, AlInP, and AlGaP

LEE, J.W., C.B. Vartuli, C.R. Abernathy, J.D. MacKenzie, J.R. Mileman, R.J. Shul, J.C. Zolper, M. Hagerott-Crawford, J.M. Zavada, R.G. Wilson, and R.N. Schwartz, "Etching processes for fabrication of GaN/InGaN/AlN microdisk laser structures," J. Vac. Sci. Technol., B, **14**(6), 3637 (1996d)

AZ400K developer solution (~10% KOH active ingredient)

Selective etchant of $In_xAl_{1-x}N$ with x as high as 75%; etch rates given over temperature range of 20–80°C; does not etch pure InN or GaN

ECR plasma etch of InN and GaN using ICl

LEE, S.H., Y. Hsu, and G.B. Stringfellow, "Effects of group V precursor and step structure on ordering in GaInP," J. Electron. Mater., **26**(10), 1244 (1997)

$NH_4OH:H_2O_2:H_2O$ (2:1:12); Application: GaAs substrate cleaning for OMVPE growth, 1 min

LEE, T.P., and C.A. Burrus, "Dark Current and Breakdown Characteristics of Dislocation-free InP Photodiodes," Appl. Phys. Lett., **36**(2), 587–89 (1980)

$AgNO_3:HF:HNO_3:H_2O$ (40 mg:16 ml:24 ml:32 ml) {RC etch}; Application: InP (1 1 1)B dislocation delineation; etch time a few hours

LEE, T.P., C.A. Burrus, and A.G. Dentai, "InGaAs/InP p–n Photodiodes for Lightwave Communications at the 0.95–1.65 μm Wavelength," IEEE J. Quantum Electron., **QE-17**, 232 (1981)

$Br_2$/methanol (1%); Application: InGaAs mesa etch

LEE, W.J., H.S. Kim, G.Y. Yeom, J.W. Lee, and T.I. Kim, "Facet formation of a GaN-based device using chemically assisted ion beam etching with a photoresist mask," J. Vac. Sci. Technol., A, **17**(4), 1230 (1999)

CAIBE of GaN with $Cl_2$ in Ar beam; etch profile dependence on tilt angle

LEE, W.-S., T. Enoki, S. Yamahata, Y. Matsuoka, and T. Ishibashi, "Submicrometer Self-aligned AlGaAs/GaAs Heterojunction Bipolar Transistor Process Suitable for Digital Applications," IEEE Trans. Electron Devices, **39**(12), 2694 (1992)

Reactive ion etch; $C_2F_6$; Application: $SiN_x/SiO_2$ deposited mask pattern etching

ECR plasma etch; $Cl_2/Ar$; InGaAs and GaAs etch

ECR plasma etch; $Cl_2/NF_3/Ar$; GaAs selective etch from AlGaAs

ECR plasma etch; $NF_3$; Ti/W metal removal from mesa sidewalls

LEE, Y.H., H.S. Kim, G.Y. Yeom, J.W. Lee, M.C. Yoo, and T.I. Kim, "Etch characteristics of GaN using inductively coupled $Cl_2/Ar$ and $Cl_2/BCl_3$ plasmas," J. Vac. Sci. Technol., A, **16**(3), 1478 (1998)

Inductively coupled plasma etch; $Cl_2/Ar$ and $Cl_2/BCl_3$ of GaN

LEGAY, P., P. Petit, J.P. Debray, A. Kohl, G. Patriarche, G. Le Roux, M. Juhel, and M. Quillec, "Wet thermal oxidation of InAlAs and AlAsSb alloys lattice-matched to InP," Proc. 9th Int'l Conf. on Indium Phosphide and Related Materials, p. 586 (1997)

Lateral oxidation of InAlAs and AlAsSb layers on InP by heating in water saturated $N_2$; study of properties

LEHENEY, R.F., R.E. Nahory, M.A. Pollack, E.D. Beebe, and J.C. DeWinter, "Characterization of InGaAs Photodiodes Exhibiting Low Dark Current and Low Junction Capacitance," IEEE J. Quantum Electron., **QE-17**(2), 227–31 (1981)

$Br_2$/methanol; Application: InGaAs mesa etch

LEMM, CH, St Kollakowski, D. Bimberg, and K. Janiak, "Reactive ion etching of InP/InAlGaAs/InGaAs heterostructures," J. Electrochem. Soc., **144**(9), L255 (1997)

Reactive ion etch; $CH_4/H_2/Ar$ of InP/InGaAlAs/InGaAs heterostructure detectors

$C_6H_8O_7$(citric acid):$H_2O_2$:$H_2O$; 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

$H_2SO_4$; 1 min cleaning step for InP/InGaAlAs/InGaAs heterostructure detectors prior to sulfide passivation in preparation for MOCVD regrowth step

$(NH_4)_2S_x$ (Ammonium polysulfide); passivation of InP/InGaAlAs/InGaAs heterostructures for MOCVD regrowth; Ref. (Iyer, R., 1991)

LEONHARDT, D., C.R. Eddy, V.A. Shamamian, R.T. Holm, and O.J. Glembocki, "Surface chemistry and damage in the high density plasma etching of gallium arsenide," J. Vac. Sci. Technol., A, **16**(3), 1547 (1998)

High density plasma etching of GaAs in $Cl_2$/Ar; study of surface chemistry and damage

LEPORE, J.J., "An Improved Technique for Selective Etching of GaAs and GaAlAs," J. Appl. Phys., **51**(12), 6441–42 (1980)

$NH_4OH$:$H_2O_2$ (1:60); GaAs selective removal from AlGaAs by jet thinning; GaAs etch rate at $0°C = 60\ \mu m/h$ with selectivity of 60

LESSOFF, H., and R. Gorman, "A Eutectic Dislocation Etch for GaAs," J. Electron. Mater., **13**(5), 733–39 (1984)

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

LI, F., G.F. Spencer, T. Wang, C.C. Andrews, and W.P. Kirk, "Effects of Low Energy Ion Exposure on Modulation-Doped GaAs Heterostructures," J. Vac. Sci. Technol., B, **11**(6), 2592–96 (1993)

$H_2PO_3$:$H_2O_2$:$H_2O$ (1:1:25); Application: GaAs mesa etch

Ar ion beam etch; GaAs damage effects on surface depletion

LI, G., "Selective Chemical Etchant for InGaAsP/InP Lasers," Sov. Phys.-Tech. Phys., **26**(6), 727 (1981)

KOH:$K_3Fe(CN)_6$:$H_2O$ (6 g:4 g:50 ml); selectively etches InGaAsP on InP

LI, J., M.M. Carrabba, J.P. Hachey, S. Mathew, and R.D. Rauh, "Photoelectrochemical Etching of Blazed Echelle Gratings in n-GaAs," J. Electrochem. Soc., **135**, 3170–71 (1988)
Photoelectrochemical etch; KCl electrolyte; GaAs; Application: sawtooth gratings using photoresist mask

LI, K., and M. M. Oprysko, Appl. Phys. Lett., **46**, 997 (1985)LI, N.Y., Y.M. Hsin, P.M. Asbeck, and C.W. Tu, "Improving the etched/regrown GaAs interface by in situ etching using tris-dimethylaminoarsenic," J. Cryst. Growth, **175/176**, 387 (1997)
Thermochemical etch; tris-dimethylaminoarsenic in situ etch of GaAs for MBE regrowth of AlGaAs

LIANG, J.J., and J.M. Ballantyne, "Self-Aligned Dry-Etching Process for Waveguide Diode Ring lasers," J. Vac. Sci. Technol., B, **12**(5), 2929–32 (1994)
$Cl_2$ 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

LIAO, A.S.H., B. Tell, R.F. Leheny, and T.Y. Chang, "InGaAs n-Channel Native Oxide Inversion Field-Effect Transistor," Appl. Phys. Lett., **41**(3), 280–82 (1982)
$H_3PO_4$:$H_2O_2$:$H_2O$ (38:1:1)? (or (1:1:38)?); Application: InGaAs FET gate channel etch

LIAO, H.-H. (UCSD), "Ti metal removal from InP," private communication, (1996)
buffered HF (i.e., HF:$NH_4F$, 1:6):$H_2O$ (1:4); Ti removal from InP; 30 s at room temperature removes ~200 Å

LIAU, Z.L., and J.N. Walpole, "A Novel Technique for GaInAsP/InP Buried Heterostructure Laser Fabrication," Appl. Phys. Lett., **40**(7), 568–69 (1982)
KOH:$K_3Fe(CN)_6$:$H_2O$(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

LILE, D.L., and D.A. Collins, "Carrier profiling of InP," Electron. Lett., **14**(15), 457 (1978)
Tartaric acid(40%):$H_2O_2$(30%) (3:1); InP; rate =~ 2000 Å/h; used as Schottky contact for C/V carrier concentration profiling

LIN, C.W., F.-R. Fan, and A.J. Bard, "High Resolution Photoelectrochemical Etching of n-GaAs with the Scanning Electrochemical and Tunneling Microscope," J. Electrochem. Soc., **134**, 1038–39 (1987)

- High resolution photoelectrochemical etch of GaAs with scanning tunneling microscope

LIN, C.L., Y.K. Su, T.S. Se, and W.L. Li, "Variety transformation of compound at GaSb surface under sulfur passivation," Jpn. J. Appl. Phys., Pt. 2, **37**(12b), L1543 (1998)
HCl:$H_2O$ (3:7); GaSb surface treatment to provide Sb surface termination prior to sulfidation
$(NH_4)_2S$:$H_2O$ (1:4) and (1:45); sulfur passivation of GaSb

LIN, J.-L., M.B. Freiler, M. Levy, R.M. Osgood Jr., D. Collins, and T. C. McGill, ‘‘Photon-assisted cryoetching of III–V binary compounds by $Cl_2$ at 193 nm,’’ Appl. Phys. Lett., **67**(24), 3563 (1995)

$NH_4OH$:$H_2O$ (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

LIN, M.E., Z.F. Fan, Z. Ma, L.H. Allen, and H. Morkoç, ‘‘Reactive ion etching of GaN using $BCl_3$,’’ Appl. Phys. Lett., **64**(7), 887 (1994)

Reactive ion etching; $BCl_3$ of GaN etch study

LINH, N.T., J.P. Hornbrouck, and N. Sol, ‘‘Epitaxie en Phase Liquide des Composes III–V sur Substrat InP,’’ J. Cryst. Growth, **31**, 204–09 (1975)

$Br_2$/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

LIU, H.C., H. Tsai, J.W. Hsu, and H.C. Shih, ‘‘The phase identification of $H_2SO_4$-etched InP by X-ray diffraction,’’ J. Electrochem. Soc., **146**(9), 3510 (1999)

$H_2SO_4$:$H_2O$ etched InP; study of surface oxides by glancing angle X-ray diffraction

$H_2SO_4$:$H_2O_2$:$H_2O$ etched InP; study of surface oxides by glancing angle X-ray diffraction; $H_2O_2$ plays no significant role in etch of InP

LIU, J.Q., M.F. Zybura, Y.C. Pao, R. Westerman, and C. Constantine, ‘‘Dry etching process in InP genn device technology utilizing inductively coupled plasma (ICP) system,’’ Proc. 10th Int’l Conf. on Indium Phosphide and Related Materials, p. 187 (1988)

Inductively coupled plasma (ICP) etch of InP using HBr/$BCl_3$/$CH_4$/$H_2$/Ar for Gunn diode mesa fabrication

LOGAN, R.A., and F.K. Reinhart, ‘‘Optical Waveguides in GaAs–AlGaAs Epitaxial Layers,’’ J. Appl. Phys., **44**(9), 4172–75 (1973a)

$NH_4OH$:$H_2O_2$ (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. $K_3Fe(CN)_6$:$K_4Fe(CN)_6$ (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

LOGAN, R.A., B. Schwartz, and W.J. Sundburg, ‘‘The Anodic Oxidation of GaAs in Aqueous $H_2O_2$ Solution,’’ J. Electrochem. Soc., **120**(10), 1385–90 (1973b)

Anodization; GaAs using $H_2O_2$ electrolyte with pH adjusted by $H_3PO_4$ or $NH_4OH$

LOOK, C.C., D.C. Walters, J.S. Sewell, S.C. Dudley, M.G. Mier, and J.S. Sizelove, ‘‘A New Technique for Whole-wafer Etch-pit Density Mapping in GaAs,’’ J. Appl. Phys., **65**(3), 1375–77 (1989)

KOH molten at 450°C; Application: GaAs defect etch pit delineation

LOSURDO, M., P. Capezzuto, and G. Bruno, "Study of the $H_2$ remote plasma cleaning of InP substrate for epitaxial growth," J. Vac. Sci. Technol., B, **14**(2), 691 (1996)

$H_2SO_4$:$H_2O_2$:$H_2O$ (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)

$H_3PO_4$:HCl:$H_2O$ (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 $CCl_2F_2$/Ar; InGaP selective etch from GaAs

LOTHIAN, J.R., J.M. Kuo, S.J. Pearton, and F. Ren, "Wet and dry etching of InGaP," Mat. Res. Soc. Proc., Vol. **240**, 307 (1992b)

$H_3PO_4$:HCl:$H_2O$ (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, $CCl_2F_2$/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:$H_2O$ (1:30); $Al_{0.5}In_{0.5}P$ etch rate = 600 Å/min at 25°C

HCl:$H_2O$ (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, $CCl_2F_2$/Ar, $CH_4$/$H_2$/Ar; AlInP selective etch from GaAs

LOTHIAN, J.R., F. Ren, and S.J. Pearton, "Mask erosion During Dry Etching of Deep features in III–V Semiconductor Structures," Semicond. Sci. Technol., **7**, 1199–1209 (1992d)

Plasma etch; $CH_4 + H_2$; InP with $SiO_2$ and $Si_3N_4$ dielectric masks and with Al and Ti/Au metal masks

Plasma etch; $PCl_3 + Ar$; GaAs with Au mask; dependence on bias

LOTHIAN, J., Ren. F., S.J. Pearton, U.K. Chakrabarti, C.R. Abernathy, and A. Katz, "Trilayer Lift-off Metallization Process Using Low Temperature Deposited $SiN_x$," J. Vac. Sci. Technol., B, **10**(6), 2361–63 (1992e)

ECR plasma etch; Application: mask patterning for AlGaAs/GaAs HBTs; $O_2$ discharge for polydimethylglutarimide mask etch; $SF_6$ discharge for SiN mask

LOURENCO, J.A., "A Defect Etchant for ⟨1 0 0⟩ InGaAsP," J. Electrochem. Soc., **131**(8), 1914 (1984)

KOH:$K_3Fe(CN)_6$:$H_2O$ (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

$HNO_3$:HBr (1:3); InP dislocation delineation, superior reproducibility to $H_3PO_4$:HBr (2:1) {Huber etch}

$HCl:H_3PO_4$ (1:1); InP selective etch from InGaAsP
$KOH:K_3Fe(CN)_6:H_2O$ (8 g:12 g:100 ml) solution used for InGaAsP selective etch from InP

LOURENCO, J.A., "Delineation of p–n Junction in Thin InGaAsP Layers Using Chemical Etchants," J. Electrochem. Soc., **130**(10), 2097–99 (1983)
$KOH:K_3Fe(CN)_6:H_2O$ (8 g:0.5 g:100 ml); InGaAsP p–n junction delineation
A–B etch tried, but too fast attack

LOWES, T.D., "The Dependence of Photoetching n-InP on Surface Preparation and Electrolyte Metal Ion Impurities," J. Electrochem. Soc., **140**(1), 256–62 (1993a)
$H_3PO_4:H_2O$ (1:9); n-InP photoetch study; etch rates are enhanced two to five times by added Cu metal ions

LOWES, T.D., and D.T. Cassidy, "Photochemical Etching of n-InP: Observations on photon efficiency and Saturation," Semicond. Sci. Technol., **8**, 97–100 (1993b)
$H_3PO_4:H_2O$ (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

LU, E.D., F.P. Zhang, S.H. Xu, P.S. Yu, Z.F. Xu, Z.F. Han, F.Q. Xu, and X.Y. Zhang, "A sulfur passivation for GaAs surface by organic molecular $CH_3CSNH_2$ treatment," Appl. Phys. Lett., **69**(15), 2282 (1996)
$HCl:H_2O_2:H_2O$ (1:1:50); GaAs surface cleaning prior to S passivation
$CH_3CSNH_2/NH_4OH$ solution; GaAs surface passivation
$CH_3CSNH_2/H+$ solution; GaAs surface passivation

LU, H., Z. Wu, and I. Bhat, "Photoassisted anodic etching of gallium nitride," J. Electrochem. Soc., **144**(1), L8 (1997)
tartaric acid (3w/o) buffered with $NH_4OH$: ethylene glycol (1:2); electrolyte for GaN photoassisted anodic etch; rate dependence on current and pH

LU, S.S., "High-current-gain $Ga_{0.51}In_{0.49}P$/GaAs heterojunction bipolar transistor grown by gas-source molecular beam epitaxy," IEEE Electron Device Lett., **13**(4), 214 (1992)
$NH_4OH:H_2O_2$ (pH = 8.4); Application: selective etch of GaAs from InGaP
$HCl:H_2O$ (1:1); Application: selective etch of InGaP from GaAs

LU, Z.H., M.J. Graham, X.H. Feng, and B.X. Yang, "Structure of S on Passivated GaAs (1 0 0)," Appl. Phys. Lett., **62**(23), 2932–34 (1993)
$(NH_4)_2S$; surface passivation of GaAs; chemical structure study

LUBZENS, D., "Photoetching of InP Mesas for Production of mm-wave Transferred-Electron Oscillators," Electron. Lett., **13**(7), 171–72 (1977)
$FeCl_3:H_2O$ (40% w/v); Application: InP photoetching of mesas; etch rate = 0.5 μm/min under illumination, followed by clean-up etch of: $Br_2:HBr:H_2O$ (1:18:81)

LUM, R.M., A.M. Glass, F.W. Ostermayer, P.A. Kohl, A.A. Ballman, and R.A. Logan, "Holographic Photoelectrochemical Etching of Diffraction Gratings in n-InP and n-GaInAsP for Distributed Feedback Lasers," J. Appl. Phys., **57**(1), 39–45 (1985)

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

LUM, W.Y., and A.R. Clawson, "Thermal Degradation of InP and its Control in LPE Growth," J. Appl. Phys., **50**(8), 5296–5301 (1979)

Thermal etching (degradation) in $H_2$; InP thermal etch in $H_2$ of LPE reactor

LUO, J.K., H. Thomas, and N.M. Pearsall, "Induced Defects in Plasma-etched p-type Indium Phosphide," Semicond. Sci. Technol., **7**, 168–71 (1992)

Plasma etch; Ar; InP; study of induced defects

MADHAN RAJ, M., S. Toyoshima, and S. Arai, "Multiple micro-cavity laser with l/4-wire deep grooves buried with benzocyclobutene," Proc. 11th Int'l Conf. on Indium Phosphide and Related Materials, p. 207 (1999a)

Reactive ion etch using $CH_4/H_2$ on InP/InGaAsP for l/4 narrow grooves; alternating with $O_2$ ashing to remove polymer buildup

$H_2SO_4$:$H_2O_2$:$H_2O$ (1:1:40); 30 s cleaning of InGaAsP after RIE. HCl:$H_2O$ (1:10); 1 min cleaning of RIE roughness on InP facets

MADHAN RAJ, M., J. Wiedmann, Y. Saka, H. Yasumoto, and S. Arai, "High reflectivity laser facets by deeply etched DBR buried with benzocyclobutene," Proc. 11th Int'l Conf. on Indium Phosphide and Related Materials, p. 10 (1999b)

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

$H_2SO_4$:$H_2O_2$:$H_2O$ (1:1:40); step 1 in damage removal from RIE etched InGaAsP/InP; 0°C for 70 s

HCl:$H_2O$ (1:10); step 2 in damage removal from RIE etched InGaAsP/InP 1 min at room temp

MAEDA, F., Y. Watanabe, and M. Oshima, "Surface Chemical Bonding of $(NH_4)_2S_x$-Treated InP (0 0 1)," Appl. Phys. Lett., **62**(3), 297–99 (1993)

$(NH_4)_2S_x$; InP surface passivation study

MAHAJAN, S., and A.K. Chin, "The Status of Current Understanding of InP and InGaAsP Materials," J. Cryst. Growth, **54**, 138–49 (1981)

Defect delineation etchants; Application to InP and InGaAsP: $H_3PO_4$:HBr (2:1) {Huber etch} at RT for ~2 min

$HNO_3$:$H_2O$: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

$H_2O$:$AgNO_3$:$CrO_3$: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

MAKI, P.A., and D.J. Ehrlich, "Laser Bilayer Etching of GaAs Surfaces," Appl. Phys. Lett., **55**(2), 91–93 (1989)

Photoassisted dry etch; $Cl_2$; GaAs; self-terminating chloronation reaction followed by laser photodesorption of surface chlorides

MALAG, A., J. Ratajczak, and J. GAZECKI, "$Al_xGa_{1-x}As$/GaAs heterostructure characterization by wet chemical etching," Mater. Sci. Eng., **B20**, 332–338 (1993)
$I_2$:KI:$H_2O$ (65 g:113 g:100 g); selective removal of $Al_xGa_{1-x}As$ from GaAs if $x > 0.1$
HCl, hot; selective removal of $Al_xGa_{1-x}As$ from GaAs if $x > 0.42$
HF, hot; selective removal of $Al_xGa_{1-x}As$ from GaAs if $x > 0.38$

MANGAT, P.S., P. Soukiassian, Y. Huttel, Z. Hurych, B. Gruzza, and A. Porte, "Low-Energy Ar+ Ion Bombardment-Induced Modification of Surface Atomic Bond Lengths on InP (1 0 0) Wafer," Appl. Phys. Lett., **63**(14), 1957–59 (1993)
Ar ion etch of InP; study of surface atomic bond lengths

MANIN-FERLAZZO, L., F. Carcenac, R. Teisier, G. Faini, and D. Mailly, "Damage chracterization of anisotropic InP patterns obtained by $SiCl_4$ Reactive Ion Etching," Microelectron. Eng., **46**, 331 (1999)
Reactive ion etch of Ni- and W-masked pattern structures on InP using $SlCl_4$; damage characterization

MAO, B.-Y., J.A. Nielsen, R.A. Friedman, and G.Y. Lee, "The Application of Citric Acid/Hydrogen Peroxide Etching Solutions in the Processing of Psedomorphic MODFETs," J. Electrochem. Soc., **141**(4), 1082–85 (1994)
Citric acid:$H_2O_2$:$H_2O$; Study of GaAs versus $Al_{0.28}Ga_{0.72}As$ etch rate dependence on citric acid:$H_2O_2$ ratio and on $H_2O$ concentration
Citric acid:$H_2O_2$:$H_2O$ (4:1:1); non-selective GaAs, AlGaAs etch rate ~4000 Å/min
Citric acid:$H_2O_2$ (4:1); selective etch of GaAs from $Al_{0.28}Ga_{0.72}As$

MARANOWSKI, S.A., N. Holonyak, T.A. Richard, and F.A. Kish, "Photon-Induced Anisotropic Oxidation along p–n Junctions in $Al_xGa_{1-x}As$–GaAs Quantum Well Heterostructures," Appl. Phys. Lett., **62**(17), 2087–89 (1993)
$H_2SO_4$:$H_2O_2$:$H_2O$ (4:1:1); Application: AlGaAs/GaAs mesa etch; HCl:$H_2O_2$:$H_2O$) (1:4:40); Application: AlGaAs/GaAs stain for SEM cross-sections
Thermal oxidation; AlGaAs/GaAs; $N_2$ saturated with $H_2O$; 70 min at 425°C

MARSHALL, D., and R.B. Jackman, "Dry etching techniques for GaAs ultra-high vacuum chamber integrated processing," Microelectron. Eng., **25**, 287 (1994)
in-vacuo maskless GaAs etching using ion or laser-induced reaction of adsorbed vapors of $SO_2Cl_2$ and 1,2-dichloroethane

MARUNO, S., Y. Morishita, T. Isu, Y. Nomura, and H. Ogata, "Molecular Beam Epitaxy of InP Using Low Energy P+ Ion Beam," J. Cryst. Growth, **81**, 338–43 (1987)
$H_2SO_4$:$H_2O_2$:$H_2O$ (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

MASLAR, J.E., P.W. Bohn, D.G. Ballegeer, E. Andideh, I. Adesida, C. Caneau, and R. Bhat, "Structural Modification in Reactive-Ion-Etched *i*-InP and n+-InP Studied by Raman Scattering," J. Appl. Phys., **73**(6), 2983–93 (1993)

Reactive ion etch; Ar, He, $CH_4$/Ar, $CH_4$/He, $CH_4/H_2$/Ar; InP; study of surface modification by Raman scattering

MASLAR, J.E., J.F. Dorsten, P.W. Bohn, S. Agarwala, I. Adesida, C. Caneau, and R. Bhat, "Structural and Electronic Effects of Argon Sputtering and Reactive Ion Etching on $In_{0.53}Ga_{0.47}As$ and $In_{0.52}Al_{0.53}As$ Studied by Inelastic Light Scattering," J. Vac. Sci. Technol., B, **13**(3), 988–94 (1995)

Ar sputtering; $In_{0.53}Ga_{0.47}As$ and $In_{0.52}Al_{0.53}As$; damage study
RIE; HBr; $In_{0.53}Ga_{0.47}As$ and $In_{0.52}Al_{0.53}As$; damage study

MASSIES, J., and J.P. Contour, "Substrate Chemical Etching Prior to MBE: An X-ray Photoelectron Spectroscopy Study of GaAs {0 0 1} Surfaces etched by the $H_2SO_4$–$H_2O_2$–$H_2O$ solution," J. Appl. Phys., **58**(2), 806–10 (1985)

$H_2SO_4$:$H_2O_2$:$H_2O$ (5:1:1); GaAs substrate cleaning for MBE; surface analysis

MASSIES, J., F. Turco, and J.-P. Contour, "A Chemical Etching Process to Obtain Clean InP (0 0 1) Surfaces," Jpn. J. Appl. Phys., **25**(8), L664–L667 (1986)

$H_2SO_4$:$H_2O_2$:$H_2O$ (2:1:1); InP etch rate = 500 Å/min at 20°C; surface study
HF-ethanol (10%): InP surface cleaning; surface deoxidation etch

MATINE, N., M.W. Dvorak, J.L. Pelouard, F. Pardo, and C.R. Bolognesi, "InP by vertical and lateral wet etching," Proc. 10th Int'l Conf. on Indium Phosphide and Related Materials, p. 195 (1998)

HCl:$H_3PO_4$ room temperature etch rate data for (1:19), (1:9), and (1:4)
HCl:$H_3PO_4$ (1:9); etch rate dependence on temperature; lateral etch behavior at 60°C; Application to self-aligned HBTs

MATSUDA, M., Y. Kotaki, H. Ishikawa, and O. Wada, "Reactively Ion Etched Non-uniform-depth Grating for Advanced DFB Lasers," 3rd Int'l Conf. on Indium Phosphide and Related Materials, Apr 8–11, 1991

Cardiff, Wales, UK, (IEEE Catalog no. 91CH2950-4) pp. 256–59, Reactive ion etch; $C_2H_6$; Application: InP grating photolithography

MATSUI, T., H. Sugimoto, T. Ohishi, Y. Abe, K. Ohtsuka, and H. Ogata, "GaInAsP/InP Lasers with Etched Mirrors by Reactive Ion Etching Using a Mixture of Ethane and Hydrogen.," Appl. Phys. Lett., **54**(13), 1193–94 (1989)

Reactive ion etch; $C_2H_6 + H_2$; Application: InGaAsP/InP lasers; InGaAsP etch rate < InP etch rate; vertical etched edges

MATSUI, T., H. Sugimoto, T. Ohishi, and H. Ogata, "Reactive Ion Etching of III–V Compounds Using $C_2H_6/H_2$," Electron. Lett., **24**(13), 798–800 (1988)

Reactive ion etch; $C_2H_6$:$H_2$; 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 $SiO_2$ mask

MATSUI, Y., H. Hayashi, and K. Yoshida, "Auger Electron Spectroscopy Study of GaAs Layer Growth on InP Substrate," J. Cryst. Growth, **81**, 245–48 (1987)

HCl:$H_2O$ (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

MATSUOKA, T., H. Nagai, Y. Itaya, Y. Noguchi, Y. Suzuki, and T. Ikegami, "CW Operation of DFB-BH GaInAsP/InP Lasers in 1.5 μm Wavelength Region," Electron. Lett., **18**, 27–28 (1982)

1N $K_2Cr_2O_7$:HBr:$CH_3COOH$ (3:1:1); Application: InP (1 0 0) grating etch for BH laser

MATSUOKA, T., H. Nagai, Y. Noguchi, Y. Suzuki, and Y. Kawaguchi, "Effect of the Grating Phase at the Cleaved Facet on DFB Laser Properties," Jpn. J. Appl. Phys., **23**(3), L138–40 (1984)

Ion beam etch with subsequent annealing in $H_2$ for 1 min at 200°C improves etched surface; Application: InGaAsP/InP distributed feedback laser diode

MATSUOKA, T., and H. Nagai, "InP Etchant for Submicron Patterns," J. Electrochem. Soc., **133**(12), 2485–91 (1986)

Saturated Br water: HBr: $H_2O$ (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 $H_2O + Br_2$ concentrations

MATSUOKA, T., K. Takahei, Y. Noguchi, and H. Nagai, "1.5 μm Region InP/GaInAsP Buried Heterostructure Lasers on Semi-Insulating Substrate," Electron. Lett., **17**(1), 12–14 (1981)

$HNO_3$:HBr:$H_2O$ (1:1:5); Application: InGaAsP/InP mesa etch for BH laser cavity

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Review: ion beam milling and sputtering of InP; with summary table of ion beam etching giving etch conditions and etch rates

MATSUSHITA, K., and H.L. Hartnagel, "Laser-Assisted Etching of InP," Properties of Indium Phosphide, EMIS Datareview Series, No. 6 (INSPEC, The Inst. of Elect. Eng., London 1990d), Chapter 15.6, pp. 354–57

Review: laser assisted etching of InP; with summary table of etchants, etch conditions, and etch rates

MATSUSHITA, K., and H.L. Hartnagel, "Plasma Etching of InP," Properties of Indium Phosphide, EMIS Datareview Series, No. 6 (INSPEC, The Inst. of Elect. Eng., London 1990a), Chapter 15.3, pp. 344–45

Review: plasma etching of InP; with table of typical etchants, etch conditions and etch rates

MATSUSHITA, K., and H.L. Hartnagel, "Reactive Ion and Ion-Beam Etching of InP," Properties of Indium Phosphide, EMIS Datareview Series, No. 6 (INSPEC, The Inst. of Elect. Eng., London 1990c), Chapter 15.5, pp. 350–53

Review: reactive ion etching and ion-beam etching of InP; with summary table of etchants, etch conditions, and etch rates

MATSUSHITA, K., N. Suzuki, S. Okuyama, and K. Okuyama, "Hydrophobicity of a hydrochloric-treated GaAs surface analyzed by contact angle measurement," J. Electrochem. Soc., **145**(4), 1381 (1998)

$H_2SO_4$:$H_2O_2$:$H_2O$ (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 $H_2O$ rinse

MATSUSHIMA, Y., K. Sakai, and T. Yamamoto, "Zn-diffused InGaAs/InP Avalanche Photodetector," Appl. Phys. Lett., **35**, 466 (1979)

$H_2SO_4$:$H_2O_2$:$H_2O$ (1:8:1); Application: InGaAs InP mesa etch

MATSUTANI, A., F. Koyama, and K. Iga, "Low bias voltage dry etching of InP by inductively coupled plasma using $SiCl_4$/Ar," Jpn. J. Appl. Phys., Pt. 1, **37**(12a), 6655 (1998)

ICP etch of InP using $SiCl_4$/Ar

MATSUTANI, A., H. Ohtsuki, F. Koyama, and K. Iga, "Vertical and smooth etching of InP by $Cl_2$/Xe inductively coupled plasma," Jpn. J. Appl. Phys., Part 1, **38**(7A), 4260 (1999)

Inductively coupled plasma etch of InP using $Cl_2$/Xe; vertical, smooth patterns

MATZ, R., "Laser Wet Etching of Diffraction Gratings in GaAs for Integrated Optics," J. Lightwave Technol., **LT-4**(7), 726–29 (1986)

$H_2SO_4$:$H_2O_2$:$H_2O$ (1:1:50); photochemical, maskless grating etch; Application: GaAs submicrometer optical gratings

MATZ, R., R. Heydel, and W. Göpel, "In situ Fabrication of InP-Based Optical Waveguides by Excimer Laser Projection," Appl. Phys. Lett., **63**(8), 1137–39 (1993)

$Cl_2$ exposure of InP surface with pattern projection, excimer laser desorption of $InCl_3$: application: waveguide fabrication

MATZ, R., and J. Zirrgiebel, "Fast Photoelectrochemical Etching of Quarter-Micrometer Diffraction Gratings in InP," J. Appl. Phys., **64**(7), 3402–06 (1988)

Photoelectrochemical etch of InP using HCl:$HNO_3$:$H_2O$ (1:1:20) electrolyte; Application: maskless diffraction grating fabrication

MAXIMOV, I., S. Jeppesen, L. Montelius, and L. Samuelson, "Chemical gas etching of InP-based structures," Microectr. Eng., **35**, 87 (1997)

Thermochemical vapor etch of InP structure in $Cl_2$ in a ECR system; optimum temperature of 280°C to minimize surface roughness

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ECR etch of GaAs/InGaP quantum wires using $CH_4/H_2/Ar$; annealing of damage

MAXIMOV, I., Q. Wang, M. Graczyk, P. Omling, L. Samuelson, W. Seifert, I. Shorubalko, K. Hieke, S. Lourdudoss, and E.R. Messmer, "Fabrication and characterization of 0.2–0.6 μm GaInAs/InP electron waveguides," Proc. 11th Int'l Conf. on Indium Phosphide and Related Materials, p. 237 (1999b)

$HCl:CH_3COOH:H_2O_2$ (1:2:2); non-selective etch of InGaAs/InP; rate = 90–130 Å/s at 15°C
SBW/$HBr:HNO_3:H_2O$ (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

MCKEOWN, P.J.A., "Controlled Chemical Etching in the Production of Semiconductor Dice," J. Electrochem. Soc., **109**(2), 269–70 (1962)

$HF:HNO_3:H_2O$; Germanium etch rate dependence on composition

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Magneton RIE plasma etch; $CH_4/H_2/Ar$; GaAs surface damage study; $H_2$ passivation

MCLANE, G.F., W.R. Buchwald, L. Casas, and M.W. Cole, "Magnetron Enhanced Reactive Ion Etching of GaAs in $CH_4/H_2/Ar$: Surface Damage Study," J. Vac. Sci. Technol., A, **12**(4), 1356–59 (1994b)

Magnetron reactive ion etching; $CH_4/H_2/Ar$; GaAs etch damage study

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Magnetron reactive ion etching of GaAs in $CCl_2F_2$ and $SiCl_4$; lower bias voltages than conventional RIE result in less damage

MCLANE, G.F., T. Monahan, D.W. Eckart, S.J. Pearton, and C.R. Abernathy, "Magnetron reactive ion etching of group III-nitride ternary alloys," J. Vac. Sci. Technol., A, **14**(3), 1046 (1996)

Magnetron ion etch; $BCl_3$, $SF_6/BCl_3$, $H_2/BCl_3$, $Ar/BCl_3$; of InGaN and InAlN (reactive ion etch with magnetic field to confine plasma electrons close to the surface)

MCLANE, G.F., M.C. Wood, D.W. Eckart, J.W. Lee, K.N. Leew, S.J. Pearton, and C.R. Abernathy, "Dry etching of InGaP in magnetron enhanced $BCl_3$ plasmas," J. Vac. Sci. Technol., A, **15**(3), 622 (1997)

Reactive ion etch; $BCl_3$ of InGaP; study of etch characteristics

MCNABB, J.W., H.G. Craighead, H. Temkin, and R.A. Logan, "Anisotropic Reactive Ion Etching of InP in Methane/Hydrogen-Based Plasmas," J. Vac. Sci. Technol., B, **9**(6), 3535–37 (1991)

Reactive ion etch; $CH_4/H_2$; InP anisotropic etching

MCNEVEN, S.C., "Rare Gas Ion≡enhanced Etching of InP by $Cl_2$," J. Vac. Sci. Technol., B, **4**(5), 1203–15 (1986a)

Ar ion beam assisted $Cl_2$ etching of InP

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Thermochemical etch; $Cl_2/H_2$ for InP and GaAs; thermodynamic analysis of etching

MEEK, R.L., and Schumaker, "Anodic dissolution and selective etching of gallium phosphide," J. Electrochem. Soc., **119**(9), 1148 (1972)

NaOH (3N); electrolyte for electrochemical etching of GaP; selective removal of p-type material from n-type

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Layer by layer etching of GaAs by $Cl_2$ adsorption followed by UV laser photochemical stripping

MELLIAR-SMITH, C.M., and C.J. Mogab, "Plasma-Assisted Etching Techniques for Pattern Delineation," Thin Film Processes, Ed. J.L. Vossen and W. Kern (Academic Press, N.Y., 1978) pp. 497–556

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Electrochemical dissolution study of GaP in electrolytes of NaOH, $K_3Fe(CN)_6$, $H_2SO_4$

MENEGHINI, G., "Grating Formation by Chemical Etching on AlInAs for MQW Devices," Electron. Lett., **25**(11), 725–26 (1989)

Saturated $Br_2$ water:$H_2O$:$H_3PO_4$ (2:15:5); InAlAs etch rate = 4000 Å/min for photolithography of second-order gratings

HF conc.; pre-etch to remove surface oxides

MENEZES, S., A. Werner, H.J. Lewerenz, F.A. Thiel, P. Lange, M. Fearheiley, C. Morrison, S. Bedair, B. Breithaupt, and K.J. Bachmann, "Photoelectrochemical Behavior of InPAs Alloys in Acidic Electrolytes," J. Electrochem. Soc., **131**(10), 2316–18 (1984)

Acid electrolytes for photochemical disolution and passivation: Application: InAsP for liquid junction solar cells

MERRITT, S.A., and M. Dagenais, "Etch characteristics of succinic acid/ammonia/hydrogen peroxide versus aluminum mole fraction in AlGaAs," J. Electrochem. Soc., **140**(9), L138 (1993)
(succinic acid:$NH_4OH$, pH adjusted over the range 4.9–5.3):$H_2O_2$ (15:1), (25:1) and (50:1). $Al_xGa_{1-x}As$ etch rate versus pH and $x$

MERZ, J.L., and R.A. Logan, "GaAs Double Heterostructure Lasers Fabricated by Wet Chemical Etching," J. Appl. Phys., **47**(8), 3503 (1976)
$CH_3OH$:$H_3PO_4$:$H_2O_2$ (3:1:1); Application: GaAs mesa etch
KI:$I_2$:$H_2O$ (113 g:65 g:100 ml); Au contact and masklayer removal from GaAs
$H_2O_2$:NaOH (1:5); GaAs etch gives rough surface texture
$H_2SO_4$:$H_2O_2$:$H_2O$ (10:15:15); destroys the Au mask layer
$Br_2$/methanol; destroys the Au mask layer

MERZ, J.L., R.A. Logan, and A.M. Sergent, "GaAs Integrated Optical Circuits by Wet Chemical Etching," IEEE J. Quantum Electron., **QE-15**(2), 72–82 (1979)
$NH_4OH$:$H_2O_2$ (1:225) $\{pH = 7\}$; Application: GaAs selective etch from AlGaAs
HF; AlGaAs selective etch from GaAs
KI:$I_2$:$H_2O$ (113 g:65 g:100 ml); Au contact/mask layer etch from GaAs

METZE, G.M., S. McPhilmy, and P. Laux, "The effects of electrochemically-induced etching non-uniformities on microwave field effect transistors," IEEE Electron Device Lett., **16**(1), 23 (1995)
citric acid:$H_2O_2$:$H_2O$ (3:15:150); GaAs gate recess etch for FETs
Electrochemical effects induced by electrical contact materials cause etch rate non-uniformities

MEYER, L.C., J. W. Lee, D. Johnson, M. Huang, F. Ren, T.J. Anderson, J.R. LaRoche, J.R. Lothian, C.R. Abernathy, and S.J. Pearton, "Study of $NH_3$ plasma damage on GaAs Schottky diode in inductively coupled plasma system," J. Electrochem. Soc., **146**(7), 2717 (1999)
Inductively couple plasma etch of GaAs using $NH_3$; damage of Schottky diode

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$HNO_3$ (65%); GaAs oxidation under illumination
$HNO_3$ (without water) vapor etch; GaAs oxidation

MICHEL, C., J.M. Guillot, B. Lepley, N. Dupont-Pavlovsky, and K. Karnicka-Moscicka, "Plasma and Chemical oxides on n-InP: Optical and Electrical characterization," J. Phys. D, **16**, 2229–37 (1983)
Plasma oxidation; $O_2$, $HNO_3$; InP

MICHELITSCH, M., W. Kappallo, and G. Hellbardt, "Reactions of GaAs with Water Vapor and HCl Gas," J. Electrochem. Soc., **111**(11), 1248–53 (1964)
Thermochemical vapor etch; $HCl + H_2 + H_2O$; GaAs

MIKAMI, O., H. Akiya, T. Saitoh, and H. Nakagome, "CW Operation of 1.5 μm Buried Heterostructure Laser with a Reactive-Ion-etched Facet," Electron. Lett., **19**(6), 213–15 (1983)
Reactive ion etch; $CCl_4/O_2$; Application: InGaAsP/InP BH laser facet

MILCH, A., "Etch Polishing of GaP Single Crystals by Aqueous Solutions of Chlorine and Iodine," J. Electrochem. Soc., **123**(8), 1256–58 (1976)
Saturated $Cl_2$ water; GaP etch rate temperature dependence is given; iodine solution etch rates were negligible

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ECR etch; $CH_4/H_2/Ar$ of GaSb and InSb

MILEHAM, J.R., S.J. Pearton, C.R. Abernathy, J.D. MacKensie, R.J. Shul, and S.P. Kilcoyne, "Wet chemical etching of AlN," Appl. Phys. Lett., **67**(8), 1119 (1995)
AZ400K photolithographic developer (KOH active ingredient); AZ400K:$H_2O$ (1:5); AlN selective etch from either GaN or $Al_2O_3$; little undercut at 65°C; significant undercut at 85°C; etching behavior is rate limited

MILLER, B.I., and K. Iga, "GaInAsP/InP Stripe Lasers with Etched Mirrors Fabricated by a Wet Chemical Etch," Appl. Phys. Lett., **37**(4), 339–41 (1980)
$HCl:CH_3COOH:H_2O_2$ (1:2:1) {KKI etch}; Application: InGaAsP/InP laser facet etch

MILLUNCHICK, J.M., L. Hultman, and S.A. Barnett, "Effect of 20–95 eV Ion Bombardment of GaAs(0 0 1): In Pursuit of Damage-Free Ion-Assisted Growth and Etching," J. Vac. Sci. Technol., A, **13**(3), 1155–59 (1995)
In situ Ar sputter etching of GaAs for MBE

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GaAs etch and electrochemical etch mechanism study

MINSKY, M.S., M. White, and E.L. Hu, "Room-temperature photoenhanced wet etching of GaN," Appl. Phys. Lett., **68**(11), 1531 (1996)
HCl:$H_2O$ (1:10); photoelectrochemical etch of GaN; rates of a few hundred Å/min
KOH:$H_2O$ (1:3); photoelectrochemical etch of GaN; rates of several μm/min

MITANI, K., H. Oda, Y. Imamura, and J. Kasai, "Effects of annealing on damage in AlGaAs induced by electron cyclotron resonance $SF_6/CHF_3$ plasma etching," J. Electrochem. Soc., **143**(3), 1151 (1996)
ECR etch; $CF_6/CHF_3$ of AlGaAs; annealing of damage

MITO, I., M. Kitamura, K. Kaede, Y. Odagiri, M. Seki, M. Sugimoto, and M. Kobayashi, "InGaAsP Planar Buried Heterostructure Laser Diode (PBH-LD) with Very Low Threshold Current," Electron. Lett., **18**, 2–3 (1982)
$Br_2$/methanol; Application: InGaAsP/InP non-selective mesa etch for BH laser

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Magnetron ion etching of via holes in GaAs using $SiCl_4$

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Thermochemical vapor etch; $Cl_2$; GaAs selective etch from InAs at 130°C in a MBE chamber

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ECR plasma etch, $Cl_2$/He; Application: InGaAs/AlGaAs HBT structures

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ECR etch; $Cl_2$/He; InGaAs/AlGaAs for HBTS

MIYAMOTO, Y., H. Hirayama, T. Suemasu, Y. Miyake, and S. Arai, "Improvement of regrown interface in InP organo-metallic vapor phase epitaxy," Jpn. J. Appl. Phys. Pt. 2, **30**(4B), L672 (1991)
$(NH_4)_2S_x$ InP surface cleaning for MOVPE regrowth; followed by hydrogen gas anneal at 450°C
HF; InP surface cleaning for MOVPE regrowth; impurities at interface
$H_2SO_4$:$H_2O_2$:$H_2O$ (1:1:40); InP surface cleaning for MOVPE regrowth; impurities at interface

MIYAMOTO, Y., A. Kokubo, T. Hattori, H. Hongo, M. Suhara, and K. Furuya, "25 nm pitch GaInAs/InP buried structure: Improvement by calixarene as an electron beam resist and *tert*-butylphosphine as a P source in organometallic vapor phase epiaxy regrowth," J. Vac. Sci. Technol., B, **16**(6), 3894 (1998)
citric acid:$H_2O_2$:$H_2O$ (20:1:50); InGaAs selective etch from InP; 7 Å/s
HCl:$CH_3COOH$(1:4); selective etch of InP from InGaAs;220 Å/s

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HF:$HNO_3$:$H_2O$ (1:3:4); GaAs first step etch followed by second step A–B etch to reveal growth striations in LEC material

MOCELLA, M.T., “The CFC-Ozone Issue in Dry Etch Process Development,” Solid State Technol., **April**, 63–64 (1991)
Dry etch environmental hazard; $CF_2Cl_2$, $CF_4$, etc

MOON, E.-A., LEE, J.-L., and H.M. Yoo, “Selective wet etching of GaAs on $Al_xGa_{1-x}As$ for AlGaAs/InGaAs/AlGaAs pseudomorphic high electron mobility transistor,” J. Appl. Phys., **84**(7), 3933 (1998)
citric acid:$H_2O_2$:$H_2O$ (1:1.4–6.2:1); selective removal of GaAs from AlGaAs; etch dependence on Al-composition and $H_2O_2$
$H_3PO_4$:$H_2O_2$:$H_2O$ (4:1:180); non-selective etch for GaAs/AlGaAs

MORAN, P.D., D.M. Hansen, R.J. Matyi, J.M. Rewing, and T.F. Kuech, “Realization and characterization of ultrathin GaAs-on-insulator structures,” J. Electrochem. Soc., **146**(9), 3506 (1999)
$NH_4OH$:$H_2O_2$:$H_2O$ (30:1:72 by weight); selective removal of GaAs substrate from $Al_{0.7}Ga_{0.3}As$ etch stop layer
HF:$H_2O$ (1:10); selective removal of $Al_{0.7}Ga_{0.3}As$ etch stop layer from wafer bonded GaAs template layer
$H_2O_2$:$H_2O$ (1:1); 2 min oxidation of GaAs surface features, followed by HCl:$H_2O$ (1:1) 2 min etch removal of oxide

MORGAN, D.V., J. Frey, and W.J. Devlin, “Rectifying and Ohmic Contacts to GaInAsP,” J. Electrochem. Soc., **127**(5), 1202–05 (1980)
$Br_2$/methanol (1%); Application: InGaAsP surface cleaning for Schottky contacts

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$H_2SO_4$:$H_2O_2$:$H_2O$ (5:1:1); InP surface etch prior to OMVPE growth, 2 min at 60°C
$H_3PO_4$:$H_2O_2$;$H_2O$ (3:1:50); InGaAs and InAlAs thinning etch for differential Hall measurement profiles

MORI, Y., and N. Watanabe, “A New Etchant System, $H_3PO_4$–$H_2O_2$–$H_2O$, for GaAs and Its Kinetics,” J. Electrochem. Soc., **125**(9), 1510–14 (1978)
$H_3PO_4$:$H_2O_2$:$H_2O$ (3:1:50); GaAs etch rate = 0.18 μm/min at 24°C
$H_3PO_4$:$H_2O_2$:$H_2O$ (1:9:210); GaAs etch rate = 0.2 μm/min at 24°C
$H_3PO_4$:$H_2O_2$:$H_2O$ (7:3:3); GaAs etch rate = 2 μm/min at 24°C
$H_3PO_4$:$H_2O_2$:$H_2O$ (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

MORIKI, K., K. Iga, M. Uchida, K. Wakao, and T. Kunikane, “1.3 μm Wavelength Mode Controlled GaInAsP/InP Etched Laser,” Electron. Lett., **17**, 559–60 (1981)
HCl:$CH_3COOH$:$H_2O$ (2:6:1); Application: InP channel etch
HCl:$CH_3COOH$:$H_2O$ (1:2:1); InP groove etch

MORIMOTO, Y., "Few Characteristics of Epitaxial GaN: etching and Thermal decomposition," J. Electrochem. Soc., **121**, 1383–84 (1974)

$H_3PO_4$ (85%); GaN etchant at $T = 100$–200°C; gives etch rate and morphology dependence on temperature

MOTTET, S., and L. Henry, "Photochemical Microetching of GaAs," Electron. Lett., **19**(22), 919–920 (1983)

KOH:$H_2O$ (1 and 5%); Photoetch of n-GaAs; no etch without illumination; does not attack AuGe contacts; Application: focused laser beam microetching

HCl:$H_2O$ (1%); Photoetch of GaAs

$H_2SO_4$:$H_2O_2$:$H_2O$ (10:13:250); Photoetch of GaAs

MOUNAIX, P., P. Delobelle, X. Mélique, L. Bornier, and D. Lippens, "Micromachining and mechanical properties of GaInAs/InP microcantilevers," Mater. Sci. Eng. B, **B51**, 258 (1998)

HCl:$H_2O$ (5:1); InP rate ~15 μm/min

HCl:$H_2O$ (1:1); InP rate < 100 Å/min

HCl:$H_2O$ (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

MOUTONNET, D., "Preferential Photoelectrochemical Etching of n-InP," Mater. Lett., **6**(5/6), 183–185 (1988)

$FeCl_3$ (21% diluted); laser scanned photochemical etch for vee-grooves in InP (1 0 0)

MUI, D.S.L., T.A. Strand, B.J. Thibeault, L.A. Coldren, P.M. Petroff, and E.L. Hu, "Characteristics of in situ $Cl_2$ Etched/Regrown GaAs/GaAs Interfaces," J. Vac. Sci. Technol., B, **11**(6), 2266–69 (1993)

Thermochemical $Cl_2$ and Ar ion beam assisted $Cl_2$ in situ etching of GaAs surfaces for MBE GaAs regrowth; surface study

MUKHERJEE, S.D., "Vertical sidewall reactive ion etching (RIE) of GaAs and $Al_xGa_{1-x}As$ ($x = 0.76$) using $BCl_3/CCl_2F_2$/He at equal rates," SPIE Proc., Advanced Processing of Semiconductor Devices, **797**, 110 (1987)

Reactive ion etching; $BCl_3/CCl_2F_2$/He; GaAs and $Al_{0.76}Ga_{0.24}As$ at equal rates; for vertical sidewall etch

MUKHERJEE, S.D., and D.W. Woodard, "Etching and Surface Preparation of GaAs for Device Fabrication," Gallium Arsenide, Ed. M. J. Howes and D.V. Morgan (John Wiley &Sons, Ltd., 1985) Chapter 4, pp. 119–160

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:$H_2O_2$; $H_3PO_4$:$H_2O_2$:$H_2O$; $HN_4OH$:$H_2O_2$:$H_2O$; $H_2SO_4$:$H_2O_2$:$H_2O$; $H_2O$:$AgNO_3$:$CrO_3$:HF {A–B etch}; HCl:$H_2O_2$:$H_2O$

MÜLLER, H., F.H. Eisen, and J.W. Mayer, "Anodic oxidation of GaAs as a technique to evaluate electrical carrier concentration profiles," J. Electrochem. Soc., **122**(5), 651 (1975)

$H_2SO_4$:$H_2O_2$:$H_2O$ (3:1:1); GaAs etch rate ~1000 Å/s at 0°C
*N*-methyacetamide ($CH_3CONHCH_3$); electrolyte for anodization of GaAs

MULLIN, D.P., "Etch study of InGaAs/InP structure in: tartaric acid:$H_2O_2$:$H_2O$ (1:1:10)," (private communication, Naval Ocean Systems Center, San Diego, CA), (1994)
tartaric acid:$H_2O_2$:$H_2O$ (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

MULLIN, J.B., A. Royle, and B.W. Straughan, "The Preparation and Electrical Properties of InP Crystals Grown by Liquid Encapsulation," GaAs and Related Compounds, 1970
(Inst. Phys. Conf. Ser. No. 9, 1971) pp. 41–49, HCl:$HNO_3$:$H_2O$ (1:6:6); Application: InP dislocation etch pit delineation

MURAD, S.K., S.P. Beaumont, M. Holland, and C.D.W. Wilkinson, "Selective reactive ion etching of InGaAs and InP over InAlAs in $SiCl_4$/$SiF_4$/HBr plasmas," J. Vac. Sci. Technol., B, **13**(6), 2344 (1995a)
reactive ion etch; $SiCl_4$/$SiF_4$/HBr; selective etch of InGaAs and InP from InAlAs; pattern etch with masks of $Si_3N_4$ or NiCr

MURAD, S.K., N.I. Cameron, S.P. Beaumont, and C.D.W. Wilkinson, "Effects of $O_2$ addition to $SiCl_4$/$SiF_4$ and the thickness of the capping layer on gate recess etching of GaAs-paseudomorphic high electron mobility transistors," J. Vac. Sci. Technol., B, **14**(6), 3668 (1996a)
reactive ion etch, $SiCl_4$/$SiF_4$; addition of $O_2$ increases selectivity of etching GaAs from AlGaAs

MURAD, S., M. Rahman, N. Johnson, S.P. Beaumont, and C.D.W. Wilkinson, "Dry etching damage in III–V semiconductors," J. Vac. Sci. Technol., B, **14**(6), 3658 (1996b)
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

MURAD, S.K., P.D. Wang, N.I. Cameron, S.P. Beaumont, and C.D.W. Wilkinson, "Damage free and selective RIE of GaAs/AlGaAs in $SiCl_4$/$SiF_4$/ plasma for MESFET and pseudomorphic HEMT's gate recess etching," Microelectron. Eng., **27**, 439 (1995b)
Reactive ion etch; $SiCl_4$/$SiF_4$; for damage free GaAs/AlGaAs MESFETs and HEMTs

MURAD, S.K., C.D.W. Wilkinson, and S.P. Beaumont, "Selective and non-selective RIE of GaAs and AlGaAs in $SiCl_4$ plasma," Microelectron. Eng., **23**, 357 (1994)
Reactive ion etch of GaAs and AlGaAs in $SiCl_4$; conditions for selective and non-selective behavior

MURAD, S.K., C.D. W. Wilkinson, P.D. Wang, W. Parkes, C.M. Sotomayor-Torres, and N. Cameron, "Very Low Damage Etching of GaAs," J. Vac. Sci. Technol., B, **11**(6), 2237–43 (1993)
Reactive ion etch, $SiCl_4$; GaAs with AlGaAs stop layer; GaAs:$Al_{0.3}Ga_{0.7}As$ etch rate ratio is >10,000:1

MUROTANI, T., E. Oomura, H. Higuchi, H. Namizaki, and W. Susaki, "InGaAsP/InP Buried Crescent Laser Emitting at 1.3 μm with Very Low Threshold Current," Electron. Lett., **16**, 566 (1980)
HCl:$H_2O$ (4:1); Application: InP selective etch from InGaAsP

NAGAI, H., Y. Noguchi, K. Takahei, Y. Toyoshima, and G. Iwane, "InP/GaInAsP Buried Heterostructure Lasers of 1.5 μm Region," Jpn. J. Appl. Phys., **19**(4), L218–L220 (1980)
$Br_2$/methanol; Application: InGaAsP/InP stripe and mesa etch for BH laser
HBr:$CH_3COOH$; InP (1 0 0) orientation determination etch

NAGMUNE, Y., S. Tsukamoto, M. Nishioka, and Y. Arakawa, "Growth process and mechanism of nanometer-scale GaAs dot-structures using MOCVD selective growth," J. Cryst. Growth, **126**, 707–717 (1993)
$NH_4OH$(30% aq.):$H_2O_2$(30% aq.) (3:100); AlGaAS on GaAs layer delineation; a few seconds

NAITOH, M., S. Sakai, and M. Umeno, "InGaAsP/InP Schottky Collector Phototransistor," Electron. Lett., **18**(15), 656–57 (1982)
$Br_2$/methanol; Application: InGaAsP surface cleaning for Schottky contact

NAKAJIMA, K., T. Tanahashi, K. Akita, and T. Yamaoka, "Determination of In–Ga–As Phase Diagram at 650°C and LPE Growth of Lattice-matched InGaAs on InP," J. Appl. Phys., **50**, 4975 (1979)
$Br_2$/methanol; Application: InP substrate cleaning for LPE

NAKAMURA, M., S. Katsura, N. Makino, E. Ikeda, K. Suga, and R. Hirano, "Effect of substrate misorientation on tear-drop-like hillock defect densities in InP and GaInAsP grown by MOCVD," J. Cryst. Growth, **129**, 456–64 (1993)
HBr:$H_3PO_4$ (1:2) {Huber etch}; Application; InP and InGaAsP epilayer etch pit defect delineation at room temperature

NARAYANAN, H., (private communication), (1974)
HCl:$H_2O_2$:$H_2O$ (40:4:1); III–V non-preferential thinning for TEM specimens

NARAYAN, S.Y., J.P. Paczkowski, S.T. Jolly, E.P. Bertin, and R.T. Smith, "Growth and Characterization of GaInAsP and GaInAs for Microwave Device," RCA Review, **42**, 491–507 (1981)
$H_2SO_4$:$H_2O_2$:$H_2O$ (5:1:1); InP substrate cleaning, first step
$Br_2$/methanol; InP substrate cleaning, second step
KOH; InP substrate cleaning, 3rd step, followed by DI water rinse

NELSON, A.W., L.D. Westbrook, and E.A.D. White, "Improved LPE technique for Low Theshold Lasers at 1.55 μm in the Quaternary In–Ga–As–P/InP System," J. Cryst. Growth, **58**, 236–242 (1982)

In–Ga–As metal solution; Application: LPE in situ etch of InP for surface cleaning
HCl:$H_2O$ (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)
$Br_2$/methanol; Application: InGaAsP/InP mesa etch

NELSON, R.J., P.D. Wright, P.A. Barnes, R.L. Brown, T. Cella, and R.G. Sobers, "High-output-power InGaAsP (1.3 μm) Stripe-buried Heterostructure Lasers," Appl. Phys. Lett., **36**(5), 358–60 (1980)
$Br_2$/methanol; Application: InP (1 0 0) vee and dovetail groove etch
$H_2SO_4$:$H_2O_2$:$H_2O$ (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 optical reflection," J. Cryst. Growth, **126**, 70–76 (1993)
Thermochemical vapor etch; $AsCl_2 + H_2$ 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 LPE," IEEE J. Quantum Electron., **QE-17**(2), 193–98 (1981)
KOH:$K_3Fe(CN)_6$:$H_2O$; 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 Heterostructure Lasers by LPE and MOCVD," Appl. Phys. Lett., **39**(3), 188–89 (1981)
HCl dilute; Application: InP selective etch from InGaAsP
$H_2SO_4$:$H_2O_2$:$H_2O$ (10:1:1); InGaAs selective etch from InP

NIEHAUS, W.C., and B. Schwartz, "A Self-Limiting Anodic Etch-to-Voltage (AETV) Technique for Fabrication of Modified Read-IMPATTS," Solid-State Electron., **19**, 175–80 (1976)
Anodization; $H_3PO_4$:$H_2O$, pH = 2.6–3.0, electrolyte; GaAs thinning
$NH_4OH$:$H_2O$ (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

NIGGEBRUGGE, U., M. Klug, and G. Garus, "A Novel Process for Reactive Ion Etching on InP, using $CH_4$/$H_2$," GaAs and Related Compounds, 1985 (Inst. Phys. Conf. Ser. No. 79 1986), pp. 367–72

Reactive ion etching; $CH_4/H_2$; InP; deep etching with photoresist and $SiO_2$ masks; near vertical sidewalls and flat bottoms

NISHI, H., M. Yano, Y. Nishitani, Y. Akita, and M. Takusagawa, "Self-Aligned Structure InGaAsP/InP DH Lasers," Appl. Phys. Lett., **35**(3), 232–33 (1979)
$H_2SO_4$:$H_2O_2$:$H_2O$ (5:1:1); Application: InGaAsP selective etch from InP for laser fabrication

NISHIDA, T., and T. Tamamura, "Microloading Effect in InP Wet Etching," J. Electrochem. Soc., **140**(8), 2414–21 (1993)
Saturated bromine water (SBW):HBr:$H_2O$ (1:10:40); Application; grating fabrication; dependence of etch depth on pattern spacing

NISHINAGA, T., P. Ge, C. Huo, J. He, and T. Nakamura, "Melt growth of striation and etch pit free GaSb under microgravity," J. Cryst. Growth, **174**, 96 (1997)
HF:$CH_3COOH$:$KMnO_4$(0.4 M) (1:1:1); Application: striation defect delineation in GaSb after 5.5 min etch
$HNO_3$:HCl:$H_2O$ (1:1:1); Application: etch pit defect delineation in GaSb

NISHIOKA, K., M. Sugiyama, M. Nezuka, Y. Shimogaki, Y. Nakano, K. Tada, and H. Komiyama, "Optimization of electron cyclotron resonance reactive ion beam etching reactors for dry etching of GaAs with $Cl_2$," J. Electrochem. Soc., **144**(9), 3191 (1997)
ECR-RIBE etch; $Cl_2$; GaAs; optimization of etch conditions

NISHITANI, Y., and T. Kotani, "Chemical Etching of InP by $H_2O_2$–$H_2SO_4$–$H_2O$ Solution," J. Electrochem. Soc., **126**(12), 2269–71 (1979)
$H_2SO_4$:$H_2O_2$:$H_2O$ (100:0.92:5); InP surface cleaning prior to $Br_2$/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 $H_2O_2$ concentration

NISHIZAWA, J., Y. Oyama, H. Tadano, K. Inokuchi, and Y. Okuno, "Observations of Defects in LPE GaAs Revealed by New Chemical Etchant," J. Cryst. Growth, **47**, 434–36 (1979)
HF:$H_2O_2$:$H_2O$ (1:1:10); GaAs photoetch dislocation etch pit delineation

NIWA, T., N. Furuhata, and T. Maeda, "Formation of an n-GaAs/n-GaAs regrowth without carrier depletion using electron cyclotron resonance plasma," J. Cryst. Growth, **175/176**, 441 (1997)
ECR etch with hydrogen; GaAs; in situ surface cleaning for MBE regrowth of GaAs

NOONEY, M.G., V. Liberman, and R.M. Martin, "Sulfur layer formation on GaAs(1 0 0) by thermal and photochemical $H_2S$ dissociation," J. Vac. Sci. Technol., A, **13**(4), 1837 (1995)
sulfidization of GaAs; thermal and photoinduced dissociation of $H_2S$

NORDELL, N., and J. Borglind, "Improved InP regrowth properties in metalorganic vapor phase epitaxy by addition of $CCl_4$," Appl. Phys. Lett., **61**(1), 22 (1992a)
Reactive ion etch; $CH_4/H_2/Ar$; Application: mesa etch on InP for MOCVD regrowth

NORDELL, N., J. Borglind, and G. Landgren, "Influence of MOVPE Growth Conditions and $CCl_4$ addition on InP Crystal Shapes," J. Cryst. Growth, **125**, 597–611 (1992b)

Reactive ion etch; $CH_4 + H_2$; Application: InP mesa etch with $SiN_x$ mask

$K_3Fe(CN)_6$:KOH:$H_2O$ (1 g:1 g:16 g); InP/InGaAs layer delineation under illumination

NORDELL, N., and J. Borglind, "MOPVE growth of InP around reactive ion etched mesas," J. Cryst. Growth, **114**, 92 (1991)

Reactive ion etch; $CH_4/H_2$; Application: mesa etch on InP prior to MOCVD regrowth

NORDHEDEN, K.J., D.W. Ferguson, and P.M. Smith, "Reactive Ion Etching of Via Holes for GaAs High Electron Mobility Transistors and Monolithic Microwave Integrated Circuits Using $Cl_2/BCl_3$/Ar Gas Mixtures," J. Vac. Sci. Technol., B, **11**(5), 1879–83 (1993)

Reactive ion etch; $Cl_2/BCl_3$/Ar; Application: GaAs photoresist patterned via holes

NORDHEDEN, K.J., X.D. Hua, Y.S. Lee, L.W. Yang, D.C. Streit, and H.C. Yen, "Smooth and anisotropic reactive ion etching of GaAs slot via holes for monolithic microwave integrated circuits using $Cl_2/BCl_3$/Ar plasmas," J. Vac. Sci. Technol., B, **17**(1), 138 (1999)

Reactive ion etch; $Cl_2/BCl_3$/Ar slot via holes in GaAs

NORDQUIST, P.E.R., R.L. Henry, and R.J. Gorman, "Sequential Etching of GaAs," J. Cryst. Growth, **128**, 483–87 (1993)

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

NOTTEN, P.H.L., Etching of III–V Semiconductors — Electrochemical Approach (Elsevier Advanced Technology, Oxford, 1991)

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)

NOTTEN, P.H.L., "The Etching of InP Solutions; A Chemical Mechanism," J. Electrochem. Soc., **131**(11), 2641–44 (1984)

HCl:$H_2O$; 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 $Br_2$/HBr Solutions and Its Relevance to Etching Behaviour," Appl. Surf. Sci., **28**, 331–44 (1987)

Electrochemical etch study of InP in aqueous bromine solutions; $CH_3COOH$:HBr:$Br_2$; mechanism of p-InP etch rate in dark and under illumination

$Br_2$:HBr:$H_2O$; etch rate is linearly proportional to the $Br_2$ concentration; rate is diffusion limited

NOTTEN, P.H.L., J.J. Kelly, and H.K. Kuihen, "Etching Profiles at Resist Edges: II. Experimental Confirmation of Models Using GaAs," J. Electrochem. Soc., **133**(6), 1226–32 (1986)
GaAs photolithography profiles for: $HCl:H_2O_2:H_2O$ (160:4:1); $HCl:H_2O_2:H_2O$ (80:4:1); 1 M NaOCl:HCl (5:1); 1 M NaOCl in 0.1 M NaOH; 0.1 M $Na_2CO_3$; 0.05 M $K_3Fe(CN)_6$ pH $= 13$; 0.5 M $K_3Fe(CN)_6$ pH $= 13$

NOVÁK, J., M. Morvic, J. Betko, A. Förster, and P. Kordos, "Wet chemical separation of low-temperature GaAs layers from their GaAs substrates," Mater. Sci. Eng. B, **B40**, 58 (1996)
citric acid:$H_2O_2$ (5:1); selective removal of GaAs substrate from a AlAs (or AlGaAs) etch stop layer
$H_2SO_4:H_2O_2:H_2O$ (3:1:1); polishing etch for thinning GaAs
HF, dilute; selective removal of AlAs from GaAs; selectivity $> 10^7$

NOVIKOVA, E.M., G.D. Kusnetsov, and S.A. Ershova, "Plasmachemical Etching of InP by Trichlorotrifluoroethane," Inorg. Mater., **22**(11), 1550–53 (1986)
Plasma etch; $C_2F_3Cl_3$; InP etch study; rate dependence on pressure and temperature

NOVIKOVA, E.M., G.D. Kuznetsov, S.A. Ershova, and M.I. Babaitseva, "Role of Oxygen in Plasmachemical Etching of InP," Inorg. Mater., **21**(8), 1113–15 (1985)
Plasma etch; $C_2F_3Cl_3:O_2$; InP etch study; best results with $C_2F_3Cl_3:O_2$ (7:3)

NOZAWA, H., T. Shibata, and T. Tamamura, "Dry etching of InP using a $CH_3Cl/Ar/H_2$ gas mixture with electron-cyclotron-resonance excitation," J. Vac. Sci. Technol., B, **16**(2), 515 (1998)
ECR plasma etch; $CH_3Cl/Ar/H_2$ of InP; smooth, residue-free surfaces above 120°C

NUESE, C.J., and J.J. Gammon, "Electrolytic Removal of p-type GaAs Substrates from Thin n-type Semiconductor Layers," J. Electrochem. Soc., **117**(8), 1094 (1970)
Electochemical etch; GaAs; NaOH electrolyte; removal of p substrate from n-layer

NUNOYA, N., M. Nakamura, S. Tanaka, H. Yasumoto, I. Fukushi, and S. Arai, "Low damage GaInAsP/InP non-structures by $CH_4/H_2$ reactive ion etching and its application to low threshold gain-coupled DFB lasers," Proc. 11th Int'l Conf. on Indium Phosphide and Related Materials, p. 349 (1999)
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)
Reactive ion etch of $SiO_2$ mask pattern using $CF_4$
$HCl:HNO_3:H_2O$ (1:2:3); step 1, 15 s, RIE damage removal from InGaAsP/InP grooves prior to MOVPE regrowth
$HCl:CH_3COOH$ (1:4); step 2, 5 s, selective RIE damage removal from InP in InGaAsP/InP grooves prior to MOVPE regrowth
$H_2SO_4:H_2O_2:H_2O$ (1:1:40); step 3, 15 s, selective RIE damage removal from InGaAsP in InGaAsP/InP grooves prior to MOVPE regrowth

OCHIAI, Y., M.K. Gamo, and S. Namba, “Maskless Etching of GaAs and InP Using a Scanning Microplasma,” J. Vac. Sci. Technol., B, **1**(4), 1047–49 (1983)
$Cl_2$ focused ion beam etch; GaAs and InP maskless etching

OCHIAI, Y., K. Gamo, S. Namba, K. Shihoyama, A. Masuyama, T. Shiokawa, and K. Toyoda, “Temperature Dependence of Maskless Ion Beam Assisted Etching of InP and Si Using Focused Ion Beam,” J. Vac. Sci. Technol. B, **5**(1), 423–26 (1987)
Ion beam assisted, maskless etch with 35 keV $Ga^+$ focused ion beam in $Cl_2$ gas atmosphere; InP and Si

O’CONNER, P., T.P. Pearsall, K.Y. Cheng, A.Y. Cho, J.C.M. Hwang, and K. Alavi, “InGaAs FETs with Insulator-Assisted Schottky Gates,” IEEE Electron Device Lett., **EDL-3**(3), 64–66 (1982)
Citric acid:$H_2O_2$ (5:1); Application InGaAs etch rate = 1000 Å/min

OE, K., S. Ando, and K. Sugiyama, “Lasing Characteristics of GaInAsP/InP Narrow Stripe Lasers,” J. Appl. Phys., **51**(7), 3541–44 (1980)
HCl:$H_2O$ (4:1); Application: InP selective etch from InGaAsP

OGURA, M., “In situ etching and regrowth process for edge-end surface-emitting laser diodes with an AlGaAs/GaAs buried heterostructure,” J. Vac. Sci. Technol., B, **13**(4), 1529 (1995)
ECR etch; $Cl_2$/Ar; Application: mesa etch on AlGaAs/GaAs prior to MOCVD regrowth
RIE etch; $CF_6$, $SF_6$; Application: mesa etch on AlGaAs/GaAs prior to MOCVD regrowth

OH, T.-H., D.L. Huffaker, L.A. Graham, and H. Deppe, D.G. Deng, “Steam oxidation of GaAs,” Electron. Lett., **32**, 2024 (1996)
Oxidation of GaAs in steam environment at 500–520°C; thickness versus time; patterns using $SiO_2$ mask

OHKUBO, M., “Anodic etching of n-type GaN films in NaOH with Cl ions,” J. Cryst. Growth, **189/190**, 734 (1998)
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

OHKUBO, M., “Photo-assisted anodic etching of GaN films in NaOH electrolyte with Cl ions,” Mater. Sci. Eng., **B59**, 355 (1999)
NaOH (0.1 mol $l^{-1}$): NaCl (0.03 mol $l^{-1}$); electrolyte for photoinduced electrochemical etching of GaN

OHNO, H., and J. Barnard, “Field Effect Transistors,” GaInAsP Alloy Semiconductors, Ed. T.P. Pearsall (John Wiley and Sons, Ltd., Chichester, 1982) Chapter 17, pp. 437–455, 447

$H_3PO_4$:$H_2O_2$:$H_2O$ (1:1:38); Application: InGaAs and InAlAs etch rate = 1000 Å/min at 21.5°C; does not attack InP
$H_3PO_4$:$H_2O_2$:$H_2O$ (1:1:8); InGaAs notch etch for FET; etch rate = 4700 Å/min

OJHA, S.M., R. Turner, J.P. Stagg, D. Boyle, and G.H.B. Thompson, "Monitoring and Control of Fabrication for Integrated Optics Devices," InP and Related Material Conference Proceedings, 1994, (IEEE cat. no. 94CH 3369-6), paper WC3, pp. 351–54
Reactive ion etch; $CH_4$/$H_2$/$CO_2$; Application: InGaAs(P)/InP mesa etch and laser mirror etch
*o*-$H_3PO_4$:$H_2O_2$:$H_2O$ (1:1:8); Application: removal of REI residual InGaAs at bottom corner recesses
*o*-$H_3PO_4$:HCl (3:1); Application: mesa preparation for InP regrowth

OKADA, H., T. Kawanaka, and S. Ohmoto, "The origin of shallow etch pit defects in low dislocation density GaP crystals," J. Appl. Phys., **86**(6), 3015 (1999)
$AgNO_3$ (10 mg):HF (4 ml):$HNO_3$ (6 ml):$H_2O$(8 ml), (RC etchant); etch pit delineation in GaP

OKAMOTO, N., and H. Tanaka, "Etching of GaAs/AlGaAs by bisdimethylaminochlorarsine," J. Vac. Sci. Technol., A, **16**(1), 96 (1998)
bisdimethylaminochlorarsine; thermochemical vapor etch for gas source MBE GaAs surface cleaning

OKU, S., M. Nakao, Y. Shibata, T. Tamamura, and Y. Itaya, "Uniform formation of a quarter-micron period diffraction grating on a 2-in. InP wafer using reactive beam etching," Proc. 9th Int'l Conf. on Indium Phosphide and Related Materials, p. 574 (1997)
Reactive beam etching of InP using $Br_2 + N_2$; fabrication of 250 nm period diffraction grating

OLDHAM, W.G., "Chemical Polishing of GaP," Electrochem. Technol., **3**(1–2), 57–58 (1965)
$Cl_2$/methanol ($Cl_2$-saturated solution): $H_3PO_4$ (1:1); GaP non-preferential chemical polish

OLIVIER, J., J.P. Landesmann, and F. Wyczisk, "Chemical Cleaning Procedures of GaAs (1 0 0) Surfaces Studied by X-ray Photoelectron Spectroscopy," GaAs and Related Compounds, 1990 (Inst. Phys. Conf. Ser. No. 112, 1991) pp. 305–11
GaAs (1 0 0) surface cleaning XPS study: $NH_4OH$:$H_2O_2$:$H_2O$ (10:5:1000); HCl conc.; GaAs (1 0 0) (leaves a nearly stoichiometric surface) HF (50%); GaAs (1 0 0); $H_2SO_4$:$H_2O_2$:$H_2O$ (5:1:1)

OLSEN, G.H., and Ban V., "Use of Thin Carbon Films for Selective Deposition of III–V Semiconductors," Appl. Phys. Lett., **28**, 734–36 (1976)
$H_2SO_4$:$H_2O_2$:$H_2O$ (5:1:1); Application: GaAs surface cleaning for CVD and LPE overgrowth on carbon film masked substrate

OLSEN, G.H., and M. Ettenburg, "Universal Stain/Etchant for Interfaces in III–V Compounds," J. Appl. Phys., **45**(11), 5112–14 (1974)
A–B etch; two part mix for indefinite storage: A solution: $H_2O$:$AgNO_3$:HF (40 ml:0.3 g:40 ml) B solution: $CrO_3$:$H_2O$ (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

OLSEN, G.H., C.J. Nuese, and R.T. Smith, "The Effect of Elastic Strain on Energy Band Gap and Lattice Parameter in III–V Compounds," J. Appl. Phys., **49**(11), 5523 (1978)
$H_2SO_4$:$H_2O_2$:$H_2O$ (5:1:1); Application: GaAs selective etch from InGaP

OLSEN, G.H., and T.J. Zamerowski, "Crystal Growth and Properties of Binary, Ternary and Quaternary (In, Ga) (As, P) Alloys Grown by Hydride Vapor Phase Epitaxy," Progress in Crystal Growth and Characterization, **2**, 309–75 (1979)
$Br_2$/methanol; Application: InGaAsP groove, stripe and channel etch
$HNO_3$; InGaAsP selective etch from InP
A–B etch: layer interface delineation
$H_3PO_4$:HCl (13:5); InP selective etch from InGaAsP
$H_2SO_4$:$H_2O_2$:$H_2O$ (5:1:1); InGaAsP selective etch from InP
0.4N $FeCl_3$ in HCl; InP(1 0 0) orientation determination

OLSEN, G.H., and T.J. Zamerowski, "Vapor-phase Growth of (In, Ga) (As, P) Quaternary Alloys," IEEE J. Quantum Electron., **QE-17**(2), 128–138 (1981)
$Br_2$/methanol; Application: InGaAsP groove, stripe and channel etch
$H_2SO_4$:$H_2O_2$:$H_2O$ (5:1:1); InP surface cleaning following 30 min $Br_2$/methanol (0.7%); followed by (5:1:1). 0.4N FeCl:HCl solution; InP (1 0 0) orientation determination

OLSON, J.M., R.K. Ahrenkiel, D.J. Dunlavy, B. Keyes, and A.E. Kibbler, "Ultralow Recombination Velocity at GaInP/GaAs Heterointerfaces," Appl. Phys. Lett., **55**, 1208 (1989)
$NH_4OH$:$H_2O_2$:$H_2O$ (2:1:10); GaAs substrate cleaning for OMVPE

OLSON, R.J., T.E. Kazior, B. Lane, W.M. Holber, and L. Bourget, "Optimization of a low damage, high resolution etch process for $SiN_x$ in an ECR reactor," J. Electrochem. Soc., **143**(1), 288 (1996)
ECR etch; $CF_4$/$O_2$/Ar; Application: patterning $SiN_x$ films on GaAs

ONO, Y., Y. Iyechika, T. Takada, K. Inui, and T. Matsue, "Reduction of etch pit density on GaN by InGaN-strained SQW," J. Cryst. Growth, **189/190**, 133 (1998)
$H_3PO_4$:$H_2SO_4$ (1:4); GaN defect delineation etch; 230°C for 10 min

OOI, B.S., A.C. Bryce, C.D.W. Wilkinson, and J.H. Marsh, "Study of Reactive Ion Etching-Induced Damage in GaAs/AlGaAs Structures Using a Quantum Well Intermixing Probe," Appl. Phys. Lett., **64**(5), 598–600 (1994)
Reactive ion etch; $C_2F_6$ and $SiCl_4$; damage assessment in GaAs/AlGaAs
$H_2SO_4$:$H_2O_2$:$H_2O$ (1:8:600); GaAs RIE damage removal

OSAKA, F., T. Ishikawa, N. Tanaka, M. López, and I. Matsuyama, "Scanning Tunneling Microscopy of $Cl_2$-gas Etched GaAs (0 0 1) Surfaces using an Ultrahigh Vacuum Sample Transfer System," J. Vac. Sci. Technol., B, **12**(5), 2894–98 (1994)
Thermochemical etch; $Cl_2$; GaAs for MBE in situ surface cleaning

OSAKA, F., K. Nakazima, T. Kaneda, T. Sakarai, and N. Susa, "InP/InGaAsP Avalanche Photodiodes with New Guard Ring Structure," Electron. Lett., **16**, 716–17 (1980)
$H_2SO_4$:$H_2O_2$:$H_2O$ (1:1:1); Application: InP etch at 50°C using $SiO_2$ pattern mask

OSGOOD, R.M. JR., "Laser Microchemistry and Its Application to Electron-device Fabrication," Ann. Rev. Phys. Chem., **34**, 77–101 (1983)
Selective photochemical laser-induced etching of InP and GaAs in $CH_3Br$

OSGOOD, R.M., A. Sanchez-Rubio, D.J. Ehrlich, and V. Daneu, "Localized Laser Etching of Compound Semiconductors in aqueous Solution," Appl. Phys. Lett., **40**(5), 391–93 (1982)
$H_2SO_4$:$H_2O_2$:$H_2O$ (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:$H_2O$ (1:10); GaAs n-type laser-induced etch
HCl:$HNO_3$:$H_2O$ (1:2:30); InP Fe-doped semi-insulating laser-induced etch

OSTERMAYER, F.W., P.A. Kohl, and R.M. Lum, "Hole Transport Equation analysis of Photoelectrochemical etching resolution," J. Appl. Phys., **58**(11), 4390–96 (1985)
Analysis of resolution for light defined patterns in photoelectrochemical etching of InP

OSTERMAYER, F.W., and P.A. Kohl, "Photochemical Etching of p-GaAs," Appl. Phys. Lett., **39**(1), 76–78 (1981)
Photoetch of p-GaAs; 0.1 M $H_2SO_4$:0.1 M NaSCN solution electrolyte; maximum etch *rate* = 1300 Å/min

OSTERMEYER, F.W., P.A. Kohl, and R.H. Burton, "Photochemical Etching of Integral Lenses on InGaAsP/InP LEDs," Appl. Phys. Lett., **43**(7), 642–44 (1983)
InP; light intensity controlled etch to form spherical lenses on n+ nP LED substrates

OTSUBO, M., T. Oda, H. Kumabe, and H. Miki, "Preferential Etching of GaAs Through Photoresist Masks," J. Electrochem. Soc., **123**(5), 676–80 (1976)
$HNO_3$:$H_2O_2$ (1:1); attacks photoresists. $NH_4OH$:$H_2O_2$:$H_2O$; attacks photoresists
$Br_2$/methanol; attacks photoresists
Citric acid:$H_2O_2$ (25:1); GaAs etch rate = 20 Å/s; does not attack photoresists

OTSUKA, N., J.-I. Nishizawa, Y. Oyama, H. Kikuchi, and K. Suto, "Digital etching of InP by intermittent injection of trisdimethylaminophosphorus in ultra high vacuum," J. Electrochem. Soc., **146**(2), 547 (1999)
In situ CBE digital etching of InP for selective epitaxy using trisdimethylaminophosphorus adsorption/desorption at 400°C

OTSUKA, N., Y. Oyama, H. Kikuchi, J.-I. Nishizawa, and K. Suto, "$Cl_2$/Ar and $Cl_2$/$N_2$ gases," Jpn. J. Appl. Phys., Pt. 2, **37**(12b), L1509 (1998)
In situ CBE digital etching of InP for selective epitaxy using *tert*-butylphosphine (TBP) adsorption/desorption at 390°C

OTTE, K., F. Frost, A. Schindler, G. Lippold, V. Gottschalch, R.-H. Flarmeyer, and F. Nibl, "Influence of etching parameters on the defect profile and the depth of damage of AlGaAs-induced by ion beam etching," Microelectronic Engineering, **41/42**, 427 (1999)

Ion beam etch of AlGaAs using nitrogen; etch damage profiles

OU, S.S., "Reactive ion etching of GaSb and GaAlSb using $SiCl_4$," J. Vac. Sci. Technol., B, **14**(5), 3226 (1996)

Reactive ion etch; $SiCl_4$; GaSb and GaAlSb etch study for selective and non-selective etch conditions

OUACHA, A., M. Willander, B. Hammarlind, and R.A. Logan, "Effect of Surface Passivation with SiN on the Electrical Properties of InP/InGaAs Heterojunction Bipolar Transistors," J. Appl. Phys., **74**(9), 5602–05 (1993)

$HCl:H_3PO_4$ (1:10); Application: InP selective etch from InGaAs using SiN mask for HBT fabrication

$H_2SO_4:H_2O_2:H_2O$ (1:1:20); Application: InGaAs selective etch from InP

HF dilute; Application: SiN passivation layer removal from InP

PAK, K., Y. Koide, K. Imai, A. Yoshida, T. Nakamura, Y. Yasuda, and T. Nishinaga, "Vapor-phase Etching of InP Using Anhydrous HCl and $PH_3$ Gas," J. Electrochem. Soc., **133**(10), 2204–05 (1986)

Thermochemical vapor etch; $HCl + H_2 + PH_3$; InP in situ etch for OMVPE

PAN, X., A.N. Broers, and C. Jeynes, "Study of Lithographic Process in Deposited Silicon Dioxide," J. Vac. Sci. Technol., B, **10**(6), 2882–85 (1992)

$HF:HNO_3:H_2O$ (15:10:300) {p-etch (Si)}; Application: patterning of electron beam irradiated $SiO_2$ mask

PANDELISEV, K.A., R.P. Bult, and D. Freschi, "Striation photoetches for semi-insulating GaAs," 6th Conference on Semi-Insulating Materials, Toronto, Canada, 1990, p. 167 (IOP Publishing Ltd, 1990)

$H_2SO_4:H_2O_2:H_2O$ (20:1:1); GaAs striation delineation etch
$H_2SO_4:H_2O_2:H_2O$ (15:1:1); GaAs striation delineation etch
$H_2SO_4:H_2O_2:H_2O$ (8:1:1); GaAs striation delineation etch
AB etch; GaAs striation delineation etch
$AB:H_2O$ (1:5); GaAs striation delineation etch
Diluted Sirtl etch; GaAs striation delineation etch

PANEPUCCI, R., E. Reuter, P. Fay, C. Youtsey, J. Kluender, C. Caneau, J.J. Coleman, S.G. Bishop, and I. Adesida, "Quantum dots fabricated in InP/InGaAs by free $Cl_2$ gas etching and metalorganic chemical vapor deposition regrowth," J. Vac. Sci. Technol., B, **14**(6), 3641 (1996)

chemically assisted Ar ion beam etch with $Cl_2$; InP/InGaAs quantum dots prior to InP MOCVD regrowth

PANEPUCCI, R., C. Youtsey, D.A. Turnbull, S.Q. Gu, C. Caneau, S.G. Bishop, and I. Adesida, "Fabrication of InP/InGaAs quantum wires by free $Cl_2$," J. Vac. Sci. Technol., B, **13**(6), 2752 (1995)

Thermochemical etch; $Cl_2$; InP/InGaAs pattern etching at $\sim 300^\circ C$ for fabricating quantum wires

PANG, S.W., "A comparison between dry etching with an electron cyclotron resonance source and reactive ion etching for GaAs and InP," Mat. Res. Soc. Symp. Proc., **240**, 273 (1992a)
ECR etch; $CCl_2F_2$, $BCl_3$, $Cl_2$; study of GaAs and InP etch characteristics and comparison with RIE

PANG, S.W., and K.K. Ko, "Comparison Between Etching in $Cl_2$ and $BCl_3$ for Compound Semiconductors Using a Multipolar Electron Cyclotron Resonance Source," J. Vac. Sci. Technol., B, **10**(6), 2703–07 (1992b)
ECR plasma; $Cl_2$, $BCl_3$; Study: comparison on GaAs and InP; shows etch rate dependences on microwave power, RF power, sample placement, and temperature

PANG, S.W., Y. Liu, and K.T. Sung, "Etching of GaAs and InP Using Microwave and RF system," J. Vac. Sci. Technol., B, **9**(6), 3530–34 (1991)
Reactive ion etch; $Cl_2$, $CCl_2F_2$; GaAs and InP

PANG, Z., K.C. Song, P. Mascher, and J.G. Simmons, "Sulfur passivation of InP/InGaAs metal–semiconductor–metal photodetectors," J. Electrochem. Soc., **146**(5), 1946 (1999)
Polysulfide solution (50 ml $(NH_4)_2S$, 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
$(NH_4)_2S$ (8.9% S); second step in passivation of InP/InGaAs MSM photodetectors

PANKOVE, J.I., "Electrolytic etching of GaN," J. Electrochem. Soc., **119**(8), 1118 (1972)
NaOH (0.1N) electrolyte for etching GaN

PAPADOPOULO, A.C., C. Dubon-Chevallier, J.F. Bresse, A.M. Duchenois, and F. Heliot, "Etching Procedures of GaAs: Cathodoluminescence Study of the Induced Damages and of Recovering Techniques," J. Vac. Sci. Technol., B, **8**(3), 407–12 (1990)
$H_3PO_4$:$H_2O_2$:$H_2O$ (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

PARK, C.-Y., J.-I. Yoo, C. Park, K.-S. Hyun, D.-K. Oh, Y.H. Lee, C. Lee, and H.-M. Park, "Fabrication of InGaAs/InP Avalanche Photodiodes by Reactive Ion Etching Using $CH_4/H_2$ Gases," J. Vac. Sci. Technol., B, **13**(3), 974–77 (1995)
RIE; $CH_4/H_2$; Application: InGaAs/InP photodiode fabrication

PARK, S. (UCSD), "Chromium etchant," private communication, (1997)
ceric sulfate (saturated solution):$HNO_3$ (9:1); chromium etchant from semiconductor surface
$I_2$:KI:$H_2O$ (56 g:112 g:500 ml); gold etchant from semiconductor surface

PARK, S.-K., C. Lee, and E.K. Kim, "Etching behavior of GaAs/AlGaAs multilayer structure during laser beam scanning," Electron. Mater., **29**(2), 195 (2000)

Thermochemical etching of GaAs/AlGaAs structure using laser-induced etch in $CCl_2F_2$ and $C_2H_2F_4$

PARKER, M. A., R.J. Michalak, J.S. Kimmet, A.R. Pinch, and B.D. Shire, "Etched-surface roughness measurements from an in situ laser refectometer," Appl. Phys. Lett., **69**(10), 1459 (1996)
ECR etch in situ surface roughness measurement with a laser reflectometer

PARMETER, J.E., R.J. Shul, A.J. Howard, and P.A. Millere, "Treatment of InP surfaces in radio frequency $H_2$ and $H_2/CH_4$/Ar plasmas: In situ compositional analysis, etch rates, and surface roughness," J. Vac. Sci. Technol., B, **14**(6), 3563 (1996)
InP surface cleaning in $H_2$ and $H_2/CH_4$/Ar plasmas; removes surface carbon and oxygen but depletes some surface phosphorus

PASSENBERG, W., and W. Schlaak, "Surface preparation for molecular beam epitaxy-regrowth on metalorganic vapor phase epitaxy grown InP and InGaAsP," J. Cryst. Growth, **173**, 266 (1997)
$HF:H_2O_2$ (1:20); InP surface cleaning for MBE regrowth gives high surface defect density
citric acid:$H_2O_2$ (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
$H_2SO_4:H_2O_2:H_2O$ (1:4:50); InP surface cleaning for MBE regrowth; best morphology
UV light/ozone InP surface oxidation; surface cleaning for MBE regrowth

PATRIN, J.C., Y.Z. Li, M. Chander, and J.H. Weaver, "Atomic Layer Etching of GaAs(1 1 0) with $Br_2$ Studied by Scanning Tunneling Microscopy," Appl. Phys. Lett., **62**(11), 1277–79 (1993a)
Thermochemical vapor etch; $Br_2$; GaAs (1 1 0); etching and desorption of etching products above $\sim$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

PAULEAU, Y., A. Bouteville, J.J. Hantzpergue, J.C. Remy, and A. Cachard, "Composition, kinetics, and mechanism of growth of chemical vapor-deposited aluminum nitride films," J. Electrochem. Soc., **129**(5), 1045 (1982)
$H_3PO_4$(85%); AlN dissolution

PEAKE, G.M., S.Z. Sun, and S.D. Hersee, "GaAs microlens arrays grown by shadow masked MOVPE," J. Electro. Mater., **26**(10), 1134 (1997)
$NH_4OH:H_2O_2:H_2O$ (1:1:20); Application: selective pattern etch through GaAs mask layer onto AlGaAs spacer layer
$KI:I_2:H_3PO_4$ (pH $<$ 2); Application: selective AlGaAs etch to transfer and undercut the GaAs mask pattern onto underlying GaAs for shadowed MOVPE regrowth
$HF:H_2O$ (1:10); Application: AlGaAs spacer layer lift-off (10 h) to reveal microlens pattern

PEAKE, G.M., L. Zhang, N.Y. Li, A.M. Saragan, C.G. Willison, R.J. Shul, and S.D. Hersee, "Micromachined, reusable shadow mask for integrated optical elements grow by metalorganic chemical vapor deposition," J. Vac. Sci. Technol., B, **17**(5), 2070 (1999)
$NH_4OH$: $H_2O$ (1:20); oxide removal from GaAs for bonding to Si
$NH_4OH$:$H_2O_2$:$H_2O$ (1:1:20); selective removal of polycrystalline GaAs from Si mask

PEARSALL, T.P., "GaInAs: a Ternary Semiconductor for Photodetector Applications," IEEE J. Quantum Electron., **QE-16**(7), 709–20 (1980)
$Br_2$/methanol (1%); Application: InGaAs mesa etch
$H_2SO_4$:$H_2O_2$:$H_2O$; InGaAs mesa etch

PEARSALL, T.P., and R.W. Hopson, "Growth and Characterization of Lattice-matched Epitaxial Films of GaInAs/InP by LPE," J. Appl. Phys., **48**(10), 4407–09 (1977)
$Br_2$/methanol; Application: InP substrate cleaning for LPE

PEARSALL, T.P., and M. Papuchon, "InGaAs Homojunction Photodiode — A New Avalanche Photodetector in the Near Infrared Between 1.0 and 1.6 μm," Appl. Phys. Lett., **33**(7), 640–42 (1978)
$Br_2$/methanol; Application: InGaAs mesa etch
$H_2SO_4$:$H_2O_2$:$H_2O$ (1:6:10); Application: InGaAs mesa etch at 50°C; etch rate = 20 μm/min

PEARTON, S.J., "Critical Review: High ion density dry etching of compound semiconductors," Mater. Sci. Eng. B, **B40**, 101 (1996d)
Review; high ion density dry etching; ECR; ICP; of GaAs, GaSb, InP, AlGaAs, GaN, InGaN, InGaAs

PEARTON, S.J., "High resolution dry etching of III–V semiconductor materials using magnetically enhanced discharges," Mater. Sci. Eng. B, **27**, 61 (1994f)
ECR etch of InP and GaAs using $Cl_2$, $BCl_3$ and $CH_4$–$H_2$ plasmas

PEARTON, S.J., "Low-Energy, Ion-Enhanced Etching of III–V's for Nanodevice Applications," J. Vac. Sci. Technol., A, **12**(4), 1966–72 (1994a)
ECR etch; $Cl_2/CH_4/H_2$; InGaAsP/InP; small dimension mesas and via holes

PEARTON, S.J., C.R. Abernathy, R.F. Kopf, F. Ren, and W.S. Hobson, "Comparison of Multipolar and Magnetic Mirror Electron Cyclotron Resonance Source for $CH_4/H_2$ Dry Etching of III–V Semiconductors," J. Vac. Sci. Technol., B, **12**(3), 1333–39 (1994b)
ECR etch; $CH_4/H_2$; InP and GaAs; comparison of multipolar and magnetic mirror ECR sources

PEARTON, S.J., C.R. Abernathy, F. Ren, and T.R. Fullowan, "Dry Etching and Inplant Isolation Characteristics of $Al_xGa_{1-x}As$ Grown by Metal Organic Molecular Beam epitaxy," Semicond. Sci. Technol., **6**, 1042–47 (1991a)
ECR plasma etch; $CH_4 + H_2$; AlGaAs

PEARTON, S.J., C.R. Abernathy, F. Ren, J.R. Lothian, P.W. Wisk, A. Katz, and C. Constantine, "Dry Etching of Thin Film InN, AlN and GaN," Semicond. Sci. Technol., **8**, 310–12 (1993a)
ECR plasma etch; $CH_4/H_2$/Ar and $Cl_2/H_2$; InN, AlN and GaN dry etching characteristics

PEARTON, S.J., C.R. Abernathy, and F. Ren, "High Density, Low Temperature dry etching in GaAs and InP Device Technology," J. Vac. Sci. Technol., A, **13**(3), 849–52 (1995a)
ECR etch; study at low temperature; $Cl_2$/Ar, $BCl_3$/Ar for GaAs, AlGaAs, GaSb; $CH_4/H_2$/Ar for InP

PEARTON, S.J., C.R. Abernathy, P.W. Wisk, and F. Ren, "Ion Implantation and Dry Etching Characteristics of InGaAsP (l = 1.3 μm)," J. Appl. Phys., **74**(3), 1610–15 (1993b)
ECR plasma etch; $CH_4/H_2$/Ar; InGaAsP smooth surfaces
ECR plasma etch; $BCl_3$/Ar; InGaAsP; In enriched surfaces for $T < 130°C$

PEARTON, S.J., C.R. Abernathy, R.F. Kopf, and F. Ren, "Low Temperature Chlorine-Based Etching of III–V Semiconductors," J. Electrochem. Soc., **141**(8), 2250–56 (1994c)
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

PEARTON, S.J., C.R. Abernathy, F. Ren, R.J. Shul, S.P. Kilcoyne, M. Haggerott-Crawford, J.C. Zolper, R.G. Wilson, R.G. Schwartz, and J. M. Zavada, "Process development for III–V nitrides," Mater. Sci. Eng. B, **B38**, 138 (1996a)
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

PEARTON, S.J., C.R. Abernathy, and F. Ren, "Selective Area Processing if InGaAsP," InP and Related Material Conference Proceedings, 1994d, (IEEE cat. no. 94CH 3369-6), paper MP31, pp. 194–197
ECR plasma etch; $CH_4/H_2$/Ar; InGaAsP anisotropic dry etch; etch rates are independent of p- and n-doping levels

PEARTON, S.J., U.K. Chakrabarti, E. Lane, A.P. Perley, C.R. Abernathy, W.S. Hobson, and K.S. Jones, "Characteristics of III–V Dry Etching in HBr-based Discharges," J. Electrochem. Soc., **139**(3), 856–64 (1992a)
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

PEARTON, S.J., U.K. Chakrabarti, A.P. Perley, C. Constantine, and D. Johnson, "Degradation-Free Electron Cyclotron Resonance Plasma Etching of InP," Semicond. Sci. Technol., **6**, 929–33 (1991b)
ECR plasma etch; $CH_4 + H_2 + Ar$; InP; addition of $PCl_3$ eliminates surface degradation

PEARTON, S.J., U.K. Chakrabarti, W.S. Hobson, C.R. Abernathy, A. Katz, F. Ren, W.S. Fullowan, and A.P. Perley, "Hydrogen Iodide-Based Dry Etching of GaAs, InP, and Related Compounds," J. Electrochem. Soc., **139**(6), 1763–72 (1992b)

Thermochemical vapor etch; HI/$H_2$/Ar, $CH_4$/$H_2$/Ar; GaAs, InP, InAs, InSb, InGaAs, InAlAs, InAlP

PEARTON, S.J., and W.S. Hobson, "Electron Cyclotron Resonance Microwave Plasma Etching of $In_{0.2}Ga_{0.8}As$–GaAs Quantum Well Laser Structures," Semicond. Sci. Technol., **6**, 948–51 (1991c)
ECR plasma etch; $PCl_3 + Ar$; Application; $In_{0.2}Ga_{0.8}As$–GaAs QW ridge waveguide lasers

PEARTON, S.J., and A. Katz, "Dry etch, integrated processing for micro- and opto-electronics," Microelectron. Eng., **25**, 277 (1994e)
ECR plasma etch; $BCl_3$, $CCl_2F2/O_2$, $SF_6$/Ar, $CH_4$/$H_2$/Ar; processing for GaAs/AlGaAs and InP/InGaAs structures

PEARTON, S.J., A. Katz, and U.K. Chakrabarti, "Effects of $PCl_3$ Addition on ECR $CH_4$/$H_2$/Ar Plasma Etching of InP and InGaAs," 3rd Int'l Conf. on Indium Phosphide and Related Materials, Apr 8–11, 1991d, Cardiff, Wales, UK, (IEEE Catalog no. 91CH2950-4) pp. 252–55
ECR etch; $CH_4$/$H_2$/Ar with $PCl_3$ added; InP and InGaAs

PEARTON, S.J., and R.F. Kopf, "Dry Etch Characteristics of InGaAlAs Alloys in $CCl_2F_2$:Ar and $CH_4$:$H_2$:Ar Discharges," J. Electron. Mater., **20**(7), 535–39 (1991e)
ECR plasma; $CH_4$:$H_2$Ar; $CCl_2F_2$:Ar; InGaAlAs/InP alloys; bias controlled etch selectivity

PEARTON, S.J., Lee. J.W., E.S. Lambers, C.R. Abernathy, W.S. Hobson, F. Ren, and R.J. Shul, "Comparison of dry etching techniques for III–V semiconductors in $CH_4$/$H_2$/Ar Plasmas," J. Electrochem. Soc., **143**(2), 752 (1996b)
ECR plasma etch with $CH_4$/$H_2$/Ar under various conditions for InP/GaP/GaAs/InGaAs/AlGaAs/InGaAsP

PEARTON, S.J., J.W. Lee, J.D. MacKenzie, C.R. Abernathy, and R.J. Shul, "Dry etch damage in InN, InGaN, and InAlN," Appl. Phys. Lett., **67**(16), 2329 (1995b)
ECR and RIE etch damage from Ar plasmas on InN, InGaN, and InAlN

PEARTON, S.J., Lee. J.W., E.S. Lambers, J.R. Mileham, C.R. Abernathy, W.S. Hobson, F. Ren, and R.J. Shul, "High power electron cyclotron resonance etching of III–V semiconductors in $CH_4$/$H_2$/Ar," J. Vac. Sci. Technol., B, **14**(1), 118 (1996c)
ECR high power plasma etch; $CH_4$/$H_2$/Ar; of InP, GaAs, GaP, AlGaAs, InGaAs, InGaAsP

PEARTON, S.J., F. Ren, C.R. Abernathy, W.S. Hobson, T.R. Followan, R. Esagui, and J.R. Lotian, "Damage Introduction in InP and InGaAs During Ar and $H_2$ Plasma Exposure," Appl. Phys. Lett., **61**(5), 586–88 (1992c)
Plasma damage; $H_2$ and Ar; on InGaAs and InP

PEARTON, S.J., F. Ren, C.R. Abernathy, T.R. Fullowan, and J.R. Lothian, "Dry etch damage in GaAs p–n junctions," Mat. Res. Soc. Symp. Proc., **240**, 301 (1992d)
ECR etch damage of GaAs p–n junctions in $O_2$ and $H_2$ discharges

PEARTON, S.J., F. Ren, W.S. Hobson, C.A. Green, and U.K. Chakrabarti, "Dry etching of submicron gratings for InP laser structures — comparison of $HI/H_2$, $CH_4/H_2$ and $C_2H_6/H_2$ plasma chemistries," Semicond. Sci. Technol., **8**, 1217 (1992d)
ECR plasma etch; $HI/H_2$, $CH_4/H_2$ and $C_2H_6/H_2$; InP submicron gratings

PEARTON, S.J., F. Ren, A. Katz, U.K. Chakrabati, E. Lane, W.S. Hobson, R.F. Kopf, C.R. Abernathy, C.S. Wu, D.A. Bohling, and J.C. Ivankovits, "Dry Surface Cleaning of Plasma-Etched High Electron Mobility Transistors," J. Vac. Sci. Technol., B, **11**(3), 546–550 (1993c)
ECR plasma etch; $CCl_2F_2$, $BCl_3/SF_6$, $SiCl_4/SF_6$; GaAs selective etch from AlGaAs or InGaAs; These require removal of residual etch stop surface components: $HF_3$ or $InCl_3$ or $InF_3$
$NH_4OH:H_2O$ with DI water rinse; removal of dry etch residues
ECR plasma; $H_2$; alternative dry etch for removal of residues

PEARTON, S.J., F. Ren, W.S. Hobson, C.R. Anernathy, and U.K. Chakrabarti, "Effects of Wet and Dry Etching and Sulphide Passivation on Surface Recombination Velocities of InGaP p–n Junctions," InP and Related Material Conference Proceedings, 1994c, (IEEE cat. no. 94CH 3369-6), paper MP29, pp. 186–189
$HCl:H_2O$ (1:1); InGaP mesa etch
$H_3PO_4:H_2O_2:H_2O$ (1:1:1); GaAs and AlGaAs mesa etch. ECR etch; $BCl_3/Ar$; GaAs and AlGaAs
ECR etch; $CH_4/H_2/Ar$; InGaP
$(NH_4)_2S_x$; InGaP surface passivation

PEARTON, S.J., F. Ren, J.R. Lothian, T.R. Fullowan, R.F. Kopf, U.K. Chakrabarti, S.P. Hui, A.B. Emerson, and S.S. Pei, "Electron cyclotron resonance plasma processing of GaAs–AlGaAs HEMT structures," Mat. Res. Soc. Symp. Proc., **240**, 293 (1992e)
ECR etch; $CCl_2F_2/O_2$, $CH_4/H_2/Ar$ processing of GaAs/AlGaAs HEMTs

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ECR etch of patterns in GaN; $CH_4/H_2/Ar$

PEARTON, S.J., F. Ren, W.S. Hobson, C.R. Abernathy, R.L. Masaitis, and U.K. Chakrabarti, "Surface Recombination Velocities on Processed InGaP p–n Junctions," Appl. Phys. Lett., **63**(26), 3610–12 (1993c)
$HCl:H_2O$ (1:1); InGaP mesa etch
$H_3PO_4:H_2O_2:H_2O$ (1:1:1); GaAs and AlGaAs mesa etch. ECR etch; $BCl_3/Ar$; GaAs and AlGaAs
ECR etch; $CH_4/H_2/Ar$; InGaP
$(NH_4)_2S_x$; InGaP surface passivation

PEARTON, S.J., F. Ren, W.S. Hobson, C.R. Abernathy, R.L. Masaitis, and U.K. Chakrabarti, "Surface Recombination Velocities on Processed InGaP p–n Junctions," Appl. Phys. Lett., **63**(26), 3610–12 (1993d)
InGaP/GaAs surface recombination study: $HCl:H_2O$ (11:1); Application: InGaP mesa etch
$H_3PO_4:H_2O_2:H_2O$ (1:1:1); Application: GaAs and AlGaAs mesa etch

ECR etch; $CH_4/H_2/Ar$; Application: InGaP mesa etch
ECR etch; $BCl_3/Ar$; Application: GaAs and AlGaAs mesa etch
$(NH_4)_2S_x$; Application: surface passivation of InGaP

PENG, L.-M., J. Jiang, A.Y. Du, and J.X. Zhou, “Application of Reflection Electron Microscopy in Cross-Sectional Study of Multilayer Semiconductor Devices,” J. Vac. Sci. Technol., B, **10**(5), 2293–96 (1992)
$H_3PO_4$:$H_2O_2$:$CH_3OH$ (2:1:1); Application: AlGaAs/GaAs mesa etch; near identical etch rates for GaAs and $Al_xGa_{1-x}As$ for $x < 0.33$

PENNER, B., M. Oallahi, and O. Nordman, “Electron cyclotron resonance reactive ion etching of GaAs in chlorine–methane,” Microelectronic Engineering, **41/42**, 383 (1999)
ECR etch of GaAs using $Cl_2/CH_4$

PEREIRA, R.G., M. de Potter, and M. Van Rossum, “Influence of $CH_4/H_2$ reactive ion etching on the deep levels of Si-doped $Al_xGa_{1-x}As$ ($x = 0.25$),” J. Vac. Sci. Technol., B, **14**(3), 1773 (1996a)
Reactive ion etch damage; $CH_4/H_2$; in $Al_{0.25}Ga_{0.75}As$; traps

PEREIRA, R., M. Van Hove, W. de Raedt, C. Van Hoof, G. Borghs, and M. Van Rossum, “Damage introduced by $CH_4/H_2$ reactive ion etching in pseudomorphic AlGaAs/InGaAs MODFETs,” Mat. Res. Soc. Symp. Proc., **240**, 361 (1992)
Reactive ion etch; $CH_4/H_2/Ar$; damage in AlGaAs/InGaAs MODFET structures

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Reactive ion etch damage; $CH_4/H_2$ of $Al_{0.25}Ga_{0.75}As$; effect on transport properties

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Pulsed UV laser assisted oxidation and oxide desorption of GaSb

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Oxide desorption from GaSb using pulsed UV laser

PETIT, E.J., and F. Houzay, “Optimal Surface Cleaning of GaAs (0 0 1) with Atomic Hydrogen,” J. Vac. Sci. Technol., B, **12**(2), 547–550 (1994)
Atomic H oxide reduction on GaAs surfaces
$H_2SO_4$:$H_2O_2$:$H_2O$ (4:1:1) GaAs surface preclean prior to H oxide reduction

PETIT, P., P. Legay, G. Le Roux, G. Patriarche, G. Post, and M. Quillec, "Controlled steam oxidation of AlInAs for microelectronics and optoelectronics applications," J. Electron. Mater., **26**(12), L32 (1997)
$H_2O$, thermal oxidation of AlInAs

PEYRE, J.L., E. Gaumont, C. Laborie, A. Pinquier, Ph Jarry, and J.L. Gentner, "$CH_4/H_2/N_2$ reactive ion beam etching for InP-based photonic devices," Proc., 1996 Indium Phosphide and Related Materials Conference, p. 125 (1996)
RIBE of InP using $CH_4/H_2/N_2$; etch study

PEYRE, J.L., C. Vannier, D. Riviere, and G. Villela, "Excimer Laser-Assisted Etching of Solids for Microelectronics," Laser Assisted Processing (1988), SPIE Vol. **1022**, pp. 145–52
Excimer laser-assisted etch; $CH_3Br$ or $CF_3Br$ at 193 or 248 nm wavelength; InP, Si, Al; Application: InP/InGaAs avalanche photodiodes

PHATAK, S.B., and G. Kelner, "Material Selective Chemical Etching in the System InGaAsP/InP," J. Electrochem. Soc., **126**(2), 287–92 (1979)
$HCl:H_3PO_4$ (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
$HNO_3$ reacts little with arsenides but has no effect on InP. $H_3PO_4$ does not attack GaAs

PING, A.T., Q. Chen, J.W. Yang, M. Asif Khan, and I. Adesida, "The effects of reactive ion etching-induced damage on the characteristics of Ohmic contacts to n-type GaN," J. Electron. Mater., **27**(4), 261 (1998)
RIE plasma etch; $SiCl_4$, Ar of n-GaN; damage effects on Ohmic contacts

PING, A.T., M.A. Khan, and I. Adesida, "Dry etching of $Al_xGa_{1-x}N$ using chemically assisted ion beam etching," Semicond. Sci. Technol., **12**, 133 (1997)
Chemically assisted ion beam etch; $Ar/Cl_2$ of AlGaN

PING, A.T., A.C. Schmitz, M. Asif Khan, and I. Adesida, "Dry etching of GaN using chemically assisted ion beam etching with HCl and $H_2/Cl_2$," J. Electron. Mater., **25**(5), 825 (1996)
CAIBE etching of GaN; with HCl and $H_2/Cl_2$

PLASKETT, T.S., and A.H. Parsons, "Detection of Striae in GaAs by Chemical etching," J. Electrochem. Soc., **112**(9), 954–55 (1965)
$HNO_3:HF:H_2O$ (3:1:4); GaAs delineation of growth striae; 2 min at 20°C

PLAUGER, L.R., "Controlled chemical etching of GaP," J. Electrochem. Soc., **121**(3), 455 (1974)
$KOH:K_3Fe(CN)_6$; etch for GaP; etch rate dependence on solution concentrations and temperature

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PLIETH, W.J., G. Pfuhl, A. Felske, and W. Badawy, "Photoetching of III/V Semiconductors," Electrochim. Acta, **34**, 1133–40 (1989)

$H_2SO_4$:$H_2O_2$:$H_2O$; photoelectrochemical etch electrolyte for n- and p-GaAs; etch study

PODLESNIK, D.V., H.H. Gilgen, and R.M. Osgood, "Deep-Ultraviolet Induced Wet Etching of GaAs," Appl. Phys. Lett., **45**(5), 563–65 (1984)

GaAs; UV illuminated etch for deep features, via holes, etc.; higher etch rates than for visible light

| | UV etch rates at 10 W/cm$^2$ (μm/min) | | |
|---|---|---|---|
| | n-type | Si-type | p-type |
| $H_2SO_4$:$H_2O_2$:$H_2O$ (1:1:100) | 18 | 13 | 0.8 |
| $HNO_3$:$H_2O$ (1:20) | 12 | 10 | 1.0 |
| KOH:$H_2O$ (1:20) | 8 | 6 | 0.5 |

PODLESNIK, D.V., H.H. Gilgen, A. Sanchez, and R. Osgood, "Maskless, Chemical Etching of Submicrometer Gratings in Single Crystalline GaAs," Appl. Phys. Lett., **43**(12), 1083–85 (1983)

$H_2SO_4$:$H_2O_2$:$H_2O$ (1:1:100); GaAs laser-enhanced maskless grating etch

PODLESNIK, D.V., H.H. Gilgen, and R.M. Osgood, "Waveguiding Effects in Laser-Induced Aqueous Etching of Semiconductors," Appl. Phys. Lett., **48**(7), 496–498 (1986)

$HNO_3$:$H_2O$ (1:20); Photoetching of deep features in GaAs; role of optical waveguiding

POOLE, P.J., R.L. Williams, C. Lacelle, V. Gupta, J.W. Fraser, B. Lamontagne, and M. Bubhanan, "Patterned substrate overgrowth for optoelectronic device integration using chemical beam epitaxy (CBE)," J. Cryst. Growth, **201/202**, 578 (1999)

Plasma etch of patterns in $SiO_2$ mask on InP using $CHF_3$/$O_2$

CAIBE etch of undercut stripe in InP using $Cl_2$/Ar with tilted sample

PORKOLAB, G.A., Y.J. Chen, S.A. Merrit, S.A. Tabatabaei, S. Agarwala, F.G. Johnson, O. King, M. Dagenais, R.A. Wilson, and D.R. Stone, "Dark-current reduction that preserves lateral dimensions of reactive ion etched $Ga_{0.47}In_{0.53}As$ p–n diode photodetectors," IEEE Photon. Technol. Lett., **9**(4), 490 (1997)InGaAs/InP photodiode surface passivation:

First step: place device wafer in OCG OPD 4262 positive photoresist developer

Second step: mix 2-propanol: $H_2SO_4$ (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

PRASAD, M., H.E. Ruda, and J.J. Dubowski, "Surface modification of InP by diffraction-patterning utilizing laser dry etching," J. Vac. Sci. Technol., B, **15**(6), 2046 (1997)

Laser assisted dry etching of InP using $Cl_2$ for diffraction patterned periodic structures

PRASEUTH, J.P., B. Descouts, and Y. LeBellegie, "MBE Overgrowth of GaInAs on Si-implanted InP Substrates," GaAs and Related Compounds, 1990 (Inst. Phys. Conf. Ser. No. 112 1991), pp. 105–10, 105–10

$H_2SO_4$:$H_2O_2$:$H_2O$ (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

PRINCE, F.C., N.B. Patel, and D.J. Bull, "InP–InGaAsP Embedded Mesa Stripe Lasers," IEEE J. Quantum Electron., **QE-16**(10), 1034–38 (1980)

Saturated $Br_2$ water: $H_3PO_4$: $H_2O$ (2:1:15); Application: InGaAsP and InP vee-groove grating etch; does not attack photoresists

$H_2O$:$H_2O_2$:HF (8:3:2) to remove $SiO_2$ mask and In droplets from first LPE step

PROPST, E.K., K.W. Vogt, and P.A. Kohl, "Photoelectrochemical Etching of GaSb," J. Electrochem. Soc., **140**(12), 3631–35 (1993)

Photochemical etching of n-GaSb; NaOH and HCl electrolytes; aerated solution to oxidize Sb; matte gray, faceted surface

QIAN, Y.H., M. Owen, A.C. Bryce, J.H. Marsh, C.D.W. Wilkinson, R.V. Penty, I.H. White, S. Perrin, D. Rogers, and M. Robertson, "Process development on the monolithic fabrication of an ultra-compact 4 × 4 optical switch matrix on InP/InGaAsP material," Proc. 11th Int'l Conf. on Indium Phosphide and Related Materials, p. 103 (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

Reactive ion etch using $SF_6$ for Ti mask patterning and mask removal from InP/InGaAsP

HF:$H_2O$ (1:4); Ti/SiN mask removal from InP/InGaAsP

QUI, B.C., B.S. Ooi, A.C. Bryce, S.E. Hicks, C.D.W. Wilkinson, R.M. De La Rue, and J.H. Marsh, "Low damage reactive ion etching process for fabrication of ridge waveguide lasers," Proc. 9th Int'l Conf. on Indium Phosphide and Related Materials, p. 578 (1997)

Reactive ion etch using $CH_4/H_2$ for InGaAs/InGaAsP ridge waveguide laser fabrication; damage profile

QUI, B.C., B.S. Ooi, A.C. Bryce, S.E. Hicks, C.D.W. Wilkinson, R.M. De La Rue, and J.H. Marsh, "Reduced damage reactive ion etching process for fabrication of InGaAsP/InGaAs multiple quantum well ridgeguide lasers," J. Vac. Sci. Technol., B, **16**(4), 1818 (1998)

Reactive ion etch; $CH_4/H_2$; of InGaAsP/InGaAs lasers; low etch damage with low etch power and post etch anneal

QUINLAN, K.P., "The mechanism of the photoelectrochemical etching of p-InP in nitric acid solutions," J. Electrochem. Soc., **144**(10), 3469 (1997)

$HNO_3$; photoelectrochemical etching of p-InP; dependence on carrier concentrations and etch pit densities; study of photoetch mechanism

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$HNO_3$:$H_2O$; study of photoelectrochemical etching of p-InP; dependence on light intensity, $HNO_3$ concentration, and potential

QUINLAN, K.P., and T.E. Erstfeld, “Formation of a Limiting Composition of $Ga_xIn_{1-x}As$ in the VPE-hydride Technique Using a Continuous Hydrogen Chloride Etch,” J. Cryst. Growth, **71**, 246–48 (1985)
Thermochemical vapor etch, HCl in VPE-hydride growth; InGaAs

QUINLAN, K.P., A.K. Rai, and T.N. Wittberg, “Study of the Oxidation of n-InP with Low Carrier Concentrations in the Negative Potential Region,” J. Electrochem. Soc., **141**(5), 1161–66 (1994)
KOH (0.1 M), electrolyte for anodic oxidation of n-InP

QUINLAN, K.P., “A study of hydrogen evolution at irradiated p-InP electrodes in nitric acid solution,” J. Electrochem. Soc., **146**(12), 4514 (1999)
$HNO_3$ (12 M)
$HNO_3$ (12 M):sulfamic acid (0.1 M); p-InP etch mechanism study

RAHMAN, M., N.P. Johnson, M.A. Foad, A.R. Long, M.C. Holland, and D.W. Wilkinson, “Model for Conductance in Dry-Etch Damaged n-GaAs Structures,” Appl. Phys. Lett., **61**(19), 2335–37 (1992)
Plasma etch damage modeling; GaAs

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Review: Photochemical processing of semiconductors

RAUH, R.D., and LeLievre, “Microphotoelectrochemical Etching of n-GaAs Using a Scanned Focused Laser,” J. Electrochem. Soc., **132**, 2811–12 (1985)
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, “$Ga_{0.51}In_{0.49}P/Ga_xIn_{1-x}As$ lattice-matched ($x = 1$) and Strained ($x = 0.85$) Two-Dimensional Electron Gas Field-effect Transistors,” Semicond. Sci. Technol., **6**, 103–07 (1991)
$NH_4OH$:$H_2O_2$:$H_2O$ (10:4:500); Application: GaAs selective etch from InGaP for FET fabrication
$H_3PO_4$:HCl (1:1); InGaP selective etch from GaAs

READER, P.D., and H.R. Kaufman, “Optimization of an Electron-Bombardment Ion Source for Ion Machining Applications,” J. Vac. Sci. Technol., **12**(6), 1344–47 (1975)
Low energy $Ar^+$ ion sputter etching of Si

REBEY, A., A. Bchetnia, and B. El Jani, “Etching of GaAs by $CCl_4$ and $VCl_4$ in a metalorganic vapor-phase epitaxy reactor,” J. Cryst. Growth, **194**, 286 (1998)

Thermochemical vapor etch; $CCl_4$; GaAs in situ pregrowth etch for OMVPE

Thermochemical vapor etch; $VCl_4$; GaAs in situ pregrowth etch for OMVPE

REED, J.D., Y.-P. Chen, E.S. Tentarelli, W.J. Schaff, and L.F. Eastman, “Size-Dependent Photoluminescence Energy and Intensity of Selective Electron Cyclotron Resonance-Etched Strained InGaAs/GaAs Quantum Boxes,” J. Vac. Sci. Technol., B, **13**(3), 995–999 (1995)

ECR etch; $Cl_2$; GaAs selective removal from InGaAs; indium chloride by-products stop etching of InGaAs at room temperature

citric acid:$H_2O$ (1 g of anhydrous citric acid to 1 ml water); Application: InGaAs selective removal from GaAs; GaAs 40 Å/min; $In_{0.2}Ga_{0.8}As$ 751 Å/min

$NH_4OH$:$H_2O$ (1:18); GaAs surface oxide removal prior to MBE overgrowth

REN, F., A.Y. Cho, J.M. Kuo, S.J. Pearton, J.R. Lothian, D.L. Sivco, R. G. Wilson, and Y.K. Chen, “Dopant passivation occurring during electron cyclotron resonance (ECR) $CH_4/H_2$ dry etching of InGaAs/AlInAs HEMTs,” Electron. Lett., **31**(5), 406 (1995a)

ECR etch; $CH_4/H_2$; InGaAs/InAlAs HEMT structures; excessive $H_2$ flux causes donor passivation

REN, F., W.S. Hobson, J.R. Lothian, J. Lopata, S.J. Pearton, J.A. Caballero, and M.W. Cole, “Extremely high etch rates of In-based III–V semiconductors in $BCl_3/N_2$-based plasma,” J. Electrochem. Soc., **143**(10), 3394 (1996a)

ECR etch; $BCl_3/N_2$ of InGaP/GaAs structures and InP

REN, F., J.W. Lee, C.R. Abernathy, S.J. Pearton, C. Constantine, C. Barratt, and R.J. Shul, “Dry etch damage in GaAs metal–semiconductor field-effect transistors exposed to inductively coupled plasma and electron cyclotron resonance Ar plasmas,” J. Vac. Sci. Technol., B, **15**(4), 983 (1997a)

inductively coupled Ar plasma; GaAs; FET device degradation study. ECR Ar plasma; GaAs; FET device degradation study

REN, F., J.R. Lothian, J.M. Kuo, W.S. Hobson, J. Lopata, J.A. Caballero, S.J. Pearton, and M.W. Cole, “$BCl_3/N_2$ dry etching of InP, InAlP and InGaP,” J. Vac. Sci. Technol., B, **14**(3), 1758 (1996b)

ECR etch; $BCl_3/N_2$; etch study of InP, InAlP, and InGaP

REN, F., J.R. Lothian, Y.K. Chen, J.D. MacKenzie, S.M. Donovan, C.B. Vartuli, C.R. Abernathy, J.W. Lee, and S.J. Pearton, “Effect of $BCl_3$ dry etching on InAlN surface properties,” J. Electrochem. Soc., **143**(9), L217 (1996c)

ECR etch; $BCl_3$, $BCl_3$/Ar, $BCl_3/N_2$; InAlN surface damage

REN, F., J.R. Lothian, S.J. Pearton, C.R. Abernathy, C.B. Vartuli, J.D. Mackenzie, R.G. Wilson, and R.F. Karlicek, “Effect of dry etching on surface properties of III-nitrides,” J. Electron. Mater., **26**(11), 1287 (1997b)

ECR plasma etch; $BCl_3$, $BCl_3$/Ar, $BCl_3/N_2$; of an InAlN and GaN FET structure

Surface N loss produces poor rectifying gate contacts for metals deposited on etched surfaces

REN, F., J.R. Lothian, S.J. Pearton, C.R. Abernathy, P.W. Wisk, T.R. Fullowan, B. Tseng, S.N.G. Chu, Y.K. Chen, L.W. Yang, S.T. Fu, R.S. Brozovich, H.H. Lin, C.L. Henning, and T. Henry, ''Fabrication of Self-Aligned GaAs/AlGaAs Microwave Power Heterojunction Bipolar Transistors,'' J. Vac. Sci. Technol., B, **12**(5), 2916–28 (1994)

$NH_4OH$:$H_2O$ (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: $CCl_2F_2$; GaAs mesa etch

$H_3PO_4$:HCl:$H_2O$; Application; InGaP selective etch from GaAs; selectivity dependence on composition

$K_2Cr_2O_7$:$H_3PO_4$:$H_2O$; Application: AlGaAs selective etch from GaAs

REN, F., S.J. Pearton, D.M. Tennant, D.J. Resnick, C.R. Abernathy, R.F. Kopf, C.S. Wu, M. Hu, C.K. Pao, B.M. Paine, D.C. Wang, and C.P. Wen, ''Dry Etching Bilayer and Trilevel Resist Systems for Submicron Gate Length GaAs-Based High Electron Mobility Transistors for Power and Digital Applications,'' J. Vac. Sci. Technol., B, **10**(6), 2949–53 (1992a)

ECR plasma; $CCl_2F_2$; Application: GaAs selective etch from AlGaAs; selectivity $> 200$

REN, F., S.J. Pearton, B. Tseng, J.R. Lothian, and B.P. Segner, ''Formation of Narrow, Dry-Etched Mesas for Long Wavelength InP–InGaAsP Lasers,'' J. Electrochem. Soc., **140**(11), 3284–89 (1993)

ECR etch; $Cl_2/CH_4/H_2/Ar$; InP/InGaAsP mesa etch at $\sim 150°C$; fast without mask narrowing

REN, F., S.J. Pearton, T.R. Fullowan, W.S. Hobson, S.N.G. Chu, and A.B. Emerson, ''Improvement of Ohmic contacts on GaAs with in situ cleaning,'' Mat. Res. Soc. Symp. Proc., **240**, 417 (1992c)

In situ Ar ion milling to remove oxide from GaAs prior to Ge/Ni/Au–Ge/Mo contact deposition to improve Ohmic contact

REN, F., S.J. Pearton, R.J. Shul, and J. Han, ''Improved sidewall morphology on dry-etched $SiO_2$ masked GaN features,'' J. Electron. Mater., **27**(4), 175 (1998)

ECR and ICP etch of $SiO_2$ patterned GaN; $SF_6$/Ar and $CF_4/O_2$

REN, F., S.J. Pearton, C.R. Abernathy, and J.R. Lothian, ''Nanoscale Structures in III–V Semiconductors Using Sidewall Masking and High Ion Density Dry Etching,'' J. Vac. Sci. Technol., A, **13**(3), 753–757 (1995b)

ECR etch; $CH_4/H_2/Ar$; InGaAsP; Application: quantum well etch dimensions

ECR etch; $BCl_3$/Ar; GaN; Application: quantum well etch dimensions

REN, F., S.J. Pearton, J.R. Lothian, C.R. Abernathy, and W.S. Hobson, ''Reduction of Sidewall Roughness During Dry Etching of $SiO_2$,'' J. Vac. Sci. Technol., B, **10**(6), 2407–11 (1992b)

ECR plasma; Study: $SiO_2$ mask etch on GaAs and InP; $SF_6$ gives superior $SiO_2$ sidewall smoothness than $CF_4$

REYNOLDS, C.L., S.E. Lengle, R.E. Ahrens, and S.M. Parker, ''Inhibition of Etching in Oxygen-Implanted AlGaAs,'' Appl. Phys. Lett., **61**(9), 1090–91 (1992)

AlGaAs etch inhibition by oxygen implantation

REZEK, E.A., R. Chin, N. Holonyak, S.W. Kirchoefer, and R.M. Kolbas, “Quantum-Well InP-InGaPAs Heterostructure Lasers Grown by LPE,” J. Electron. Mater., **9**(1), 1–27 (1980)

$Br_2$/methanol (1%); Application: InP substrate cleaning for LPE

Indium metal in situ etch surface cleaning prior to LPE layer growth

$KOH:K_3Fe(CN)_6:H_2O$ (6 g:4 g:50 ml); Application: InGaAsP/InP cleaved cross-section layer delineation; ~5 s at 20°C

RIBAS, R.P., J.L. Leclercq, J.M. Karam, B. Courtois, and P. Viktorovitch, “Bulk micromachining characteristics of 0.2 μm HEMT MMIC technology for GaAs MEMS design,” Mater. Sci. Eng. B, **B51**, 267 (1998)

$NH_4OH:H_2O_2$ (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

$NH_4OH:H_2O_2$ (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:$NH_4OH$):$H_2O_2$ (15:1); Application: selective removal of GaAs from AlGaAs etch stop layer for micromachining; very slow lateral etch rate. citric acid:$H_2O_2$ (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

$H_2SO_4:H_2O_2:H_2O$ (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

$H_2SO_4:H_2O_2:H_2O$ (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

$H_3PO_4:H_2O_2:H_2O$ (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

$NH_4OH:H_2O_2:H_2O$ (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

$NH_4OH:H_2O_2:H_2O$ (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

RICHARDS, J.L., and A.J. Crocker, “Etch Pits in GaAs,” J. Appl. Phys., **31**, 611–12 (1960)

$AgNO_3:HF:HNO_3:H_2O$ (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

RIDEOUT, V.L., “An Improved Polishing Technique for GaAs,” J. Electrochem. Soc., **119**(12), 1778–79 (1972)

$NaOCl:H_2O$ (1:20); GaAs chemi-mechanical polishing solution

RIM, A., and R. Beserman, “Oxidation Processes in Undoped GaAs and Si-Doped GaAs,” J. Appl. Phys., **74**(2), 897–901 (1993)

Thermal oxidation of GaAs; effects of temperature and doping; studied with Raman scattering, AES, and ellipsometry

RISHTON, S.A., Y.H. Lee, K.R. Milkove, J.M. Hong, V. Boegli, M. DeFranza, U. Sivan, and D.P. Kern, "Integrated Approach to Quantum Dot Fabrication," J. Vac. Sci. Technol., B, **11**(6), 2607–11 (1993)

ECR plasma etch; $CCl_2F_2$/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

RITTENHOUSE, G.E., K. Early, B.S. Meyerson, H.I. Smith, and J.M. Graybeal, "Novel Vertical Silicon-Membrane Structure and its Application to Josephson Devices," J. Vac. Sci. Technol., B, **10**(6), 2860–63 (1992)

KOH (40%) at 60°C and ethylenediamine-pyrocatechol: Application: Si selective etch from B-doped $> 1 \times 10^{20}$ $cm^{-3}$ Si layers
$HF:H_2O$ (1:50); $Si_3N_4$ removal
$NH_4OH:H_2O_2$ Si surface cleaning

RIVERA, T., A. Izraël, R. Azoulay, R. Kuszelewicz, J.F. Bresse, J.L. Oudar, and F.R. Ladan, "Fabrication of All-Optical Quantum Well Bistable Microresonators by Reactive Ion Etching," J. Vac. Sci. Technol., B, **13**(2), 268–72 (1995)

Reactive Ion Etch; $SiCl_4$ gas; Application: patterned etch with $Si_3N_4$ mask on GaAs, AlGaAs, AlAs; vertical sidewalls

ROBACH, Y., M. Phaner, C. de Villeneuve, and L. Porte, "Evaluation of Surface Roughness of Technological InP Substrates by in situ Scanning Tunneling Microscopy Imaging in $H_2SO_4$ solution," Appl. Phys. Lett., **61**(21), 2551–53 (1992)

$H_2SO_4$ (0.25 M); oxide-free interface for STM surface imaging
$HNO_3$ InP oxidation; 200 Å under illumination; then: HF oxide dissolution

ROBERTS, D.A., M.A. Pate, and P.A. Claxton, "Reactive Ion Etched InP/GaInAs Multiple Quantum Well Rib Waveguides Grown by Solid Source MBE," Electron. Lett., **24**(22), 1395–96 (1988)

Reactive ion etch; $CH_4 + H_2$; Application: InGaAs/InP MQW rib waveguide; 10 vol.% $CH_4$ in $H_2$ plasma at RF power of 100 W (0.44 $W/cm^2$) at 13.56 MHz; 30°C table temperature, 6–7 sccm $CH_4$ and 60 sccm $H_2$, 37 mTorr chamber pressure and 290 V bias voltage

RODE, D.L., B. Schwartz, and J.V. DiLorenzo, "Electolytic Etching and Electron Mobility of GaAs for FET's," Solid-State Electron., **17**, 1119–23 (1974)

Anodization; $H_2O_2$ electrolyte; Application: GaAs anodize-strip thinning of layers for FETs

ROSSLER, J.M., Y. Royter, D.E. Mull, W.D. Goodhue, and C.G. Fonstad, "Bromine ion-beam-assisted etching of InP and GaAs," J. Vac. Sci. Technol., B, **16**(3), 1012 (1998)

$Br_2$ assisted Ar ion beam etch; smooth, vertical sidewalls in GaAs and InP

ROSZTOCZY, F.E., G.A. Antypas, and C.J. Casau, "Distribution Coefficients of Ge, Sn, and Te InP Grown by LPE," GaAs and Related Compounds, 1970 (Inst. Phys. Conf. Ser. No. 9, 1977), pp. 86–91

$AgNO_3:CrO_3:HF:H_2O$ (40 mg:5 g:8 ml:10 ml) {A–B etch}; Application: InP layer delineation

ROTHMAN, M.A., J.A. Thompson, and C.A. Armiento, "Multichamber RIE processing for InGaAsP ridge waveguide laser arrays," Mat. Res. Soc. Symp. Proc., **240**, 341 (1992)

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
$HCl:H_3PO_4$ (1:8); selective removal of InP from InGaAsP in laser array process

ROTHSCHILD, M., and D.J. Ehrlich, "A Review of Excimer Laser Projection Lithography," J. Vac. Sci. Technol. B, **6**(1), 1–17 (1988)

Review: projection lithography using excimer laser; includes photochemical etching

ROTTER, T., J. Aderhod, D. Mistele, O. Semchinova, J. Stemmer, D. Uffman, and J. Graul, "Smooth GaN surfaces by photoinduced electro-chemical etching," Mater. Sci. Eng., **B59**, 350 (1999)

KOH (0.5 M); electrolyte for photoinduced electrochemical smoothing-etch for GaN surfaces

ROULEAU, C.M., and R.M. Park, "GaAs Substrate Cleaning for Epitaxy Using a Remotely Generated Atomic Hydrogen Beam," J. Appl. Phys., **73**(9), 4610–13 (1993)

$H_2$ atomic beam cleaning of GaAs in situ for MBE

RUBERTO, M.N., A.E. Willner, D.V. Podlesnik, and R.M. Osgood, "Effect of Carrier Confinement on Laser-Induced Etching of GaAs/AlGaAs heterostructures," Appl. Phys. Lett., **55**(10), 984–86 (1989)

$HNO_3:H_2O$ (1:20); GaAs and AlGaAs photoetch with AlAs stop layer; hole confinement to the GaAs buried layer results in its lateral etching

RUBERTO, M.N., X. Zhang, R. Scarmozzino, A.E. Willner, D.V. Podlesnik, and R.M. Osgood, "The Laser-Controlled Micrometer-Scale Photochemical Etching of III–V Semiconductors," J. Electrochem. Soc., **138**(4), 1174–85 (1991)

$HNO_3:H_2O$ (1:20); GaAs photoetching p–n junction delineation; dopant selective: n-etching under illumination; p-type does not etch; no GaAs dark etching
$H_2SO_4:H_2O_2:H_2O$; GaAs; discussion of reaction chemistry
$HF:H_2O$ (1:10); GaAs and InP photoetch p–n junction delineation; dopant selective; n-etches under illumination; p-type does not etch
$HNO_3:HCl:H_2O$ (1:1:100); InP photoetch p–n junction delineation

SABIN, E.W., "Estimation of the activation energy for $Ar/Cl_2$ plasma etching of InP via holes using electron cyclotron resonance," J. Vac. Sci. Technol., B, **16**(4), 1841 (1998)

ECR etch; $Ar/Cl_2$ of InP via holes; dependence on wafer temperature

SAH, R.E., J.D. Ralston, J. Daleiden, K. Eisele, E.C. Larkins, S. Weisser, and J. Fleissner, "Fabrication of Dry-Etched Mirrors in GaAs-Based and InP-Based Lasers Using Chemically-Assisted Ion-Beam Etching at Low Temperatures (EMC abstract)," J. Electron. Mater., **24**(7), A25 (1995)

CAIBE; $Cl_2$ and $BCl_3$ with Ar ion beam; Application: laser mirrors in $In_{0.35}Ga_{0.65}As/GaAs$

SAH, R.E., J.D. Ralston, J. Daleiden, E.C. Larkins, S. Weisser, J. Fleissner, and W. Benz, "Fabrication of dry-etched mirrors in GaAs-based and InP-based lasers using chemically assisted ion-beam etching at low temperatures," J. Electron. Mater., **25**(9), 1446 (1996)
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

SAITO, H., Y. Noguchi, and H. Nagai, "High Performance InGaAsP/InP 1.3 μm Laser Structures with Both Facets Etched," Electron. Lett., **22**(22), 1157–58 (1986a)
Angled reactive ion etch; $Cl_2$:Ar; InGaAsP/InP; Application: heterostructure laser diode; $TiO_2$ mask

SAITO, H., and Y. Noguchi, "InGaAsP/InP Etched Mirror Lasers Fabricated by Inclined RIE," Jpn. J. Appl. Phys., **28**(10), 1836–42 (1989a)
Reactive ion etch; $Cl_2 + Ar$; InP; Application: InGaAsP/InP etched mirror laser

SAITO, H., and Y. Noguchi, "InGaAsP/InP Lasers with Monolithically Integrated Monitoring Photodiodes Fabricated by Inclined Reactive Ion Etching," Electron. Lett., **25**(11), 719–20 (1989b)
Reactive ion etch; $Cl_2$:Ar; Application: InGaAsP/InP for 1.3 μm laser; $TiO_2$ mask; 55° tilted sample resulted perpendicular etched walls to junction plane; 50° titled sample in $Cl_2$:Ar

SAITO, H., Y. Noguchi, and H. Nagai, "Low Threshold InGaAsP/InP 1.3 μm Doubly Buried-Heterostructure Lasers with a Reactive-Ion Etched Facet," Electron. Lett., **22**(1), 36–38 (1986b)
Angled reactive ion etch; $Cl_2 + Ar$; Application: InGaAsP/InP 1.3 μm laser diode
$Cl_2$–Ar gas mixture (4 sscm $Cl_2$, 1 sccm Ar at 0.45 Pa and power of 0.16 W/cm$^2$); the 'windward' site is perpendicular at 40° tilted substrate; etch rate is maximum at 10° tilted sample; $TiO_2$ mask is used

SAITO, H., and Y. Noguchi, "A Reflection-Type Surface-Emitting 1.3 μm InGaAsP/InP Laser Array with Microcoated Reflector," Jpn. J. Appl. Phys., **27**(7), L 1239–41 (1989c)
Reactive ion etch; $Cl_2 + Ar$; 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

SAITOH, T., O. Mikani, and H. Nagome, "New Chemical Etching Solution for InP and InGaAsP Gratings," Electron. Lett., **18**(10), 408–09 (1982)
Saturated $Br_2$ water:$H_3PO_4$:$H_2O$ (2:1:15); InP etch rate = 56 Å/s at 22°C; InGaAs etch rate = 43 Å/s
Saturated $Br_2$ water:HCl:$H_2O$ (10:1:20); gives etch rate dependence on acid concentration

SAKAI, K., F. Tanaka, Y. Noda, Y. Matsushima, S. Akiba, and T. Yamamoto, "Transverse Mode Controlled InGaAsP/InP Lasers at 1.5 μm Range with Buffer-Layer Loaded Plano-Convex Waveguide Structure," IEEE J. Quantum Electron., **QE-17**(7), 1245–49 (1981)
KOH:$K_3Fe(CN)_6$:$H_2O$; Application: InGaAsP/InP cleaved cross-section layer delineation
HCl:$H_2O$ (4:1); InP $SiO_2$ masked channel etch on InGaAs etch stop layer
$H_2SO_4$:$H_2O_2$:$H_2O$ (1:8:1); InP 1 min substrate cleaning followed by 3 min $Br_2$/methanol (0.6%)

SAKAI, S., T. Aoki, Y. Amemiya, and M. Umeno, “A New InGaAsP/InP Dual-Wavelength LED,” Appl. Phys. Lett., **35**(8), 588–89 (1979a)

$HCl:CH_3COOH:H_2O_2$ (1:1:1) {KKI etch}; Application: InGaAsP/InP non-selective mesa etch at 25°C

SAKAI, S., M. Umeno, T. Aoki, M. Tobe, and Y. Amemiya, “InGaAsP/InP Native Oxide Stripe Lasers,” Jpn. J. Appl. Phys., **18**(5), 1003–04 (1979)

Tartaric acid (3%):propylene glycol (1:3), $pH = 7.2$ adjusted with NaOH; anodization; Application: InP for InGaAsP/InP stripe laser

SAKAI, S., M. Umeno, T. Aoki, M. Tobe, and Y. Ameniya, “InGaAsP/InP Photodiodes Antireflectively Coated with InP Native Oxide,” IEEE J. Quantum Electron., **QE-15**(10), 1077–78 (1979b)

Anodization; InP; Application: antireflective coating on InGaAsP/InP photodiodes

SALESSE, A., R. Alabedra, Y. Chen, M. Lakrimi, R.J. Nicholas, N.J. Mason, and P.J. Walker, “Improved photoluminescence from electrochemically passivated GaSb,” Second. Sci. Technol., **12**, 413 (1997)

citric acid (1 $mol\,l^{-1}$): thiourea (1/3 $mol\,l^{-1}$): isopropanol; electrolyte for anodic passivation of GaSb

SALETES, A., F. Turco, J. Massies, and J.P. Contour, “Morphology of GaAs and InP (0 0 1) Substrates after different Preparation Procedures Prior to Epitaxial Growth (MBE),” J. Electrochem. Soc., **135**(2), 504–09 (1988)

$Br_2$/methanol (0.1–1%); and $H_2SO_4:H_2O_2:H_2O$ (2:1:1); GaAs and

InP etch procedures to obtain the best morphologies. HF:ethanol (1:9); deoxidization post etch solution

SALIMEN, S., C.B. Cooper, and M.E. Day, “Dry etching of via connections for GaAs monolithic microwave integrated circuits fabrication,” J. Vac. Sci. Technol., B, **5**, 1606 (1987)

Reactive ion etch of via holes in GaAs using $Cl_2/SiCl_4$

SANGWAI, K., “Chemical Etching: Principles and Applications,” Electrochemistry of Semiconductors and Electronics: Processes and Devices, Ed. J. McHardy and F. Ludwig, (Noyes Publications, Park Ridge NJ 1992), pp. 53–126

Review: chemical etching principles: dissolution of ionic crystals; dissolution of semiconductors; etch pit formation; electrochemical etching; photoetching; gas phase etching

SANKARANARAYANAN, K., R.R. Sumathi, M. Udhayasankar, P. Jayavel, and J. Kumar, “A new etchant to reveal the subsurface damage on polished gallium arsenide substrates,” J. Cryst. Growth, **178**, 229 (1997)

$Bi(NO_3)_3:H_2O_2:HCl$ (0.38 g ($Bi(NO_3)_2 5H_2O$) in 15 ml $H_2O_2$ mixed with conc. HCl in the ratio 3:1); subsurface defect delineation on polished GaAs

SANKARAN, R., R.L. Moon, and G.A. Antypas, ‘‘Liquid Phase Epitaxial Growth of InGaAs on InP,’’ J. Cryst. Growth, **33**, 271–280 (1976)
$Br_2$/methanol; Application: InP substrate cleaning for LPE
$H_2SO_4$:$H_2O_2$:$H_2O$ (10:1:1); InGaAs selective etch from InP

SARTORIUS, B., and K. Pfanner, ‘‘Origin and penetration of thermal degradation in InP,’’ Appl. Phys. Lett., **54**(25), 2539 (1989)
Thermal degradation of InP; correlation of thermal pits to crystal defects; enhancement of dark defects in the crystal volume

SASAKI, Y., T. Katayama, T. Koishi, K. Shibahara, S. Yokoyama, S. Miyazaki, and M. Hirose, ‘‘High-speed GaAs epitaxial lift-off and bonding with high alignment accuracy using a sapphire plate,’’ J. Electrochem. Soc., **146**(2), 710 (1999)
HF:$H_2O$ (10 wt.%); selective etch of AlAs layer from GaAs for lift-off separation. HF:$H_2O$ (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

SAUER, N.J., and K.B. Chough, ‘‘A Selective Etch for InAlAs over InGaAs and for Different InGaAlAs Quaternaries,’’ J. Electrochem. Soc., **139**(1), L10–L11 (1992)
HCl:$H_2O$ (3:1); Study: $In_{0.52}Al_{0.48}As$ selective etch from $In_{0.53}Ga_{0.47}As$; etch rate = 108 Å/s; InGaAs etch rate < 200 Å/h; more dilute solutions will not etch InAlAs; $(InGa)_{0.8}Al_{0.2}As$ exhibits no etch rate; $(InGa)_{0.66}Al_{0.34}As$ etch rate = 18.3 Å/s

SAUL, R.H., ‘‘The Defect Structure of GaP Crystals Grown from Gallium Solutions, Vapor Phase and Liquid Phase Epitaxial Deposition,’’ J. Electrochem. Soc., **115**(11), 1184–90 (1968)
GaP defect delineation using:
$H_2O$:$AgNO_3$:$CrO_3$:HF (10 ml:40 mg:5 g:8 ml); 15–60 min at 75°C; {A–B etch}
$H_2O$:$AgNO_3$:$HNO_3$:HF (8 ml:10 mg:6 ml:4 ml); 1–3 min at 60°C; {RC etch}
$H_2O$:KOH:$K_3Fe(CN)_6$ (50 ml:6 g:4 g); 1–2 min at 100°C; etch rate = 20–25 μm/h
$H_2O$:HCl:$HNO_3$: (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

SAWAFUJI, Y., and J. Nishizawa, ‘‘$Al_xGa_{1-x}As$ (1 1 1)A substrate with atomically flat polished surface,’’ J. Electrochem. Soc., **146**(11), 4253 (1999)
NaClO:$(CH_3CO)_2O$:KOH:$H_2O$; solution for mechano-chemical polishing of AlGaAs (1 1 1)A flat surfaces

SAXENA, R.R., S.B. Hyder, P.E. Gregory, and J.S. Escher, ‘‘Vapor Phase Epitaxial Growth of InGaAs/InAsP Heterojunctions for Long Wavelength Transferred Electron Photocathodes,’’ J. Cryst. Growth, **50**, 481–84 (1980)
$H_2SO_4$:$H_2O_2$:$H_2O$ (4:1:1); Application: InP substrate cleaning for LPE followed by surface treatment in:
$Br_2$:HBr:$H_2O$ (1:17:300); etch rate = 0.8 μm/min for 2–4 min

SCHADE, U., Sty Kollakowski, E.H. Böttcher, and D. Bimberg, "Improved performance of large-area InP InGaAs metal–semiconductor–metal phototdetectors by sulfide passivation," Appl. Phys. Lett., **64**(11), 1389 (1994)

$(NH_4)_2S_x$ (3.5 ml supersaturated solution; Ref. (Iyer, R., 1991): 45 ml $H_2O$); InP passivation; 15 min at 50°C under illumination of a 250 W tungsten lamp; reduction in dark current of MSM photodetectors; good stability

SCHERER, A., O. Painter, B. D'Urso, R. Lee, and A. Tariv, "InGaAsP photonic band gap crystal membrane microresonators," J. Vac. Sci. Technol., B, **16**(6), 3906 (1998)

CAIBE; $Cl_2$/Ar; Application: Patterned hole etch in InGaAs/InGaAsP QWs

SCHILLING, M., K. Daub, E. Lach, and G. Laube, "Tunable Y Laser with Reactive Ion Etched Mirror Facets Suitable for Integration," InP and Related Material Conference Proceedings, 1994, (IEEE cat. no. 94CH 3369-6), paper $MC_3$, pp. 37–40

Reactive ion etch; $CH_4/H_2/CO_2$; Application: InP waveguide and mirror facet etch

SCHILLING, M., G. Schemmel, and F.-J. Tegude, "Selective LPE-Growth of InGaAs on Semi-insulating InP," J. Electron. Mater., **15**(5), 259–62 (1986)

$HCl:CH_3COOH:H_2O_2$ (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 ~3000 Å/min

SCHILLING, O., A. Forchel, A. Kohl, and S. Brittner, "Optical Analysis of Quantum Confined Stark Effect in Overgrown InGaAs/InP Quantum Wires," J. Vac. Sci. Technol., B, **11**(6), 2556–59 (1993)

$HBr:CH_3COOH:K_2Cr_2O_7$; Application: InP and InGaAs etch with patterned Ti mask for quantum wires

HF (1%); Ti mask removal from InP

SCHIMMEL, D.G., "A Comparison of Chemical Etches for Revealing ⟨1 0 0⟩ Silicon Crystal Defects," J. Electrochem. Soc., **123**(5), 734–41 (1976)

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

$HF:K_2Cr_2O_7$ (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

$HF:HNO_3:CH_3COOH$ (1:3:1) {Dash etch}; Si non-linear etch rate ~0.1 μm/min, n-substrate with illumination

$HF:HNO_3$ (155:1) {Schimmel etch}; Si non-linear etch rate ~1.8 μm/min, n-substrate with illumination

SCHINELLER, B., Y. Junas, M. Heuken, and K. Heime, "Investigation of process technologies for the fabrication of AlGaInP mesa ultra high brightness light emitting diode," Mater. Sci. Eng. B, **B51**, 34 (1998)

HCl (37%):$CH_3COOH$(99.8%):$H_2O$ (31:62:7); mesa etchant for AlGaInP/GaAs LED structures; 2.2 μm/min; gives etch rate dependence on etchant composition

SCHMID, H., F. Fidorra, and D. Grutzmacher, "Endpoint Detection for $CH_4/H_2$ Reactive Ion Etching of InGaAsP Heterostructures by Mass Spectrometry," GaAs and Related Compounds, 1988 (Inst. Phys. Conf. Ser. No. 96, 1989), pp. 431–34

Reactive ion etch; $CH_4/H_2$; Application InGaAsP/InP heterostructures

SCHMIDT, A., A. Forchel, J. Straka, I. Gyuro, P. Speier, and E. Zielinski, "Investigation of High-Quantum Efficiency InGaAs/InP and InGaAs/GaAs Quantum Dots," J. Vac. Sci. Technol., B, **10**(6), 2896–99 (1992)

HBr:$CH_3COOH$ (1:1); Application: InGaAs/InP quantum dot patterning; at 5°C for 3 s

$H_2O_2$ (30%) buffered with $NH_4OH$ to pH = 7.0; GaAs etch rate = 740 Å/min; $In_{0.18}Ga_{0.82}As$ etch rate = 67 Å/min

SCHMITT, F., and N. Susa, "An Etchant for InP Native Oxide," Jpn. J. Appl. Phys., **22**(4), 761 (1983)

Anodization; InP with tartaric acid (3%):propylene glycol (1:3) electrolyte

$H_3PO_4$ (10%); InP etch rate = 0.27 μm/min with no mask undercutting

$H_2SO_4$ (10%); InP etch rate ~ 8 μm/min; undercutting

HCl (10%); InP etch rate =~ 40 μm/min; undercutting

HF:$NH_4F$ (45:500) {buffered HF}; InP etch rate + 0.04 μm/min with no mask undercutting

SCHNEIDER, J., M. Moser, and K. Affolter, "Low Loss Corner Mirrors in InP/InGaAsP/InP for Integrated Optics Etched with Chlorinated Gases," InP and Related Material Conference Proceedings, 1994, (IEEE cat. no. 94CH 3369-6), paper MP37, pp. 216–219

Reactive ion etch; $SiCl_2/Cl_2$ at 240°C; Application: InP/InGaAsP waveguides and mirrors

SCHNEIDER, M., C. Colvard, K. Alavi, and E. Kohn, "Characteristics of non-selective GaAs/AlGaAs heterostructure etching at very low etch rates," SPIE Proc., Advanced Processing of Semiconductor Devices, **797**, 149 (1987)

citric acid:$H_2O_2$ (100:1); study of oxidation/dissolution etch mechanism and selectivity of GaAs and AlGaAs

$NH_4OH$:$H_2O$ (1:5); initial oxide removal from GaAs prior to etching

SCHRAMM, J.E., D.I. Babic', E.L. Hu, J.E. Bowers, and J.L. Merz, "Anisotropy Control in the Reactive Ion Etching of InP Using Oxygen in Methane/Hydrogen/Argon," InP and Related Material Conference Proceedings, 1994a, (IEEE cat. no. 94CH 3369-6), paper WE4, pp. 383–86

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

SCHRAMM, J.E., D.I. Babic, E.L. Hu, J.E. Bowers, and J.L. Merz, "Fabrication of high-aspect-ratio InP-based vertical-cavity laser mirrors using $CH_4/H_2/O_2/Ar$ reactive ion etching," J. Vac. Sci. Technol., B, **15**(6), 2031 (1997)

reactive ion etching; $CH_4/H_2/O_2/Ar$; InP-based materials; 10 μm vertical etch profiles

SCHRAMM, J.E., E.L. Hu, J.L. Merz, J.J. Brown, M.A. Melendes, M.A. Thompson, and A.S. Brown, "Highly Selective Reactive Ion Etch Process for InP-Based Device Fabrication Using Methane/Hydrogen/Argon," J. Vac. Sci. Technol., B, **11**(6), 2280–83 (1993)

Reactive ion etch; $CH_4/H_2/Ar$; InGaAs selective etch from InAlAs

SCHRAMM, J.E., M. Mondry, E.L. Hu, and J.L. Merz, “Conductance Transient Characterization of Reactive Ion Etched HEMT Gate Recesses,” InP and Related Material Conference Proceedings, 1994b, (IEEE cat. no. 94CH 3369-6), paper MP25, pp. 170–73

Reactive ion etch surface damage ssessment; InAlAs/InGaAs HEMTs

SCHRIMPF, T., D. Piester, H.-H. Wehmann, P. Bönsch, D. Wüllner, A. Schlachetski, C. Mendorf, and H. Lakner, “Preparation and characterization of InGaAs quantum wires on vee-groove patterned InP,” Proc. 11th Int’l Conf. on Indium Phosphide and Related Materials, p. 507 (1999)

HF buffered; Ti mask removal from vee-groove patterned InP

HF (5%) for 10 s followed by $H_2SO_4$ (80%) for 60 s to clean InP vee-grooved surface prior to MOVPE regrowth without affecting vee-groove shape

SCHUBERT, E.F., W.T. Tsang, M.D. Feuer, and P.M. Mankiewich, “High-Transconductance Heterostructure $Ga_{0.47}In_{0.53}As$/InP Metal–Insulator–Semiconductor Field-Effect Transistors Grown by Chemical Beam Epitaxy,” IEEE Electron Device Lett., **9**(3), 145–47 (1988)

$H_3PO_4$:$H_2O_2$:$H_2O$ (1:1:20); Application: InGaAs selective etch from InP for MISFET gate recess

SCHULER, H., T. Kaneko, M. Lipinski, and K. Eberl, “In situ etching with $AsBr_3$ and regrowth in molecular beam epitaxy,” Semicond. Sci. Technol., **15**(169), (2000)

$AsBr_3$ 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

SCHUMACHER, C., W. Faschinger, V. Hock, H.R. ReB, J. Nürnberger, and M. Ehinger, “In situ lateral structuring during II–VI growth with $Al_{50}Ga_{50}As$–GaAs shadow masks,” J. Cryst. Growth, **201/202**, 599 (1999)

$NH_4$:$H_2O_2$:$H_2O$ (1:10:10); selective patterning of a GaAs mask on AlGaAs

HF conc.; selective undercut pattern in AlGaAs masked by GaAs

SCHWARTZ, B., J.C. Dyment, and S.E. Haszko, “The Influence of Native Oxides on the Degradation and Passivation of GaAs Junction Lasers,” GaAs and Related Compounds, 1972 (Inst. Phys. Conf. Ser. No. 13 1973), pp. 187–196

$H_2O_2$; $H_2O_2$:$NH_4OH$, pH = 7; and $H_2O$; Application: GaAs surface oxidation for study of effects on laser degradation

SCHWARTZ, B., F. Ermanis, and M.H. Brastad, “The Anodization of GaAs and GaP in Aqueous Solutions,” J. Electrochem. Soc., **123**(7), 1089–97 (1976a)

GaAs anodization in:
$H_3PO_4$:$H_2O$, (acidic electrolyte
$NH_4OH$:$H_2O$, (basic electrolyte)
$(NH_4)_2HPO_4$:$H_2O$, (neutral electrolyte)

SCHWARTZ, B., and H. Robbins, “Chemical Etching of Silicon,” J. Electrochem. Soc., **123**(12), 1903–09 (1976b)

HF:$HNO_3$:$H_2O$; Silicon etch kinetics; dependence on concentrations

SCIMECA, T., K. Prabhakaran, Y. Watanabe, F. Maeda, and M. Oshima, "Novel Method for Rejuvinating and Fabricating Stable Se/GaAs Surfaces," Appl. Phys. Lett., **63**(13), 1807–09 (1993)
Se passivation of GaAs surfaces

SEASSAL, C., J.L. Leclerq, X. Letartre, A. Gagnaire, M. Gendry, and P. Viktorovitch, "Micromachined structures for vertical microelectrooptical devices on InP," Proc., 1996 Indium Phosphide and Related Materials Conference, p. 2765 (1996)
$HCl:H_2O$ (3:1); selective removal of $In_{0.52}Ga_{0.48}As$ from $In_{0.53}Ga_{0.47}As$ for MEMS

SEAWARD, K.L., N.J. Moll, and W.F. Stickle, "The role of aluminum in selective reactive ion etching of GaAs on AlGaAs," J. Vac. Sci. Technol., B, **6**(6), 1645 (1988)
Reactive ion etch; $CCl_2F_2$; study of the role of $AlF_3$ as etch stop in selective removal of GaAs from AlGaAs

SECCO D'aragona, F., "Dislocation Etch for (1 0 0) Planes in Silicon," J. Electrochem. Soc., **119**(7), 948–51 (1972)
$HNO_3:CH_3COOH:HF$ (3:2:2); Si wafer chemical polish prior to etch pit study
$HF:K_2Cr_2O_7$ (0.15 M) (2:1) {Secco etch}; Study: Si dislocation etch pit delineation; etch rate = 1.5 μm/min

SENDRA, J.R., G. Armelles, and J. Anguita, "Optical study of InP etched in methane-based plasmas by reactive ion beam etching," Semicond. Sci. Technol., **11**, 238 (1996a)
RIBE/ECR etch; $CH_4/H_2/N_2$; InP, Raman study of etch damage

SENDRA, J.R., G. Armelles, T. Utzmeier, J. Anguita, and F. Briones, "Resonant Raman scattering study of InSb etched by reactive ion beam etching," J. Appl. Phys., **79**(11), 8853 (1996b)
ECR etch; $CH_4/H_2/N_2$; InSb damage study using Resonant Raman scattering

SENGA, T., Y. Matsumi, and M. Kawasaki, "Chemical dry etching mechanisms of GaAs surface by HCl and $Cl_2$," J. Vac. Sci. Technol., B, **14**(5), 3230 (1996)
Thermochemical and photochemical etching; GaAs in HCl and $Cl_2$; study of etching mechanisms

SEO, J.M., Y.-K. Kim, H.G. Lee, Y.-S. Chung, and S. Kim, "Reduction of gap states of ternary III–V semiconductor surfaces by sulfur passivation: Comparative studies of AlGaAs and InGaP," J. Vac. Sci. Technol., A, **A14**(3), 941 (1996)
$(NH_4)_2S_x$ solution; study of AlGaAs and InGaP surface passivation

SEWELL, J.S., S.C. Dudley, M.G. Mier, D.C. Look, and D.C. Walters, "Automated and Calibrated Whole Wafer Etch Pit Density Measurements in GaAs," J. Electron. Mater., **18**(2), 191–97 (1989)
KOH molten at 450°C; GaAs defect etch pit delineation

SHARMA, B.L., "Chemical Etchants for InAs," Solid-State Electron., **9**, 728–29 (1966)
$Br_2$/methanol (0.5%); InAs (1 1 1)B etch rate = 1 μm/min

$HF:HNO_3:H_2O$ (1:3:2); InAs p–n junction delineation; 1–3 min
$HNO_3:H_2O_2$ (1:5); InAs cleaning; 1–2 min at 75°C

SHAW, D.W., "Localized GaAs Etching with Acidic Hydrogen Peroxide Solutions," J. Electrochem. Soc., **109**(3), 874–79 (1981)
GaAs etching anisotropy and cross-sectional profiles for:
$H_2SO_4:H_2O_2:H_2O$ (1:8:1)
$H_2SO_4:H_2O_2:H_2O$ (1:8:40)
$H_2SO_4:H_2O_2:H_2O$ (1:8:80)
$H_2SO_4:H_2O_2:H_2O$ (1:8:160)
$H_2SO_4:H_2O_2:H_2O$ (1:8:1000)
$H_2SO_4:H_2O_2:H_2O$ (4:1:5)
$H_2SO_4:H_2O_2:H_2O$ (8:1:1)
$H_2SO_4:H_2O_2:H_2O$ (3:1:1)
$HCl:H_2O_2:H_2O$ (1:1:9)
$HCl:H_2O_2:H_2O$ (1:4:40)
$HCl:H_2O_2:H_2O$ (40:4:1)
$HCl:H_2O_2:H_2O$ (80:4:1)

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$H_2O$; GaAs photowash surface passivation; reduces surface state density

SHENG, T.Y., Z.Q. Yu, and G.J. Collins, "Disk hydrogen plasma assisted chemical vapor deposition of aluminum nitride," Appl. Phys. Lett., **52**(7), 576 (1988)
$H_3PO_4$(85%); AlN etch rate at 60°C is dependent on layer quality

SHEU, J.K., Y.K. Su, G.C. Chi, M.J. Jou, C.C. Liu, C.M. Chang, and W.C. Hung, "Inductively coupled plasma etching of GaN using $Cl_2$/Ar and $Cl_2/N_2$ gases," J. Appl. Phys., **85**(3), 1970 (1999)
Inductively coupled plasma etch of GaN using $Cl_2$/Ar and $Cl_2/N_2$ gases

SHIH, M.C., M.B. Freiler, G. Haase, R. Scarmozzino, and R.M. Osgood, "Condensed Chlorine Etching of GaAs Induced by Excimer Laser Radiation," Appl. Phys. Lett., **61**(7), 828–30 (1992)
Laser-assisted $Cl_2$ etch; GaAs low temperature etch from physisorbed $Cl_2$

SHIH, M.C., M.B. Freiler, R. Scarmozzino, and R.M. Osgood, "Patterned, Photon-Driven Cryoetching of GaAs and AlGaAs," J. Vac. Sci. Technol., B, **13**(1), 43–54 (1995)
Photochemical removal of layers from surface adsorbed $Cl_2$; low temperature (140 K) enhances photo selectivity

SHIMANO, A., H. Takagi, and G. Kano, "Light-Controlled Anodic Oxidation of n-GaAs and its Application to Preparation of Specified Active Layers for MESFET's," IEEE Trans. Electron Devices, **ED-26**(11), 1690–95 (1979)
Light controlled anodization; Application: GaAs anodize-strip thinning for MESFETs

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Neutral charge fast atom etching of GaAs

SHIMOYAMA, K., Y. Inoue, M. Katoh, H. Gotoh, Y. Suzuki, and H. Yajima, "A New MOVPE Regrowth Process Utilizing in situ vapor phase etching for Optoelectronic Integrated Circuits," J. Cryst. Growth, **107**, 767–71 (1991)
Thermochemical etch of AlGaAs/GaAs in HCl with $H_2$ at 710°C; Application: for OMVPE regrowth

SHIOTA, I., K. Motoya, T. Ohmi, N. Miyamoto, and J. Nishizawa, "Auger Characterization of Chemically Etched GaAs Surfaces," J. Electrochem. Soc., **124**(1), 155–57 (1977)
Measurement of GaAs residual surface oxide:
etchant A = $H_2SO_4$:$H_2O_2$:$H_2O$ (4:1:1)
etchant B = HF conc.; etchant C = NaOH:$H_2O_2$ (1:1)

| Surface characteristics | Residual oxide (Å) |
|---|---|
| A at 50°C for 3 min | 50 |
| A + B for 5 min | 30 |
| A + B + C at 30°C for 1 min | <10 |
| C at 55°C for 10 min | 60 |
| C + B | 25 |
| C + B+ C at 30°C for 1 min | 10 |

SHIRAFUJI, J., M. Amano, M. Inoue, and Y. Inuishi, "Characteristics of Anodic Native Oxide MIS Diodes of InGaAs," Electron. Lett., **18**, 653 (1982)
InGaAs anodization; electrolyte is tartaric acid (3%) with pH adjusted to 7 by adding $NH_4OH$. $H_2O_2$:$NH_4OH$ (10:1); InGaAs surface cleaning prior to anodization

SHIRAFUJI, J., A. Tamura, K. Oka, M. Inoue, and Y. Inuishi, "Influence of Lattice Mismatch on Properties of InGaAsP Layers Epitaxially grown on InP Substrates," J. Appl. Phys., **52**, 4704 (1981)
$H_2O$:$AgNO_3$:$CrO_3$:HF (10 ml:40 mg:5 g:8 ml) {A–B etch}; InGaAsP LPE layer defect delineation; 25 min at 65°C

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$(NH_4)_2S_x$ sufidation of GaAs for contact metalization

SHOJIMA, K., "Atomic force microscopy and transmission electron microscopy observations of KOH-etched GaN surfaces," J. Vac. Sci. Technol., B, **18**(1), 37 (2000)
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ECR etch; $Cl_2/H_2/CH_4/Ar$ at 170°C; GaN, InN, AlN

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ECR etch; $Cl_2/H_2/Ar/CH_4$; etch study on AlN, InN, InGaN, InAlN

SHUL, R.J., A.J. Howard, C.B. Vartuli, P.A. Barnes, and W. Seng, "Temperature dependent electron cyclotron resonance etching of InP, GaP and GaAs," J. Vac. Sci. Technol., A, **14**(3), 1102 (1996b)
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

SHUL, R.J., M.L. Lovejoy, J.C. Word, A.J. Howard, D.J. Rieger, and S. H. Kravitz, "High rate reactive ion etch and electron cyclotron resonance etching of GaAs via holes using thick polyimide and photoresist masks," J. Vac. Sci. Technol., B, **15**(3), 657 (1997a)
RIE ($Cl_2/BCl_3/SiCl_4$) and ECR ($Cl_2/BCl_3$) high rate plasma etch of via holes in GaAs

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ECR and RIE etch of refractory metal contacts on GaAs; induced damage

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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

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ICP etch of GaN in $Cl_2/H_2/Ar$

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ICP of GaN, AlN, InN in $Cl_2/Ar$, $XCl_2/N_2$, $Cl_2/H_2$, $Cl_2/SF_6$, $BCl_3/Ar$, $BCl_3/H_2$, $BCl_3/N_2$, and $BCl_3/SF_6$ plasmas

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$H_2S$ gas sulfidization of GaAs
$H_2SO_4$:$H_2O_2$:$H_2O$ (1:8:500); GaAs etched surface contains elemental As
NaS solution GaAs sulfidization
$(NH_4)_2S$ solution GaAs sulfidization

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$(NH_4)_2S_x$ solution; GaAs surface treatment to reduce carbon and oxide contamination prior to CBE regrowth, 40°C for 30 min
HCl:$H_2O$ (1:1); GaAs deoxidation, 1 min

SIK, H., M. Riet, C. Dubon-Chevallier, and B. Sermage, "$(NH_4)_2S_x$ passivation treatment and UVCVD stabilization for GaInP/GaAs heterojunction bipolar transistors," Microelectron. Eng., **25**, 293 (1994)
$(NH_4)_2S_x$ sulfur passivation of GaAs structures; study of dependence on S concentration in the solution

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$H_3PO_4$:$H_2O_2$:$H_2O$ (1:1:38); Application: InGaAs slow thinning etch

SIMPSON, W.C., D.K. Shuh, W.H. Hung, M.C. Håkansson, J. Kanski, U.O. Karlsson, and J.A. Yarmoff, "Role of surface stoichiometry in the $Cl_2$/GaAs(0 0 1) reaction," J. Vac. Sci. Technol., A, **14**(3), 1815 (1996)
Thermochemical etch mechanism study of $Cl_2$ on GaAs (0 0 1) surfaces

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A–B etch; Application: GaAs epilayer p–n junction delineation
$H_2SO_4$:$H_2O_2$:$H_2O$ (8:1:100); GaAs thinning etch

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$HF:H_2O$ (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)

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Ion-beam etching; $Cl_2$ assisted; AlGaAs; H∗ enhances etch rate and roughness

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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

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SMITH, L.L., S.W. King, R.J. Nemanich, and R.F. Davis, "Cleaning GaN surfaces," J. Electron. Mater., **25**(5), 805 (1996)
$HCl:H_2O$ (1:1); GaN surface cleaning; good removal of O and C
HCl:methanol (1:1); GaN surface cleaning; good removal of O and C
$HF:H_2O$ (1:20); GaN surface cleaning; good removal of O and C
$HF:H_2O$ (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

SMOLINSKY, G., R.P. Chang, and T.M. Mayer, "Plasma Etching of III–V Compound Semiconductor Materials and Their Oxides," J. Vac. Sci. Technol., **18**(1), 12–16 (1981)
Plasma etching characteristics:
HF, $C_2F_6$, $CF_3Cl$, $CHF_3$, $C_2Cl_4$, $CBrCl_2$, $CHCl_3$, $PH_3$, $H_2$, $H_2O$; these do not etch GaAs or its oxide
$CCl_4$, $CCl_2F_2$, $PCl_3$, HCl etch both GaAs and its oxide
$Cl_2$, $COCl_2$ etch GaAs but not its oxide
$Cl_2$ etches GaP and GaSb but not their oxides
HCl etches GaP and GaSb and their oxides but not InP

SMOLINSKY, G., R.A. Gottscho, and S.M. Abys, "Time-Dependent Etching of GaAs and InP with $CCl_4$ or HCl Plasmas: Electrode Material and Oxidant Additional Effects," J. Appl. Phys., **54**(6), 3518–23 (1983)
Plasma etch; $CCl_4$; HCl; InP and GaAs; HCl/graphite electrode exhibits constant etch rate; $O_2$ or $Cl_2$ presence in $CCl_4$ enhanced etch rate; HCl plasma is less effective than $CCl_4$ in etching InP;

$CCl_4$ and graphite electrodes should be used as less polychlorocarbon is produced and etch rate is increased

SNOW, E.S., P.M. Campbell, and B.V. Shanabrook, "Fabrication of GaAs Nanostructures with a Scanning Tunneling Microscope," Appl. Phys. Lett., **63**(25), 3488–90 (1993)
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
$NH_4OH:H_2O_2:H_2O$ (1:2:1 by weight), diluted 1:100 by $H_2O$; GaAs pattern etch through Si mask

SNYDER, P.G., and S.-J. Cho, "Investigation of citric acid–hydrogen peroxide etched GaAs and $Al_{0.3}Ga_{0.7}As$ surfaces by spectroscopic ellipsometry," J. Vac. Sci. Technol., B, **16**(5), 2680 (1998)
citric acid:$H_2O_2$ ($x$:1, for $1 < x < 10$); study of GaAs and $Al_{0.3}Ga_{0.7}As$ etched surface interface layers and roughness by variable angle spectroscopic ellipsometry

SNYDER, P.G., N.J. Ianno, B. Wigert, S. Pittal, B. Johs, and J.A. Woollam, "Spectroscopic ellipsometric monitoring of electron cyclotron resonance plasma etching of GaAs and AlGaAs," J. Vac. Sci. Technol., B, **13**(6), 2255 (1995)
ECR etch; $CH_4/H_2/Ar$ of GaAs and AlGaAs; study of surface damage with spectroscopic ellipsometry

SO, B.K.L., R.W.M. Kwok, G. Jin, G.Y. Cao, G.K.C. Hui, L. Huang, W.M. Lau, and S.P. Wong, "Reordering at the gas-phase polysulfide passivated GaAs (1 1 0) surface," J. Vac. Sci. Technol., A, **14**(3), 935 (1996)
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

SOLTZ, D., M.-A. De Paoli, and L. Cescato, "Fringe stabilization and depth monitoring during the holographic photelectrochemical etching of n-InP (1 0 0) substrates," J. Vac. Sci. Technol., B, **14**(3), 1784 (1996b)
HCl (1 M); monitoring of grating depth during photoelectrochemical etching on n-InP

SOMOGYI, K., "Electrochemical Carrier Profiling to Determine the Thickness of a Thin Removed Semiconductor Layer," Semicond. Sci. Technol., **5**, 358–60 (1990)
Etch thickness monitoring by use of ECV profiling with spaced marker layers

SONG, J.-I., C. Caneau, K.-B. Chough, and W.-P. Hong, "GaInP/GaAs Double Heterojunction Bipolar Transistor with High $F_t$, $F_{max}$, and Breakdown Voltage," IEEE Trans. Electron Devices, **15**(1), 10–12 (1994)
$HCl:H_3PO_4$ (1:3); Application: InGaP selective etch from GaAs; HBT fabrication

SONG, Z., S. Shogen, M. Kawasaki, and I. Suemune, "X-ray Photoelectron Spectroscopy and Atomic Force Microscopy Surface Study of GaAs(1 0 0) Cleaning Procedures," J. Vac. Sci. Technol., B, **13**(1), 77–82 (1995)
$H_2SO_4$:$H_2O_2$:$H_2O$ (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 $H_2O$ rinse dissolves oxides leaving an As-rich surface

SRNANEK, R., M. El Gomati, I. Novotny, and D. Pudis, "Chemical beveling of InP-based structures by HBr–$H_3PO_4$–$K_2Cr_2O_7$ solution," J. Cryst. Growth, **179**, 320 (1997a)
HBr(46%):$H_3PO_4$(85%):$K_2Cr_2O_7$ (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

SRNANEK, R., I. Novotny, I. Hotovy, and M. El Gomati, "Chemical beveling of GaAs-based structures," Mater. Sci. Eng., **B47**(2), 127–130 (1997b)
$H_3PO_4$:$H_2O_2$:$H_2O$ (7:3:3)
$H_3PO_4$:$H_2O_2$:$H_2O$ (3:1:6)
$H_3PO_4$:$H_2O_2$:$H_2O$ (3:1:10)
$H_3PO_4$:$H_2O_2$:$H_2O$ (3:1:50)
Chemical beveling of GaAs by lifting a sample through a constant flow of etchant

SRNÁNEK, R., and A. Satka, "Revealing of Defects in {1 1 0} InP," J. Cryst. Growth, **126**, 270–74 (1993)
$HNO_3$:$H_2O_2$ (1:1); InP {1 1 0} defect delineation etch at 100°C; etch rate ~2.5 μm/min
$K_3Fe(CN)6$:$H_2O$ (15 g:100 ml) = part 1, and
KOH:$H_2O$ (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)

STANO, A., "Chemical Etching Characteristics of InGaAs/InP and InAlAs/InP Heterostructures," J. Electrochem. Soc., **134**(2), 448–52 (1987)
$Br_2$/methanol 1 vol.%; InGaAs (1 0 0), MBE-grown, etch rate = 6 μm/min
InAlAs (1 0 0) etch rate = 8 μm/min
$H_2SO_4$:$H_2O_2$:$H_2O$ (3:1:1); InGaAs etch rate = 2.5 μm/min; InAlAs etch rate = 3 μm/min
$H_2SO_4$:$H_2O_2$:$H_2O$ (5:1:1); InGaAs etch rate = 1.9 μm/min; InAlAs etch rate = 2.5 μm/min
$H_2SO_4$:$H_2O_2$:$H_2O$ (8:1:1); InGaAs etch rate = 1.2 μm/min; {selective from InP}
$H_3PO_4$:$H_2O_2$ (2:1); InGaAs etch rate = 3.3 μm/min; InAlAs etch rate = 3 μm/min
$H_3PO_4$:$H_2O_2$ (5:1); InGaAs etch rate = 2.4 μm/min; InAlAs etch rate = 1.5 μm/min
$H_3PO_4$:$H_2O_2$ (10:1); InGaAs etch rate = 0.7 μm/min; InAlAs etch rate = 0.5 μm/min
$H_3PO_4$:$H_2O_2$:$H_2O$ (1:8:1); InGaAs etch rate = 1.6 μm/min; InAlAs etch rate = 1.5 μm/min
$H_3PO_4$:$H_2O_2$:$H_2O$ (1:8:40); InGaAs etch rate = 0.4 μm/min; InAlAs etch rate = 0.6 μm/min
$H_3PO_4$:$H_2O_2$:$H_2O$ (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 $Br_2$/methanol forms positive angle sidewalls on both ⟨1 1 0⟩ directions, giving good morphology

and mesa shapes; same for InAlAs except also $H_3PO_4$:$H_2O_2$ (10:1) does not exhibit sidewall crystal habits

STANO, A., C. Coriasso, and G. Meneghini, ‘‘High-resolution depth monitoring of reactive ion etching of InP/InGaAs(P) MQWs using reflectance measurements,’’ Semicond. Sci. & Technol., **11**, 968 (1996)

Reactive ion etch, $CH_4$/$H_2$/Ar; depth monitoring of quantum well thicknesses of ~5 nm in InGaAsP/InP

STARKEEV, G., H. Künzel, and G. Dortman, ‘‘A Controllable Mechanism of Forming Extremely Low-Resistance Non-alloyed Ohmic Contacts to Group III–V Compound Semiconductors,’’ J. Appl. Phys., **74**(12), 7344–56 (1993)

$H_2SO_4$:$H_2O_2$:$H_2O$; 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

STECK, A.J., and I. Chyr, ‘‘Focused ion beam micromilling of GaN and related substrate materials (sapphire, SiC, and Si),’’ J. Vac. Sci. Technol., B, **17**(2), 362 (1999)

Ga focused ion beam micromilling of GaN; rates up to 0.6 $\mu m^3$/nA s; rates two to five times lower for substrates (sapphire, SiC and Si)

STEPANEK, B., and V. Sestakova, ‘‘Indium and nitrogen doping of GaSb single crystal,’’ J. Cryst. Growth, **123**, 306–08 (1992)

$HNO_3$:HF:$CH_3COOH$ (6:2:1); GaSb polycrystalline material cleaning prior to Czochralski growth

KOH:$H_2O$ (45% solution); GaSb first step prior to defect etching; 2 min under continuous stirring at room temperature

$CH_3COOH$:$HNO_3$:HF (20:9:1); GaSb ⟨1 1 1⟩ first step etch pit defect delineation for 1 min, followed by:

$Br_2$/methanol (5%) for 11 min

STERN, M.B., and P.F. Liao, ‘‘Reactive Ion Etching of GaAs and InP Using $SiCl_4$,’’ J. Vac. Sci. Technol., B, **1**(4), 1053–55 (1983)

Reactive ion etch; $SiCl_4$, $SiCl_4$/Ar; InP and GaAs (1 0 0)

STEVENTON, A.G., R.E. Spillet, R.E. Hobbs, M.G. Burt, P.J. Fiddyment, and J.V. Collins, ‘‘CW Operation of GaInAsP Stripe Lasers,’’ IEEE J. Quantum Electron., **QE-17**(5), 602–08 (1981)

$H_2SO_4$:$H_2O_2$:$H_2O$ (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:

| $x$ in $(Al_xGa_{1-x})_{0.5}In_{0.5}P$ undoped (Å/s) | | | | |
|---|---|---|---|---|
| | 0 | 0.4 | 0.7 | 1 |
| $H_2SO_4$ (60°C) | 2.5 | 29 | 97 | 217 |
| $H_2SO_4$ (70°C) | 6.3 | 53 | 171 | 373 |
| $HCl:H_2O$ (1:1) (25°C) | 2.9 | 102 | 383 | 478 |

$(AlGa)_{0.5}In_{0.5}P$ dopant selectivity

| | n = $1 \times 10^{18}$ (Å/s) | Undoped (Å/s) | p = $5 \times 10^{17}$ (Å/s) |
|---|---|---|---|
| $H_2SO_4$ (60°C) | 148 | 97 | 7.0 |
| $H_2SO_4$ (70°C) | 181 | 171 | 163 |
| $HCl:H_2O$ (1:1) (25°C) | 483 | 383 | 0.6 |

STIRLAND, D.J., "The AB Etch: a Reappraisal," GaAs and Related Compounds, 1976 (Inst. Phys. Conf. Ser. No. 33a 1977), pp. 150–57
A–B etch; GaAs dislocation etch pit delineation study

STIRLAND, D.J., "The Identification of Saucer-pit (S-pit) Defects in GaAs," J. Mater. Sci., **13**, 657–65 (1978)
$H_2SO_4:H_2O_2:H_2O$ (3:1:1); GaAs removal of polish damages; 15 min at 45°C
A–B etch; GaAs dislocation etch pit delineation
KOH molten at 300°C; GaAs dislocation etch pit delineation

STIRLAND, D.J., G.J. Rees, and A. Ritson, "The Relationship Between Etch Pit Density and Dislocation Density for (0 0 1) GaAs," J. Cryst. Growth, **79**, 493–502 (1986)
KOH molten at 400°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

STIRLAND, D.J., and B.W. Straughan, "A Review of Etching and Defect Characterization of Gallium Arsenide Substrate Material," Thin Solid Films, **31**, 139–70 (1976)
Review of GaAs etchant types, defect types, and defect revealing etchants

STOCKER, D.A., and E.F. Schubert, "Reduction of surface roughness in photoenhanced electrochemical wet-etched GaN," J. Electrochem. Soc., **146**(7), 2702 (1999)
KOH electrolyte; photochemical etching of Ti-masked patterns in GaN; reduction of surface roughness

STOCKER, D.A., I.D. Goepfert, E.F. Schubert, K.S. Boutros, and J.M. Redwing, "Crystallographic wet chemical etching of p-type GaN," J. Electrochem. Soc., **147**(2), 763 (2000)
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
$H_3PO_4$; transverse (i. e., sidewall) etch for GaN; no etch in the (0 0 0 1) direction

TEAH (tetraethylammonium hydroxide) (40%):$H_2O$; transverse (i. e., sidewall) etch for GaN; no etch in the (0 0 0 1) direction

STOCKER, H.J., and D.E. Aspnes, "Surface Chemical Reactions on $In_{0.53}Ga_{0.47}As$," Appl. Phys. Lett., **42**(1), 85–87 (1983)

$Br_2$/methanol (1%); Application: InGaAs mesa photodiode etch, shows high dark current compared to peroxide etch

$H_2SO_4$:$H_2O_2$:$H_2O$ (1:1:$x$) $\{10 < x < 500\}$; InGaAs mesa photodiode etch; low dark current; InGaAs surface behavior depends on solution pH

$H_2SO_4$:$H_2O_2$:$H_2O$ (1:1:50); InGaAs etch rate = 2200 Å/min

STOCKMAN, S.A., A.W. Hanson, C.M. Colomb, M.T. Fresina, J.E. Baker, and G.E. Stillman, "A Comparison of TMGa and TEGa for Low-Temperature Metalorganic Chemical Vapor Deposition Growth of $CCl_4$-Doped InGaAs," J. Electron. Mater., **23**(8), 791–99 (1994)

Thermochemical vapor etch; $CCl_4$ in MOCVD reactor; GaAs and InAs etch rates from 500 to 650°C; InAs $\gg$ GaAs

STONE, J., J.M. Wiesenfeld, A.G. Dentai, T.C. Damen, M.A. Duguay, T.Y. Chang, and E.A. Caridi, "Optically Pumped Ultrashort Cavity InGaAsP Lasers: Picosecond Operation Between 0.83 and 1.59 μm," Opt. Lett., **6**(11), 534–36 (1981)

$H_3PO_4$:HCl (1:1); Application: InP selective etch from InGaAsP

$H_2SO_4$:$H_2O_2$:$H_2O$ (2:3:2); InGaAsP selective etch from InP

STONEHAM, E.B., "A Non-aqueous Electrolyte for Anodizing GaAs and $GaAs_{0.6}P_{0.4}$," J. Electrochem. Soc., **121**, 1382 (1974)

$KMnO_4$:acetone (1:25); anodization electrolyte for GaAs and $GaAs_{0.6}P_{0.4}$

STRADTMANN, R.R., J.W. Lee, C.R. Abernathy, and S.J. Pearton, "Ar plasma-induced damage in AlGaAs," J. Electrochem. Soc., **143**(9), L219 (1996)

ECR etch; Ar; AlGaAs; surface damage study; p-type more susceptible to damage than n-type

STRINGFELLOW, G.B., and P.E. Greene, "Dislocations in GaAsP," J. Appl. Phys., **40**(2), 502–06 (1969)

A–B etch; Application: GaAsP dislocation etch pit delineation

STRUBBE, K., and W.P. Gomes, "Bromine-Methanol as an Etchant for Semiconductors: A Fundamental Study on GaP, II. Interaction Between Chemical and Anodic Etching of p-Type GaP," J. Electrochem. Soc., **140**(11), 3301–05 (1993a)

$Br_2$/methanol; p-type GaP; etch mechanism study

STRUBBE, K., and W.P. Gomes, "Bromine—Methanol as an Etchant for Semiconductors: A Fundamental Study on GaP, I. Etching Behavior of n- and p-Type GaP," J. Electrochem. Soc., **140**(11), 3294–3300 (1993b)

$Br_2$/methanol; n- and p-type GaP; etch mechanism study

STULZ, L.W., and L.A. Coldren, "Orientation of (1 0 0) InGAsP/InP Wafers by HCl Chemical Etching," J. Electrochem. Soc., **130**(7), 1628–30 (1983)
HCl; InP (1 0 0) orientation determination identification of [1 1 0] and [1 1 0] directions

SU, C., H.-Q. Hou, G.H. Lee, Z.-G. Dai, W. Luo, M.F. Vernon, and B.E. Bent, "Identification of the Volatile Reaction Products of the $Cl_2 + GaAs$ Etching Reaction," J. Vac. Sci. Technol., B, **11**(4), 1222–42 (1993)
Thermochemical etch; $Cl_2$; GaAs; identification of the reaction products over the temperature range 330–950 K

SUEMATSU, Y., K. Iga, and K. Kishino, "Double Heterostructure Lasers," GaInAsP Alloy Semiconductors, Ed. T.P. Pearsall (John Wiley and Sons, Ltd., 1982) Chapter 14, pp. 341–378
$HCl:H_2O$ (4:1); Application: InP (1 0 0) orientation determination; $\langle 1\,1\,0 \rangle$ versus $\langle 1\,\underline{1}\,0 \rangle$

SUGG, A.R., E.I. Chen, T.A. Richard, N. Holonyak, and K.C. Hsieh, "Native Oxide-Embedded $Al_yGa_{1-y}As$–GaAs–$In_xGa_{1-x}As$ Quantum Well Heterostructure lasers," Appl. Phys. Lett., **62**(11), 1259–61 (1993)
$H_2SO_4:H_2O_2:H_2O$ (4:1:1); Application:
AlGaAs/GaAs mesa etch
$HCl:H_2O_2:H_2O$ (1:4:40); Application: AlGaAs/GaAs cross section stain, 5 s
$NH_4OH:H_2O_2$ (pH $\sim$ 7.6); Application: GaAs selective substrate removal
Vapor oxidation of AlGaAs at 425°C with $H_2O$ in $N_2$

SUGIMOTO, H., Y. Abe, T. Osishi, K. Ohtsuka, T. Matsui, H. Yoshiyasu, and Y. Nomura, "Fabrication of Submicron Gratings for 1.5 μm InGaAsP/InP Distributed Feedback Lasers by Reactive Ion Etching Using $C_2H_6/H_2$," J. Electrochem Soc., **139**(10), 2969–74 (1992)
Reactive ion etch; $C_2H_6/H_2$; Study: InP $SiO_2$ masked 240 nm period grating etch; shows profiles

SUGIMOTO, H., T. Isu, H. Tada, T. Miura, T. Shiba, T. Kimura, and A. Takemoto, "Suppression of Side-Etching in $C_2H_6/H_2/O_2$ Reactive Ion Etching for the Fabrication of an InGaAsP/InP p-Substrate Buried-Heterostructure Laser Diode," J. Electrochem. Soc., **140**(12), 3615–20 (1993)
Reactive ion etch; $C_2H_6/H_2/O_2$ mesa etch for InGaAsP/InP; suppressed side etching for laser diode mesa fabrication

SUGIMOTO, Y., H. Kawanishi, and K. Akita, "Electron-Beam-Induced Modification of GaAs Oxide for in situ Patterning of GaAs by $Cl_2$ Gas Etching," Semicond. Sci. Technol., **7**, 160–63 (1992)
Electron beam-induced $Cl_2$ etch; GaAs; oxidized surface is resistive to etching, whereas irradiated region etches easily for maskless patterning

SUGINO, T., T. Miyazaki, K. Matsuda, and J. Shirafuji, "Effect of phosphine plasma on suppression of plasma-induced defects in InGaAs," Proc. 10th Int'l Conf. on Indium Phosphide and Related Materials, p. 171 (1998)
Study of surface damage to InGaAs during Ar plasma exposure; suppression of damage in phosphine plasma

SUGIYAMA, M., S. Maeyama, and M. Oshima, "X-ray standing wave study of the S-passivated InP (0 0 1) surface," J. Vac. Sci. Technol., A, **A14**(3), 1812 (1996)
$(NH_4)_2S_x$-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

SULLIVAN, M.V., and G.A. Kolb, "The Chemical Polishing of GaAs in Bromine–Methanol," J. Electrochem. Soc., **110**(6), 585–87 (1963)
$Br_2$/methanol; GaAs polishing

SUN, J., D.J. Seo, W.L. O'Brien, F.J. Himpsel, A.B. Ellis, and T.F. Kuesch, "Chemical bonding and electronic properties of $SeS_2$-treatec GaAs (1 0 0)," J. Appl. Phys., **85**(2), 969 (1999)
$SeS_2$ solution passivation of GaAs surfaces; study of bonding and electrical properties

SUSA, N., H. Nakagome, H. Ando, and H. Kanbe, "Characteristics in InGaAs/InP Avalanche Photodiodes with Separated Absorption and Multiplication Regions," IEEE J. Quantum Electron., **QE-17**(2), 243–49 (1981)
$KOH:K_3Fe(CN)_6:H_2O$ (6 g:4 g:50 ml); Application: InP cleaved cross-section layer delineation; ~5 min at 20°C
$Br_2$/methanol; InP substrate cleaning
$HF:H_2O_2:H_2O$ (1:1:10); InGaAsP/InP interface delineation
HF:HBr (5:1); InP dislocation etch pit delineation
$NH_4OH:H_2O_2:H_2O$; InGaAs dislocation etch pit delineation
$H_2SO_4:H_2O_2:H_2O$ (3:1:1); InGaAs selective etch from InP

SUSA, N., Y. Yamauchi, and H. Kanbe, "Punch-through Type InGaAs Photodetector Fabricated by Vapor-Phase-Epitaxy," IEEE J. Quantum Electron., **QE-16**(5), 542–45 (1980a)
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. $H_2SO_4:H_2O_2:H_2O$ (1:1:10); InGaAs/InP interface delineation
$H_2SO_4:H_2O_2:H_2O$ (3:1:1); InGaAs mesa etch

SUSA, N., Y. Yamauchi, and H. Kanbe, "Vapor Phase Epitaxially Grown InGaAs Photodiodes," IEEE Trans. Electron Devices, **ED-27**(1), 92–98 (1980b)
$H_2SO_4:H_2O_2:H_2O$ (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
$H_2SO_4:H_2O_2:H_2O$ (1:1:10); InGaAs/InP interface delineation
$H_2SO_4:H_2O_2:H_2O$ (3:1:1); InGaAs mesa etch

SUZUKI, T., and M. Ogawa, "Degradation of photoluminescence intensity caused by excitation-enhanced oxidation of GaAs surfaces," Appl. Phys. Lett., **31**(7), 473 (1977)

HCl; deoxidation of GaAs surface; photoluminescence degradation caused by surface oxide

SVORCIK, V. RYBKA, V., and V. Myslik, "Photoelectrochemical Etching of n-GaAs and n-InP," Phys. Stat. Sol. (a), **106**, K35–39 (1988)

Photoelectrochemical etching of n-GaAs with $H_2SO_4$:$H_2O_2$:$H_2O$ and KOH electrolytes and n-InP with HCl:$HNO_3$:$H_2O$ electrolyte. He–Ne laser (wavelength = 632.8 nm) at 1–10 W/cm$^2$ current density with wet chemical solution of $H_2SO_4$ (98% conc.), $H_2O_2$ (30% conc.), $HNO_3$ (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.

SVORCIK, V., V. Rybka, and A. Dohnalkova, "Laser Etching of InP in Aqueous Solutions," Semicond. Sci. Technol., **6**, 942–44 (1991)

n-InP photoetch with HeNe laser in:
$FeNH_4(SO_4)_2$:$H_2O$ (1:12)
$FeSO_4(NH_4)_2SO_4$:$H_2O$ (1:6)
$FeCl_3$ HCl:$HNO_3$:$H_2O$ (5:8:10)
HCl:$HNO_3$:$H_2O$ (5:2:10)
HCl:$HNO_3$:$H_2O$ (3:8:10)

SZAPLONCZAY, A., K. Fox, and J.C. Dyment, "Mirror Formation by Chemical Etching and Microcleaving of InP-based Lasers," Can. J. Phys., **65**, 937–44 (1987)

$Br_2$/methanol; Application: InGaAsP/InP laser cantilever etch for microcleaving
$K_2Cr_2O_7$:HBr:$CH_3COOH$
HCl:$CH_3COOH$:$H_2O_2$ (1:2:1)
HCl:$HNO_3$: (1:1.2–2)
HCl:$HNO_3$:$H_2O$: (1:2:1)
HCl:$HNO_3$:$H_3PO_4$ (1:1.2–2:1–1.5)
HCl:$HNO_3$:$H_3PO_4$:$H_2SO_4$ (1:1.2–2:1–1.5:0.005–0.1): Application:
InGaAsP/InP laser mirror etching. Wet chemical selective etch; freshly mixed
HCl:$HNO_3$ etchant gives InP vertical and smooth walls;2 step etchant
HCl:$H_3PO_4$ for InP and $H_2SO_4$:$H_2O_2$:$H_2O$ for InGaAs and InGaAsP and single step etchant of $K_2Cr_2O_7$:HBr:$CH_3COOH$ are difficult to control; InP vertical walls and flat etched bottom are obtained from (1:1.2) HCl:$HNO_3$ but (1:2) ratio gives curved bottom; InP etch rate in HCl:$HNO_3$(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:$HNO_3$ (1:2) is 3 μm/m while (1:1.2) ratio etch rate is 6 μm/m; InP etch rate in HCl:$HNO_3$:$H_3PO_4$ (1:2:1) is 1.8 μm/m at RT; addition of $H_3PO_4$ helps the smoothness of etched surface; however, increasing from 1 to 1.5 parts of $H_3PO_4$ results negative slope; 0.2 parts of $H_2SO_4$ to HCl:$HNO_3$:$H_3PO_4$ 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 $Br_2$–$CH_3OH$; 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 $Br_2$ concentration

TADAYON, B., C.S. Kyono, M. Fatemi, S. Tadayon, and J.A. Mittereder, "Extremely Low Specific Contact Resistivities for p-type GaSb, Grown by Molecular Beam Epitaxy," J. Vac. Sci. Technol., B, **13**(1), 1–3 (1995)
$H_2SO_4$:$H_2O_2$:$H_2O$ (7:1:1); GaAs surface cleaning for MBE growth of GaSb layers
HCl:$H_2O$ (1:1); p-GaSb surface cleaning first step, 30 s, followed by:
buffered HF:$H_2O$ (1:1); p-GaSb surface cleaning, 30 s, for low resistance Au contacts

TADOKORO, T., F. Koyama, and K. Iga, "Classification of Etching Mechanism in Reactive Ion Beam Etch," J. Vac. Sci. Technol. B, **7**(5), 1111–14 (1989)
Reactive ion beam etch; $Cl_2$; GaAs and InP

TADOKORO, T., F. Koyama, and K. Iga, "Comparison of Luminescence from InP Processed by Reactive Ion Beam Etching," Jpn. J. Appl. Phys., **29**(2), 242–43 (1990)
Reactive ion beam etch; $Cl_2$; InP; photoluminescence study of surface damage

TADOKORO, T., F. Koyama, and K. Iga, "A Study on Etching Parameters of a Reactive Ion Beam Etch for GaAs and InP," Jpn. J. Appl. Phys., **27**(3), 389–92 (1988)
Reactive ion beam etch; $Cl_2$; GaAs and InP

TAI, K., T.R. Hayes, S.L. McCall, and W.T. Tsang, "Optical Measurement of Surface Recombination in InGaAs Quantum Well Mesa Structures," Appl. Phys. Lett., **53**(4), 302–03 (1988)
Plasma etch; $CH_4$:$H_2$(1:5); Application: $In_{0.53}Ga_{0.47}As$/InP quantum well mesas
InP etch rate ~InGaAs etch rate ~= 750 Å/min at 125 mTorr and 300 sccm (1:5)
$CH_4$:$H_2$ flowrate; 1 μm photoresist mask; during etching hydrocarbon deposit on photoresist at 50 Å/m rate; horizontal etch rate is about 1/5 of vertical etch rate

TAKADO, N., S. Kohmoto, Y. Sugimoto, M. Ozaki, M. Sugimoto, and K. Asakawa, "New in situ Electron Beam Patterning Process for GaAs Using an Electron-cyclotron-resonance Plasma-Oxidized mask and $Cl_2$ Gas Etching," J. Vac. Sci. Technol., B, **10**(6), 2711–15 (1992)
ECR Plasma, $O_2$ oxidation of GaAs; $Cl_2$ etch; Study: in situ mask formation with electron beam patterning

TAKAGISHI, S., H. Yao, and H. Hirotaro, "Origin and Formation mechanism of Elliptic-Shaped Surface Defect on GaAs Layers Grown By Molecular Beam Epitaxy," J. Cryst. Growth, **129**, 443–448 (1993)
KOH molten; GaAs defect delineation; 3 μm etch depth
AB etch; GaAs defect delineation; 10 μm etch depth; correlation of MBE layer defects to substrate etch pits

TAKAGISHI, S., H. Yao, and H. Mori, "Surface defects of GaAs epitaxial layers grown by OMVPE," J. Cryst. Growth, **123**, 203–12 (1992)
$H_2SO_4$:$H_2O_2$:$H_2O$ (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

TAKAHASHI, K., T. Murotani, M. Ishii, W. Susaki, and S. Takamiya, "A Monolithic 1 × 10 Array of InGaAsP/InP Photodiodes with Small Dark Current and Uniform Responsivities," IEEE J. Quantum Electron., **QE-17**(2), 239–42 (1981)
$Br_2$/methanol; Application: InGaAsP/InP non-selective etch for photodiodes

TAKAHASHI, S., H. Saito, and G. Iwane, "Channeled Substrate buried Heterostructure InGaAsP/InP Laser Emitting at 1.55 μm," Electron. Lett., **16**(24), 922–23 (1980)
$Br_2$/methanol; Application: InGaAsP/InP channel etch for BH laser fabrication

TAKAI, M., N. Nakai, J. Tsuchimoto, K. Gamo, and S. Namba, "Local Temperature Rise During Laser Induced Etching of Gallium Arsenide in $SiCl_4$ Atmosphere," Jpn. J. Appl. Phys., **24**(9), L705–L708 (1985)
Thermochemical laser-induced dry etching of GaAs in $SiCl_4$

TAKAI, M., J. Tokuda, H. Nakai, K. Gamo, and S. Namba, "Laser Induced Local Etching of Gallium Arsenide in Gas Atmosphere," Jpn. J. Appl. Phys., **22**(12), L757–L759 (1983)
Laser-induced thermochemical dry etch of GaAs with $CCl_4$

TAKAI, M., J. Tsuchimoto, J. Tokuda, H. Nakai, K. Gamo, and S. Namba, "Laser-Induced Thermochemical Maskless-Etching of III–V Compound Semiconductors in Chlorine Gas Atmosphere," Appl. Phys. A, **45**, 305–312 (1988)
Laser-induced thermochemical dry etch in $Cl_2$; GaAs, InP, InSb and GaP

TAKAI, M., J. Tsuchimoto, H. Nakai, K. Gamo, and S. Namba, "Maskless Dry Etching of Gallium Arsenide with a Submicron Line-Width by Laser Pyrolysis in $CCl_4$ Gas Atmosphere," Jpn. J. Appl. Phys., **23**(11), L852–L854 (1984)
Thermochemical laser-induced dry etch of GaAs in $CCl_4$

TAKANASHI, Y., and N. Kondo, "Characterization of an n-GaAs layer grown on a GaAs substrate cleaned by an electron cyclotron resonance hydrogen plasma," J. Vac. Sci. Technol., B, **16**(1), 216 (1998)
ECR plasma; hydrogen; surface cleaning of GaAs for MBE regrowth

TAKANO, H., K. Sumitani, H. Matsuoka, K. Sato, O. Ishihara, and N. Tsubouchi, "Surface characterization of sidewall protection on GaAs steep via holes etched by magnetron ion etching," J. Vac. Sci. Technol., B, **14**(1), 112 (1996)
Magnetron ion etch; $SiCl_4/Cl_2$ of GaAs; via hole sidewall passivation by etch residues

TAKATANI, S., S. Yamamoto, H. Takazawa, and K. Mochiji, "Excimer laser assisted etching of AlGaAs and GaAs," J. Vac. Sci. Technol., B, **13**(6), 2340 (1995)
Laser assisted $Cl_2$ etch of AlGaAs and GaAs. Laser desorbs non-volatile $GaCl_3$

TAKAZAWA, H., and S. Takatani, "Highly-selective etching of InAlAs over InGaAs assisted by ArF excimer laser," Proc. 10th Int'l Conf. on Indium Phosphide and Related Materials, p. 183 (1998)
$Cl_2$ photochemical etching using ArF excimer laser; selective removal of InAlAs from InGaAs

TAKEBE, T., T. Yamamoto, M. Fujii, and K. Kobayashi, "Fundamental Selective Etching Characteristics of $HF + H_2O_2 + H_2O$ Mixtures for GaAs," J. Electrochem. Soc., **140**(4), 1169–80 (1993)

$HF:H_2O_2:H_2O$ mixtures; GaAs; etch rate and sidewall profile dependence on etchant composition

TAKEDA, Y., and A. Sasaki, "Low EPD High Avalanche Multiplication of Lattice-matched InGaAs on InP Substrate," Jpn. J. Appl. Phys., **20**(Suppl. 20–1), 189–92 (1980)

A–B etch; Application: InP dislocation delineation; 60°C for 20–30 min; for InGaAs 3 min at 20°C

$H_2SO_4:H_2O_2:H_2O$ (3:1:1); InGaAs selective mesa etch from InP

TAKEDA, Y., A. Sasaki, Y. Imamura, and T. Takagi, "Properties of LPE InGaAs on InP," J. Electrochem. Soc., **125**(1), 130–35 (1978)

$Br_2$/methanol; Application: InP substrate cleaning for LPE

$HCl:H_2O_2$ (1:19); Indium cleaning for LPE

$AgNO_3:HF:HNO_3:H_2O$ (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

TAKENAKA, T., H. Hayashi, K. Murata, and T. Inoguchi, "Various Dislocation Etch pits Revealed on LPE GaAs (0 0 1) Layer by Molten KOH," Jpn. J. Appl. Phys., **17**(6), 1145–46 (1978)

KOH, molten (350°C); GaAs (1 0 0) dislocation etch pit delineation

TAKIMOTO, K., K. Ohnaka, and J. Shibata, "Reactive Ion Etching of InP with $Br_2$-containing Gases to Produce Smooth, Vertical Walls: Fabrication of Etched-faceted Lasers," Appl. Phys. Lett., **54**(20), 1947–49 (1989)

Reactive ion etch; $Br_2 + N_2$; $Br_2 + Ar$; Application: etched facet laser of InP. etch rate $= 2$ μm/m; vertical walls of etched InP surface smoothness is improved with heating substrate; 4000 Å Ti is used as upper layer mask; 2000 Å $Si_3N_4$ is lower mask used to prevent reaction between Ti and InP; pure $Br_2$ caused roughness while 80% $Br_2$ and 20% $N_2$ can produce vertical walls; $Br_2 + Ar$ can produce smoother etched surface at higher temperature; at 10°C, etch rate of $Br_2 + Ar = 1.8$ μm/m and at 40°C, etch rate $= 2.1$ μm/min

TAMARI, N., "Growth and Characterization of Cd-doped InGaAsP/InP Double Heterostructure Lasers," J. Electron. Mater., **11**(4), 611–29 (1982a)

$H_3PO_4:HBr$ (2:1) {Huber etch}; Application: InP dislocation etch pit delineation

TAMARI, N., and H. Shtrikman, "High To Low Threshold Crescent InGaAsP Mesa-substrate Buried-heterojunction Lasers," Electron. Lett., **18**, 177–78 (1982b)

$H_3PO_4:HCl$ (1:1): Application: InP $Si_3N_4$ masked mesa etch

TAMURA, H., Y. Okuno, and H. Kato, "Chemical Etching of ZnSe Crystals," J. Electron. Mater., **23**(8), 835–38 (1994)

$KMnO_4:H_2SO_4:H_2O$ (100 mg:10 ml:40 ml); polish etch for ZnSe; etch rate ~1 μm/min

TAMURA, M., S. Ando, N. Nunoya, S. Tamura, S. Arai, and G.U. Bacher, "Surface damage in GaInAsP/InP wire structures by $Cl_2/H_2$-ECR dry etching," Proc. 9th Int'l Conf. on Indium Phosphide and Related Materials, p. 582 (1997)

ECR etch of InGaAsP/InP in $Cl_2/H_2$; surface damage study

TAN, I.-H., Y.-L. Chang, S. Shi, R. Mirin, E. Hu, J. Bowers, and J. Merz, "Evaluation of the Etch Depth Dependence of Three-dimensional Confinement in Strain-induced Quantum Well Dot Structures," J. Vac. Sci. Technol., B, **10**(6), 2851–54 (1992)

Saturated $Br_2$ water:$H_3PO_4$:$H_2O$ (4:15:2); Application: InGaAs submicron photolithography for quantum well dots

Citric acid:$H_2O_2$ (1:1); GaAs/AlGaAs/InGaAs blanket etch; AlGaAs etch rate is ~1/3 that of GaAs and InGaAs

TAN, S.S., M. Ye, and A.G. Milnes, "Diffusion limited chemical etching effects in semiconductors," Solid-State Electron., **38**(1), 17 (1995)

$Br_2$:methanol (2%); GaSb; study and modeling of diffusion limited etching

TANAHASHI, T., I. Ushijima, I. Umebu, S. Nakai, Y. Nishitani, and K. Akita, "Deformation of vee-grooves on InP Substrate by Heat Treatment," J. Cryst. Growth, **64**, 492–98 (1983)

HCl:$H_3PO_4$ (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 $SiO_2$ mask but does not affect on InP vee-groove with $SiO_2$ mask on shoulders; deformation increases with increasing ratio of $H_2/(H_2 + N_2)$ under heat treatment; deformation saturated at $H_2/(H_2 + N_2)$ ratio is higher than 0.1; deformation of vee-groove also happens in 1000 ppm $PH_3$ in $H_2$ but not after Ar+ ion sputtering treated surface; deformation area $S \sim e$ $(-Ea/KT)$ where $Ea =$ activation energy, $T =$ treatment temperature, $k =$ const.; for deposition $Ea = 1$ eV; deformation happens in $PH_3$, $H_2$ and chemical residue

TANAKA, J., S. Habibi, H. Hattori, and S. Matsumoto, "Material system using HBr gas and a 172 nm excimer laser," Proc. 1996 Indium Phosphide and Related Materials Conference, p. 420 (1996)

HBr gas; photochemical etch using a 172 nm excimer lamp, selective removal of InGaAs from InAlAs

TANAKA, N., M. López, I. Matsuyama, and T. Ishikawa, "Etching temperature dependence of the surface composition and reconstruction for $Cl_2$-etched GaAs layers," J. Vac. Sci. Technol., B, **13**(6), 2250 (1995)

Thermochemical etch; $Cl_2$ of GaAs; study of temperature dependence of surface composition and reconstruction

TANZER, T.A., P.W. Bohn, I.V. Roschin, and L.H. Green, "Ion-etch produced damage on InAs(1 0 0) studied through collective-mode electronic Raman scattering," J. Vac. Sci. Technol., B, **18**(1), 144 (2000)

Ar+ low energy ion milling of InAs; damage study using Raman scattering

TARTAGLIA, J.M., S.M. Crochiere, C.E. Kalnas, D.L. Farrington, J.A. Kronwasser, and P.J. Pearah, "A Study of Etch Pit Density and X-ray Rocking Curves for GaAs Substrate Evaluation," J. Electron. Mater., **20**(5), 345–52 (1991)

KOH molten at 350°C; GaAs defect etch pit delineation; relationship of pit density to structural defects

TARUI, Y., Y. Komiya, and Y. Harada, "Preferential Etching and Etched Profile of GaAs," J. Electrochem. Soc., **118**(1), 118–22 (1971)

$Br_2$/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
$H_2SO_4$:$H_2O_2$:$H_2O$ (5:1:1); GaAs surface cleaning/polish prior to applying $Al_2O_3$ etch mask
$CrO_3$:HF:$H_2O$ (33 w/o:46 w/o water solution) {Sirtl etch}; GaAs orientation determination from etch pit shape
$H_3PO_4$; $Al_2O_3$ mask removal etch; 4 min at 50°C
Gives etch profile orientation dependence

TATENO, K., Y. Kohama, and C. Amano, "Carbon doping and etching effects of $CBr_4$ during metalorganic chemical vapor deposition of GaAs and AlAs," J. Cryst. Growth, **172**, 5 (1997)

Thermochemical etch; $CBr_4$; in situ MOCVD etch of GaAs and AlAs

TEMKIN, H., L.R. Harriott, R.A. Hamm, J. Weiner, and M.B. Panish, "In situ Pattern Formation and High Quality Overgrowth by Gas Molecular Beam Epitaxy," Appl. Phys. Lett., **54**(15), 1463–65 (1989)

Ar ion beam assisted $Cl_2$ 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 $\mu A/cm^2$

TEMKIN, H., L.R. Harriott, and M.B. Panish, "Ultrathin Semiconductor Layer Masks for High Vacuum Focused Ga Ion Beam Lithography," Appl. Phys. Lett., **52**(18), 1478–80 (1988)

HCl:$H_2O$ (3:1); InP selective etch from ~30 Å InGaAs mask layer; InP etch rate at 4°C ~300 Å/s
$H_2SO_4$:$H_2O_2$:$H_2O$ (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 $Cl_2$ selective etching of InP and InGaAs
High vacuum focused Ga ion beam; Application: lithography patterns on InP/InGaAs structures; exposed patterns are transfered to underlying layer by selective wet chemical etchant; HCl:$H_2O$ (3:1) attacks InP at 300 Å/s at 4°C; $H_2SO_4$:$H_2O_2$:$H_2O$ (1:1:10) selectively etch InGaAs

TEMKIN, H., M.B. Panish, R.A. Logan, and J.P. van der Ziel, "l = 1.5 μm InGaAsP Ridge Laser Grown by Gas Source MBE," Appl. Phys. Lett., **45**(4), 330–32 (1984)

HCl:$H_3PO_4$ (3:1); Application: InP selective etch from InGaAsP

TEMPEZ, A., N. Medelci, N. Badi, I. Berishev, D. Starikov, and A. Bensaoula, "Photoenhanced reative ion etching of III–V nitrides in $BCl_3/Cl_2/Ar/N_2$ plasmas," J. Vac. Sci. Technol., A, **17**(4), 2209 (1999)

Photoenhanced reactive ion etch of GaN and BN using $BCl_3/Cl_2/Ar/N_2$

TENNANT, D.M., T.L. Koch, P.P. Mulgrew, R.P. Gnall, F. Ostermayer, and J.-M. Verdiell, "Characterization of Near-field Holography Grating Masks for Optoelectronics Fabrication by Electron Beam Lithography," J. Vac. Sci. Technol., B, **10**(6), 2530–35 (1992)

Reactive ion etch; $CHF_3/H_2$; Study: InP grating etch

THEIL, F.A., and R.L. Barns, "Etching and X-ray Diffraction Studies of the III-A and III-B Faces of GaInAsP Crystals," J. Electrochem. Soc., **126**(7), 1272–74 (1979)

$H_3PO_4$:HBr (2:1) {Huber etch}; InGaAsP dislocation etch pit delineation; 2 min at 25°C
HCl:$HNO_3$:$H_2O$ (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: $H_2O$:$AgNO_3$:$CrO_3$: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 $H_2O_2$ solution," J. Electrochem. Soc., **144**(4), 1390 (1997)

$H_2SO_4$ (1.3 mol/l); (photo)electrochemical and etching properties of n- and p-$In_{0.53}Ga_{0.47}As$
$H_2SO_4$:$H_2O_2$(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

THEUWIS, A., I.E. Vermeir, and W.P. Gomes, "Chemical and electrochemical interaction of acidic $H_2O_2$ solutions with (1 0 0) InP," J. Electroanal. Chem., **410**, 31 (1996)

$H_2O_2$ 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 $K_3Fe(CN)_6$ solutions," J. Electrochem. Soc., **146**(3), 1172 (1999b)

$K_3Fe(CN)_6$ (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

THIRSTRUP, C., S.W. Pang, O. Alberktsen, and J. Hanberg, "Effects of Reactive Ion Etching on Optical and electro-optical Properties of GaInAs/InP-Based Strip-loaded Waveguides," J. Vac. Sci. Technol., B, **11**(4), 1214–21 (1993)

Reactive ion etch; $CH_4/H_2$; Application: InGaAs/InP strip-loaded waveguides; sensitivity of optical loses to etch conditions

THOMAS III, S., E.W. Berg, and S.W. Pang, "In situ fiber optic thermometry of wafer surface etched with an electron cyclotron resonance source," J. Vac. Sci. Technol., B, **14**(3), 1807 (1996a)

ECR etch; Ar plasma; InP; study of plasma temperature effects

THOMAS III, S., K.K. Ko, and S.W. Pang, "Monitoring InP and GaAs Etched in $Cl_2$/Ar Using Optical Emission Spectroscopy and Mass Spectrometry," J. Vac. Sci. Technol., A, **13**(3), 894–99 (1995a)

ECR etch, optical monitoring; $Cl_2$/Ar; InP and GaAs

THOMAS III, S., and S.W. Pang, "Atomic force microscopy study of III–V materials etched using an electron cyclotron resonance source," J. Vac. Sci. Technol., B, **13**(6), 2350 (1995b)

ECR etch; $Cl_2$/Ar of InP, GaAs and InGaAs; atomic force microscopy study of surface roughening

THOMAS, S., and S.W. Pang, "Dependence of Contact Resistivity and Schottky Diode Characteristics on Dry Etching Induced Damage of GaInAs," J. Vac. Sci. Technol., B, **12**(5), 2941–46 (1994)

ECR plasma etch; $Cl_2$; InGaAs study of etch rates and surface damage

THOMAS III, S., and S.W. Pang, "Dry etching of horizontal distributed Bragg relector mirrors for waveguide lasers," J. Vac. Sci. Technol., B, **14**(6), 4119 (1996b)

ECR $Cl_2$/Ar etch process for distributed Bragg mirrors in laser structures on InP and GaAs, using Ni mask

THRUSH, E.J., "Large-area Electrochemical Planing of p-type GaAs for Photocathodes," J. Phys. E: Sci. Instrum., 327–32 (1978)

Anodic etching with a mechanically scanned jet of KOH (20%) electrolyte with the etching current controlled by IR transmitted intensity to achieve uniform thickness

THRUSH, E.J., "A Method for Selective Substrate Removal from Thin p-type GaAs Layers," J. Phys. E: Sci. Instrum., **7**, 493–95 (1974)

Two step thinning: (1) p-GaAs substrate is anodically dissolved down to an n-blocking layer. (2) $H_2SO_4$:$H_2O_2$ (3:2) photoetch removes n-blocking layer from the thin p-layer

TIHANYI, P., D.K. Wagner, A.J. Roza, H.J. Vollmer, C.M. Harding, R.J. Davis, and E.D. Wolf, "High-power AlGaAs/GaAs single quantum well lasers with chemically assisted ion beam etched mirrors," Appl. Phys. Lett., **50**(23), 1640 (1987)

Chemically assisted ion beam etch (CAIBE); $Cl_2$/Ar of AlGaAs/GaAs laser mirrors

HCl conc.; removal of Cr mask from GaAs

TIJBURG, R., "Advances in Etching of Semiconductor Devices," Physics in Technology, Sept., 202–07 (1976a)

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

TIJBURG, R.P., and T. van Dongen, "Selective Etching of III–V Compounds with Redox Systems," J. Electrochem. Soc., **123**(5), 687–91 (1976b)
$Ce(SO_4)_2$: $Ce(NO_3)_3$; AlGaAs selective etch from GaAs; p-type AlGaAs selective from n-type
$FeCl_3$:$FeCl_2$; AlGaAs selective etch from GaAs
$C_6H_4O_2$:$C_4H_6O_2$ (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); $Al_xGa_{1-x}As$ ($x < 0.15$) selective etch from GaAs; with pH = 11 is GaP selective etch from InGaP or AlGaAs

TISONE, G.C., and A.W. Johnson, "Laser-controlled Etching of Chromium-doped ⟨1 0 0⟩ GaAs," Appl. Phys. Lett., **42**(6), 530–32 (1983)
$HNO_3$ (10% solution); GaAs Cr-doped semi-insulating laser-induced etch

TOBE, M., Y. Amamiya, S. Sakai, and M. Umeno, "High Sensitivity InGaAsP/InP Phototransistors," Appl. Phys. Lett., **37**(1), 73–75 (1980)
HCl:$CH_3COOH$:$H_2O_2$ (1:1:1) {KKI etch}; Application: InGaAsP/InP mesa etch

TONG, M., K. Nummila, A. Ketterson, I. Adesida, C. Caneau, and R. Bhat, "InAlAs/InGaAs/InP MODFET's with Uniform Threshold Voltage Obtained by Selective Wet Gate Recess," IEEE Electron Device Lett., **13**(10), 525–27 (1992c)
citric acid:$H_2O_2$ (1:1); InGaAs selective etch from InAlAs; selectivity 25
InGaAs etch rate 22 Å/s; InAlAs etch rate 0.89 Å/s

TONG, M., K. Nummila, A.A. Ketterson, I. Adesida, L. Aina, and M. Mattingly, "Selective Wet Etching Characteristics of Lattice-matched InGaAs/InAlAs/InP," J. Electrochem. Soc., **139**(10), L91–L93 (1992a)
Citric acid:$H_2O_2$ (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:$H_2O_2$ (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

TONG, N., D.G. Ballegeer, A. Jetterson, E.J. Roan., K.Y. Cheng, and I. Adesida, "A Comparative Study of Wet and Dry Selective Etching Processes for GaAs/AlGaAs/InGaAs Pseudomorphic MODFETs," J. Electron. Mater., **21**, 9 (1992b)
Citric acid:$H_2O_2$ (4:1); GaAs selective etch from $Al_xGa_{1-x}As$

| $x$ | Etch rate ratio |
|---|---|
| 0.17 | 1.5 |
| 0.30 | 155 |
| 0.45 | 260 |
| 1.00 | 1450 |

Reactive ion etch; $SiCl_4$:$SiF_4$ (1:9); GaAs selective etch from AlGaAs

TOPF, M., F. Cavas, B.K. Meyer, B. Kempf, W. Betz, and P. Veit, "Ion beam sputter etching of gallium nitride grown by chloride transport LP-CVD," Mater. Sci. Eng., **B59**, 345 (1999)
Ion beam etch of GaN using $CO_2$

TOWE, E.D., and T.J. Zamerowski, "Properties of Zn-doped InGaAs Grown by VPE on InP Substrates," J. Electron. Mater., **11**(5), 957–66 (1982)
$H_2SO_4$:$H_2O_2$:$H_2O$ (5:1:1) {Caro's etch}; Application: InP substrate cleaning first step, followed by:
$Br_2$/methanol (1%); Application: InP substrate cleaning second step for VPE

TRAPP, K.D.C., and F. Ermanis, "Origin and Elimination of Crescent-shaped growth defects in LPE Layers of InGaAs/InP Alloys," J. Electrochem. Soc., **130**(6), 1381–83 (1983)
$H_2SO_4$:$H_2O_2$:$H_2O$ (10:1:1); Application: InP substrate cleaning for LPE; needs careful $H_2O$ rinse to remove S contamination

TRASSAERT, S., B. Boudart, S. Piotrowicz, and Y. Crosnier, "Bromine/methanol wet chemical etching of via holes for InP microwave devices," J. Vac. Sci. Technol., B, **16**(2), 561 (1998)
$Br_2$/methanol (3%); Application: via holes in InP FETs; rate ~8 μm/min

TSAI, H.H., Y.K. Su, H.H. Lin, R.L. Wang, and T.L. Lee, "p–n Double Quantum Well Resonant Interband Tunneling Diode with Peak-to-Valley Current Ratio of 144 at Room Temperature," IEEE Electron Device Lett., **15**(9), 357–59 (1994)
$H_3PO_4$:$H_2O_2$:$H_2O$ (1:1:20); Application; InAlAs/InGaAs/InP mesa etch

TSANG, W.T., "In situ Monolayer Etching and Regrowth of InP/InGaAsP," IPRM'95, 789–92 (1995)
$AsCl_3$ in situ MBE vapor etch; GaAs surface cleaning
$PCl_3$ in situ MBE vapor etch; InP pattern etching for regrowth

TSANG, W.T., and A.Y. Cho, "Growth of GaAs–GaAlAs Over Preferentially Etched Channels by MBE: A Technique for Two-dimensional Thin-film Definition," Appl. Phys. Lett., **30**(6), 293–95 (1977)
$H_2SO_4$:$H_2O_2$:$H_2O$ (1:8:40); Application: GaAs (1 0 0) photolithography channel etch at 24°C; [0 1 1] and [0 1 1] cross-sectional profiles

TSANG, W.T., R. Kapre, and Sciortino, “Reactive Chemical Beam Etching of InP Inside a Chemical Beam Epitaxial Growth Chamber Using phosphorus Trichloride,” Appl. Phys. Lett., **62**(17), 2084–86 (1993)
Thermochemical vapor etch; $PCl_3$; InP in situ CBE etch

TSUKADA, N., S. Semura, H. Saito, S. Sugata, K. Asakawa, and Y. Mita, “Laser-Enhanced Reactive Ion Etching of GaAs with $CCl_4$ and $H_2$ Mixed Gas,” J. Appl. Phys., **55**(9), 3417–3420 (1984)
Reactive ion etch, laser enhanced; $CCl_4 + H_2$; GaAs

TSUKADA, N., S. Sugata, H. Saitoh, and Y. Mita, Appl. Phys. Lett., **43**(189), G011 (1983)TU, C.W., R.P.H. Chang, and A.R. Schlier, “Summary Abstract: Surface-etching Kinetics of Hydrogen Plasma on III–V Semiconductors,” J. Vac. Sci. Technol., A, **1**(2), 637–38 (1983)
Plasma; $H_2$; InP, GaAs, InGaAs surface cleaning

TU, C.W., P.H. Chang, and A.R. Schlier, “Surface Etching Kinetics of Hydrogen Plasma on InP,” Appl. Phys. Lett., **41**(1), 80–82 (1982)
$H_2$ plasma; high vacuum removal of surface contaminants form InP

TUCK, B., “Review: The Chemical Polishing of Semiconductors,” J. Mater. Sci., **10**, 321–39 (1975)
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

| Etch rates | (1 1 1)B ($mg/cm^2/s$) | (1 0 0) ($mg/cm^2/s$) |
|---|---|---|
| $HCl:HNO_3$ | 0.27 | 0.08 |
| HCl conc. | 0.15 | 0.08 |
| 0.4N $Fe^{3+}$ | 0.03 | 0.03 |
| $Br_2$/methanol (1%) | 0.016 | 0.03 |

TUCKER, A.W., and M. Birnbaum, “Laser Chemical Etching of Vias in GaAs,” IEEE Electron Device Lett., **EDL-4**(2), 39–41 (1983)
Thermochemical laser assisted dry etch of GaAs in $Cl_2$

TURLEY, S.E.H., and P.D. Greene, “LPE Growth on Structured (1 0 0) InP Substrates and Their Fabrication by Preferential Etching,” J. Cryst. Growth, **58**, 409 (1982)
Reactive ion etch; $CCl_2F_2/Ar/O_2$; InP and GaAs
$H_3PO_4:HCl$ (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 =∼ 12 μm/min at 25°C; gives $SiO_2$ masked profiles

UEDA, O., S. Yamakoshi, S. Komiya, K. Akita, and T. Yamaoka, "Transmission Electron Microscope Observation of Dark-spot Defects in InGaAsP/InP Double-heterostructure Light-emitting Diodes Aged at High Temperature," Appl. Phys. Lett., **36**(4), 300–01 (1980a)
HF:HBr (1:10); Application: InP selective etch from InGaAsP

UEDA, O., S. Yamakoshi, and T. Yamaoka, "Transmission Electron Microscope Observation Of Mechanical Damaged InGaAsP/InP Double-heterostructure Light-emitting Diode," Jpn. J. Appl. Phys., **19**(5), L251–L254 (1980b)
HF:HBr (1:10); Application: InP selective etch from InGaAsP
Ar ion thinning for TEM

UEKUSA, S., K. Oigawa, and M. Tacano, "Preferential Etching of InP for Submicron Fabrication with HCl/$H_3PO_4$ Solution," J. Electrochem. Soc., **132**(3), 671–73 (1985)
HCl:$H_3PO_4$ (5:95); InP (1 0 0) etch rate = 0.09 μm/min at 23°C
HCl:$H_3PO_4$ (10:90); InP (1 0 0) etch rate = 0.24 μm/min
HCl:$H_3PO_4$ (15:85); InP (1 0 0) etch rate = 0.40 μm/min
HCl:$H_3PO_4$ (20:80); InP (1 0 0) etch rate = 0.70 μm/min
HCl:$H_3PO_4$ (25:75); InP (1 0 0) etch rate = 1.05 μm/min
HCl:$H_3PO_4$ (20:80); InP (1 1 0) etch rate = 3.4 μm/min
HCl:$H_3PO_4$ (20:80); InP (1 1 1) etch rate = 2.6 μm/min

UEN, W.Y., and T. Nishinaga, "Growth of GaAs on Si by employing AlAs/GaAs double amorphous buffer.," J. Cryst. Growth, **128**, 521–26 (1993)
KOH molten at 400°C for 3–4 s; GaAs epilayer etch pit dislocation delineation

UENISISHI, Y., H. Tanaka, and H. Ukita, "Characterization of AlGaAs microstructure fabricated by AlGaAs/GaAs micromachining," IEEE Trans. Electron Devices, **41**(10), 1778 (1994)
$NH_4OH$:$H_2O_2$ (1:30); selective etch of $Al_{0.6}Ga_{0.4}As$ sacrificial layer for micromachining GaAs

UNGER, P., V. Boegli, P. Buchmann, and R. Germann, "Fabrication of Curved Mirrors for visible Semiconductor Lasers Using Electron-Beam Lithography and Chemically Assisted Ion-Beam Etching," J. Vac. Sci. Technol., B, **11**(6), 2514–18 (1993)
$Cl_2$ assisted Ar ion beam etching; Application: vertical sidewall laser mirrors in AlGaAs/AlGaInP

UNVALA, B.A., D.B. Holt, and A. San, "Jet Polishing of Semiconductors III. Polishing and shaping of Si, Ge, GaAs and GaP slices," J. Electrochem. Soc., **119**(3), 318 (1972)
NaOCl:HCl:$H_2O$ (2:2:16); scanning jet polishing of GaP
NaOCl:HCl:$H_2O$ (10:20:170); scanning jet polishing of GaAs

URAGAKI, T., H. Yamanaka, and M. Inoue, "Selective Etching of GaP Crystals with Hot Phosphoric Acid," J. Appl. Electrochem., **123**(4), 580–82 (1976)
HCl:$HNO_3$:$H_2O$ (2:1:2); GaP substrate etch to remove polish damage

$I_2$:KI:$H_2O$ (25 g:50 g:500 ml); photolithographic pattern etch in deposited Au layer
$H_3PO_4$ (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

UTAKA, K., K. Kobayashi, K. Kishino, and Y. Suematsu,. "1.5–1.6 μm GaInAsP/InP Integrated Twin-guide Lasers with First-Order Distributed Bragg Reflectors," Electron. Lett., **16**(12), 455–56 (1980a)
$H_2SO_4$:$H_2O_2$:$H_2O$ (3:1:1); Application: InGaAsP selective etch from InP
HCl:$H_2O$ (4:1); InP selective etch from InGaAsP

UTAKA, K., Y. Suematsu, K. Kobayashi, and H. Kawanishi, "GaInAsP/InP Integrated Twin-guide Lasers with first-order Distributed Bragg Reflectors at 1.3 μm Wavelength", Jpn. J. Appl. Phys., **19**(2), L137–L140 (1980b)
$H_2SO_4$:$H_2O_2$:$H_2O$ (3:1:1); Application: InGaAsP selective etch from InP
HCl:$H_2O$ (4:1); InP selective etch from InGaAsP

VAL'KOVSKAYA, M.I., and Yu S. Boyarskaya, "Revelation of Dislocations and Dislocation Structure Emerging During the Deformation of Gallium Phosphide Single Crystals," Sov. Phys. Solid State, **8**(8), 1976–78 (1967)
$Br_2$/ethanol (20%), hot; GaP dislocation etch pit delineation; 30–60 s
$FeCl_3$:HCl:$H_2O$ (27 g:250 ml:350 ml), boiling; GaP dislocation etch pit delineation; 12–18 min
KOH:$K_3Fe(CN)_6$:$H_2O$ (6 g:4 g:50 ml) boiling; GaP dislocation etch pit delineation; 1–2 min

VAN De VEN, J., A.F. Lourens, J.L. Weyher, and L.J. Giling, "Defect-selective Etching of GaAs in $CrO_3$–HCl, Chemtronics," **1**, 19–26 (1986a)
$CrO_3$:HCl:$H_2O$; GaAs defect delineation study; shows etch characteristics dependence on composition; gives high defect sensitivity for low HCl/$CrO_3$ ratios under illumination

VAN DE VEN, J., and H.J.P. Nabben, "Analysis of Determining Factors in the Kinetics of Anisotropic Photoetching of GaAs," J. Appl. Phys., **67**(12), 7572–75 (1990a)
GaAs n-type photoetching study

VAN DE VEN, J., and H.J.P. Nabben, "Anisotropic Photoetching of III–V Semiconductors: I. Electrochemistry," J. Electrochem. Soc., **137**(5), 1603–10 (1990b)
$H_2O_2$/$H_2SO_4$ and $S_2O_8^{2-}$/$H_2SO_4$ aqueous solution electrolytes; Study: GaAs photochemical etch behavior

VAN DE VEN, J., and H.J.P. Nabben, "Anisotropic Photoetching of III–V Semiconductors: II. Kinetic and Structural Factors," J. Electrochem. Soc., **138**(1), 144–52 (1991)
$H_2SO_4$:$H_2O_2$:$H_2O$; GaAs n-type photoetching behavior

VAN DE VEN, J., J.L. Weyher, J.E.A.M. van der Meerakker, and J.J. Kelly, "Kinetics and Morphology of GaAs Etching in Aqueous $CrO_3$–HF Solutions," J. Electrochem. Soc., **133**(4), 799–805 (1986b)
$CrO_3$:HF; GaAs etch and photoetch chemical kinetics

VAN ES, C.M., T.J. Eijkemans, J.H. Wolter, R. Pereira, M. Van Hove, and M. Van Rossum, "Transport and Optical Properties of AlGaAs/GaAs Pseudomorphic AlGaAs/InGaAs/GaAs Heterostructures Subjected to $CH_4/H_2$ Reactive Ion Etching," J. Appl. Phys., **74**(10), 6242–50 (1993)

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

VAN GEELEN, A., P.R. Hageman, G.J. Bauhuis, P.C. van Rijsingen, P. Schmidt, and L.J. Giling, "Epitaxial lift-off GaAs solar cell from a reusable GaAs substrate," Mater. Sci. Eng. B, **B45**, 162 (1997)

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)

VAN GURP, G.J., J.M. Jacobs, J.J.M. Binsma, and L.F. Tiemeijer, "InGaAsP/InP Lasers with Two Reactive-Ion-Etched Mirror Facets," Jpn. J. Appl. Phys., **28**(7), L 1236–38 (1989)

Reactive ion etch; $Cl_2 + CH_4 + H_2 + Ar$; Application: mirror facet etch for InGaAsP/InP lasers

VAN HASSEL, J.G., H.C. Heyker, and J.J.M. Kwaspen, "Influence of in situ argon cleaning of GaAs on Schottky diodes and metal–semiconductor field-effect transistors," J. Vac. Sci. Technol., B, **13**(6), 2245 (1995)

Ar ion surface cleaning of GaAs; damage effects on Schottky diodes

VAN ROIJEN, R., C.W.T. Bulle-Lieuwma, and E.A. Montie, "Formation and Damage of Sidewalls after $Cl_2/CH_4$-Based Reactive Ion Beam of InP," J. Vac. Sci. Technol., B, **10**(5), 2188–91 (1992)

Reactive ion etch study; $Cl_2/Ar/CH_4/H_2$; InP photolithography sidewall damage

VAN ROIJEN, R., M.B.M. Kemp, C.W.T. Bulle-Lieuwma, L.J. van Ijzendoorn, and T.L.G. Thijssen, "Surface Analysis of Reactive Ion-etched InP," J. Appl. Phys., **70**(7), 3983 (1991)

$H_2SO_4:H_2O_2$ (5:1); InP substrate cleaning; removal of surface contaminants and oxides prior to RIE

Reactive ion etching; $Cl_2$; InP

VARTULI, C.B., J.D. MacKenzie, J.W. Lee, C.R. Abernathy, S.J. Pearton, and R.J. Shul, "$Cl_2/Ar$ and $CH_4/H_2/Ar$ dry etching of III–V nitrides," J. Appl. Phys., **80**(7), 3705 (1996a)

ECR and RIE with $Cl_2/Ar$ and $CH_4/H_2/Ar$; rates for GaN, AlN, InN, and InGaN

VARTULI, C.B., S.J. Pearton, J.W. Lee, A.Y. Polyakov, M. Shin, D.W. Greve, M. Skronowski, and R.J. Shul, "Electron cyclotron resonance plasma etching of AlGaN in $Cl_2/Ar$ and $BCl_3/Ar$ plasmas," J. Electrochem. Soc., **144**(6), 2146 (1997a)

ECR etch; $Cl_2/Ar$ and $BCl_3/Ar$; AlGaN etch behavior

VARTULI, C.B., S.J. Pearton, J.W. Lee, J.D. MacKenzie, C.R. Abernathy, and R.J. Shul, "Electron cyclotron resonance etching of III–V nitrides in IBr/Ar plasmas," J. Vac. Sci. Technol., B, **15**(1), 98 (1997b)

ECR etch study; IBr/Ar of GaN, InN, InAlN, Aln, and InGaN

VARTULI, C.B., S.J. Pearton, C.R. Abernathy, C.R. Shul, A.J. Howard, S.P. Kilcoyne, J.E. Parmeter, and M. Hagerott-Crawford, ‘‘High density plasma etching of III–V nitrides,’’ J. Vac. Sci. Technol., A, **14**(3), 1011 (1996b)

ECR, high density plasma etch; $CH_4/H_2$, $Cl_2H_2$, $HBr/H_2$, $HI/H_2$ of GaN, InN and AlN

VARTULI, C.B., S.J. Pearton, J.W. Lee, J. Hong, J.D. MacKenzie, C.R. Abernathy, and R.J. Shul, ‘‘ICl/Ar electron cyclotron resonance plasma etching of III–V nitrides,’’ Appl. Phys. Lett., **69**(10), 1426 (1996c)

ECR etch; ICl/Ar of GaN, InN, InAlN, AlN, and InGaN

VARTULI, C.B., S.J. Pearton, J.W. Lee, J.D. MacKenzie, C.R. Abernathy, R.J. Shul, C. Constantine, and C. Barrat, ‘‘Inductively coupled plasma etching of III–V nitrides in $CH_4/H_2/Ar$ and $CH_4/H_2/N_2$ chemistries,’’ J. Electrochem. Soc., **144**(8), 2844 (1997c)

ICP etch; $CH_4/H_2/Ar$ and $CH_4/H_2/N_2$; GaN, AlN, InN, InGaN, and InAlN

VARTULI, C.B., S.J. Pearton, J.W. Lee, J.D. MacKenzie, C.R. Abernathy, and R.J. Shul, ‘‘Plasma etching of III-nitrides in ICl/Ar and IBr/Ar plasmas,’’ J. Vac. Sci. Technol., A, **15**(3), 638 (1997d)

ECR plasma etch of GaN, InN, and InGaN in ICl/Ar and IBr/Ar; selective etch of GaN from InN, AlN, or InAlN

VARTULI, C.B., S.J. Pearton, J.W. Lee, C.R. Abernathy, J.D. Mackensie, J.C. Zolper, R.J. Shul, and F. Ren, ‘‘Wet chemical etching of AlN and InAlN in KOH solutions,’’ J. Electrochem. Soc., **143**(11), 3681 (1996d)

AZ400K photolithographic developer (active ingredient KOH); etch study of AlN and InAlN between 20 and 80°C

VARTULLI, C.B., S.J. Pearton, J.D. MacKenzie, C.R. Abernathy, and R.J. Shul, ‘‘Selective Dry Etching of III–V Nitrides in $Cl_2/Ar$, $CH_4/H_2/Ar$, ICl/Ar, and IBr/Ar,’’ J. Electrochem. Soc., **143**(10), L246 (1996e)

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

VAWTER, G.A., J.F. Klem, and R.E. Leibenguth, ‘‘Improved Epitaxial Layer Design for Real-Time Monitoring of Dry Etching in III–V Compound Heterostructures with Depth Accuracy of $\neq 8$ nm,’’ J. Vac. Sci. Technol., A, **12**(4), 1973–77 (1994)

Reactive ion beam etch, in situ optical monitoring; AlGaAs/GaAs

VENABLES, J.D., and R.M. Broudy, ‘‘Dislocations and Selective Etch Pits in InSb,’’ J. Appl. Phys., **29**(7), 1025–28 (1958)

$HF:HNO_3$ (1:1); InSb polish etch, 2–5 s, following mechanical polishing to delineate dislocation etch pits

VERMAAK, J.S., L.W. Snyman, and F.D. Auret, ‘‘On the Growth of Au on Clean and Contaminated GaAs (0 0 1) Surfaces,’’ J. Cryst. Growth, **42**, 132–35 (1977)

GaAs surface cleaning analysis by Auger analysis and Au layer epitaxy behavior: $H_2SO_4$:$H_2O_2$:$H_2O$ (3:1:1); $NH_4OH$:$H_2O_2$:$H_2O$ (1:1:2); HF:$HNO_3$:$H_2O$ (2:2:1)

VERMEIR, I.E., and W.P. Gomes, "The etching of InP by acidic iodine solutions; A kinetic and electrochemical study," J. Electrochem. Soc., **143**(4), 1319 (1996)
$I_2$:KI:HCl; study of etch and photoelectrochemical etch of InP (0 0 1)

VERMEIR, I.E., H.H. Goossens, P. Vanden Kerchov, and W.P. Gomes, "Electrochemical and Etching Behavior of InP Single Crystals in Iodic Acid," J. Electrochem. Soc., **139**(5), 1389–96 (1992)
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:$H_2SO_4$; study of etch and photoelectrochemical etch of $Al_{0.25}Ga_{0.75}As$ and GaAs on etch conditions

VOGT, K.W., and P.A. Kohl, "Gallium Arsenide Passivation Through Nitridation with Hydrazine," J. Appl. Phys., **74**(10), 6448–50 (1993)
Surface passivation; GaAs; nitridation with hyrazine

VOZMILOVA, L.N., and M.M. Berdichenko, "Local Etching of InP in Anisotropic Etching Agents," Inorg. Mater., **21**(8), 1110–12 (1985)
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:$H_3PO_4$ (1:1), etch rate = 2.6 μm/min
HCl:$CH_3COOH$ (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:$H_3PO_4$ (1:1), etch rate = 7.3 μm/min
HBr:$CH_3COOH$ (1:1), etch rate = 0.9 μm/min
$HNO_3$:HCl:$HClO_4$:$CH_3COOH$ (6:1:1:1), etch rate = 3.1 μm/min
$HNO_3$:HCl:$H_2O$:$CH_3COOH$ (3:1:1:1), etch rate = 2.5 μm/min
All etchants show no undercutting in the $\langle 1\ 1\ 0\rangle$A direction and are suitable for self-limiting vee-grooves. Only the anhydrous $Br_2$ etch shows no undercutting in the $\langle 1\ 1\ 0\rangle$B direction

VUIK, C., and C. Cuvelier, "Numerical solution of an etching problem," J. Comput. Phys., **59**, 247 (1985)
Modeling of resist pattern etching

WADA, O., "Ion-beam Etching of InP and its Application to the Fabrication of High Radiance InGaAsP/InP LEDs," J. Electrochem. Soc., **131**(10), 2373–80 (1984)
Ar ion etching; Application: InP LED microlenses

WADA, O., S. Yamakoshi, M. Abe, Y. Nishitani, and T. Sakurai, "High Radiance InGaAsP/InP Lensed LEDs for optical Communication Systems at 1.2–.3 μm," IEEE J. Quantum Electron., **QE-17**(2), 174–78 (1981)

Ar ion beam etching; Application: InP spherical lens formation

WADA, O., S. Yanagisawa, and H. Takanashi, "Process for GaAs Monolithic Integration Applied to Gunn-effect Logic Circuits," J. Electrochem. Soc., **123**(10), 1546–51 (1976)

$H_2SO_4$:$H_2O_2$:$H_2O$ (1:8:1); GaAs photolithography; use of undercutting of a metal layer as a fabrication step

WAGER, J.F., D.L. Ellsworth, S.M. Goodnick, and C.W. Wilmsen, "Composition and Thermal Stability of Thin Native Oxides on InP," J. Vac. Sci. Technol., **19**(3), 513–18 (1981)

Study of oxide formation on $Br_2$/methanol etched InP

WAGNER, W.R., L.I. Greene, and L.I. Koszi, "Defect-revealing Etches on GaAs: A Comparison of the AHA with the A/B and KOH Etches," J. Electrochem. Soc., **128**(5), 1091 (1981)

$NH_4OH$ electrochemical etch; GaAs; dislocation etch pit delineation; comparison with A–B etch and molten KOH etch

WAKAO, K., K. Moriki, M. Kitamura, K. Iga, and Y. Suematsu, "GaInAsP Terraced Substrate Single Mode Laser," IEEE J. Quantum Electron., **QE-17**, 1009 (1981)

HCl:$CH_3COOH$:$H_2O_2$ (1:2:1) {KKI etch}; Application: InGaAsP groove and mesa etch

WALKER, D.M., (NOSC monthly progress report, SDSU Contract, Naval Ocean Systems Center, San Diego, CA), (June), (1980)

$HgCl_2$: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 $HgCl_2$: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 $Br_2$ or $Br_2$/methanol can be neutralized with 5–10% sodium thiosulfate solution

WALLIN, J., G. Landgren, K. Streubel, S. Nilsson, and M. Oberg, "Selective Area Regrowth of Butt-joint Coupled Waveguides in Multi-section DBR Lasers," J. Cryst. Growth, **124**, 741–46 (1992)

$H_2SO_4$:$H_2O_2$:$H_2O$ (8:1:1); Application: InGaAsP selective etch from InP; HBr:$H_2O_2$:$H_2O$ (1:1:10); InGaAsP/InP non-selective etch; HCl:$H_2O$ (4:1); InP selective etch from InGaAsP at 4°C

WANG, C.A., C.W. Krueger, M. Flytzani-Stephanopoulis, and R.A. Brown, "OMVPE Regrowth of $CH_3I$-vapor-etched GaAs," J. Electron. Mater., **21**(3), 299–304 (1992)

Thermochemical vapor etch; $CH_3I$; GaAs in situ OMVPE gas etch at 450°–500°C

WANG, J., B.J. Robinson, D.A. Thompson, and J.G. Simmons, "InGaAs/InP quantum wires grown by gas source molecular beam epitaxy onto vee-grooved InP substrates with (1 1 1)A facet sidewalls," Appl. Phys. Lett., **67**(16), 2358 (1995)
$HBr:H_3PO_4:K_2Cr_2O_7$ (2:2:1); InP vee-groove (1 1 1)A facet etch through $SiO_2$ mask at 23°C

WANG, J., D.A. Thompson, and J.G. Simmons, "Wet chemical etching for vee-grooves into InP substrates," J. Electrochem. Soc., **145**(8), 2931 (1998)
$Br_2$/methanol (2%); vee-groove etching behavior with $SiO_2$ and photoresist masks
$HBr:H_3PO_4:K_2Cr_2O_7$ (2:2:1); vee-groove etching behavior with $SiO_2$ and photoresist masks
$HCl:H_3PO_4$ (5:1); vee-groove etching behavior with $SiO_2$, photoresist and InGaAs masks. Shows groove shape dependence on mask alignment. Citric acid (50 wt.%):$H_2O_2$ (3:1); selective etch to define InGaAs mask pattern for HCl etching of InP

WANG, X.-S., R.J. Pechman, and J.H. Weaver, "Ion sputtering of GaAs(1 1 0): From individual bombardment events to multilayer removal," J. Vac. Sci. Technol., B, **13**(5), 2031 (1995)
Ar and Xe ion sputtering of GaAs (1 1 0); STM study of damage

WANG, X.-L., A. Wakahara, and A. Sasaki, "Strong Electroluminescence of AlP/GaP Disordered Superlattices," 1993 Electronic Materials Conference, UCSB, Santa Barbara, CA, June 23–25; paper E2; Abstract in J. Electron. Mater., **22**(7A), (1993)
$HNO_3:HCl:H_2O$; Application: GaP (1 0 0) substrate cleaning for OMVPE followed by: $(NH_4)_2S_x$ solution surface treatment to remove oxide

WAREKOIS, E.P., and P.H. Metzger, "X-ray Method for the Determination of {1 1 1} Surfaces in III–V Semiconductor Compounds," J. Appl. Phys., **30**(7), 960–62 (1959)
$HNO_3:HF:CH_3COOH:Br_2$ (75:15:15:0.06); InSb {1 1 1}A and {1 1 1}B etch figures for determining orientation polarity

WATANABE, H., and S. Matsui, "Low-damage Electron-Beam Assisted Dry Etching of GaAs and AlGaAs Using Electron Cyclotron Resonance Plasma Electron Source," J. Vac. Sci. Technol., B, **11**(6), 2288–93 (1993a)
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
$HCl:H_2O$ (1:10); GaAs native oxide removal at 25°C
$H_3PO_4$; AlGaAs native oxide removal at 60°C
$H_3PO_4:H_2O_2:H_2O$ (4:1:90); Application: n-GaAs selective etch from $Al_{0.4}Ga_{0.6}As$ at 25°C

WATANABE, H., Y. Ochiai, and S. Matsui, "Effects of Electron-Beam-Assisted Dry Etching on Optical and Electrical Properties," Appl. Phys. Lett., **63**(11), 1516–18 (1993b)
Electron beam assisted dry etch; $Cl_2 + SF_6$; GaAs selective etch from AlGaAs
$H_3PO_4:H_2O_2:H_2O$ (4:1:90); GaAs selective etch from AlGaAs
$HCl:H_2O$ (1:10); GaAs native oxide removal, 3 min

WATANABE, N., T. Nittono, H. Ito, N. Kondo, and Y. Nanishi, "Surface Cleaning of C-Doped p+ GaAs with Hydrogen Electron Cyclotron Resonance Plasma," J. Appl. Phys., **73**(12), 8146–50 (1993)
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

WEBB, A.P., "In situ monitoring during ion beam processing of multilayer epitaxial III–V device structures," Semicond. Sci. Technol
CAIBE etch, in situ monitoring of secondary ion species

WEBB, A.P., and R.S. Sussmann, "Ion Beam Etching InP at Elevated Temperatures," Vacuum, **36**(1–3), 47–49 (1986)
Ion beam etch; $Ar + O_2$; InP
cone appearance on InP surface when etched with Ar alone; reducing $O_2$ 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

WEBB, A.P., and C.D.W. Wilkinson, "Ion Beam Etching GaAs for Integrated Optics Applications," Vacuum, **34**(1–2), 159–62 (1984)
Ion beam; Ar, $CCl_2F_2$; GaAs, AlGaAs, InP; Application: stripe waveguide profiles

WEI, C., K. Rajeshwar, K. Pathak, R.N. Alavi, and L.T. Wang, "Photoelectrochemical Depth Profiling of Molecular Beam Epitaxy Grown Group III–V Heterostructures," Appl. Phys. Lett., **60**(11), 1348–50 (1992)
HCl (0.5 M); photoelectrochemical depth profile etch for AlGaAs/GaAs

WENDT, J.R., G.A. Vawter, R.E. Smith, and M.E. Warren, "Fabrication of subwavelength, binary, antireflection surface-relief structures in the near infrared," J. Vac. Sci. Technol., B, **14**(6), 4096 (1996)
reactive ion beam etch process; $Cl_2$; GaAs process for fabricating antireflection surface structure

WESTBROOK, L.D., A.W. Nelson, and P.J. Fiddyment, "New Diffraction Grating profiles in InP DFB Lasers and Integrated Optics," Electron. Lett., **19**(25/26), 1076–77 (1983)
{$SiO_2$ masked etch profile study.}
HCl conc.; InP
$HCl:H_3PO_4$ (1:3) and $HCl:CH_3COOH$ (1:1) give rectangular groove grating
$HBr:CH_3COOH$ (1:1) gives sawtooth grating

WESTPHALEN, R., B. Elsber, M. Maassen, O. Kayser, K. Heime, and P. Balk, "Selective embedded growth by LP-MOVPE in the GaInAsP system," J. Cryst. Growth, **125**, 347–62 (1992)

$HCl:HNO_3:H_3PO_4$ (1:1:5); InP (1 0 0) groove etch; rectangular shaped along ⟨0 1 1⟩
$HCl:H_3PO_4$ (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⟩
$Br_2$/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⟩
$H_3PO_4:H_2O_2:H_2O$ (1:9:3); GaAs (1 0 0) groove etch, reverse-mesa shaped groove along ⟨0 1 1⟩
$H_2SO_4:H_2O_2:H_2O$ (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 Densities Grown by Isoelectronic Doping of Hydride VPE Grown InP," J. Cryst. Growth, **96**, 982–84 (1989)
$H_3PO_4:HBr$ (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," J. Appl. Phys., **58**(1), 219–22 (1985)
$CrO_3:HF:H_2O$ {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 $CrO_3$–HF Aqueous Solutions, part I," J. Cryst. Growth, **63**, 285–91 (1983a)
$CrO_3:HF:H_2O$; GaAs (1 0 0) etch and photoetch defect delineation

WEYHER, J., and W.J. Van Enckevort, "Selective Etching and Photoetching in $CrO_3$–HF Aqueous Solutions, part 2," J. Cryst. Growth, **63**, 292–98 (1983b)
$CrO_3:HF:H_2O$; GaAs (1 0 0) etch and photoetch defect delineation

WEYHER, J.L., and J. Van De Ven, "Selective etching and photoetching of GaAs in $CrO_3$–HF aqueous solutions III. Interpretation of defect-related etch figures," J. Cryst. Growth, **78**, 191 (1986)
$CrO_3:HF:H_2O$ (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–$K_2Cr_2O_7$–$H_2O$ etching system for indium phosphide," Mater. Sci Eng. B, **28**, 488 (1994)
HBr–$K_2Cr_2O_7$–$H_2O$ (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 GaN," J. Cryst. Growth, **182**, 17–22 (1997)
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. Sci. Eng. B, **B55**, 79 (1998)
$H_2SO_4:H_2O_2:H_2O$ (5:1:1); jet thinning of GaAs for TEM
DSL (dilute Syrtl like) etch to reveal as precipitates for TEM study

WHALEY, R.D., B. Gopalan, M. Gagenais, R.D. Gomez, F.G. Johnson, S. Agarwala, O. King, and D.R. Stone, "Use of atomic force microscopy for analysis of high performance InGaAsP/InP semiconductor lasers with dry-etched facets," J. Vac. Sci. Technol., B, **16**(3), 1007 (1998)
Reactive ion etch; $CH_4/H_2/Ar$; facet formation in InGaAsP/InP lasers

WHELAN, C.S., T.E. Kazior, and K.Y. Hur, "High rate $CH_4:H_2$ plasma etch processes for InP," J. Vac. Sci. Technol., B, **15**(5), 1728 (1997)]
ECR plasma etch; $CH_4/H_2/Ar$; InP etch process with rate in excess of 120 nm/min
RIE using $CH_4/H_2/O_2$; InP etch process with rate in excess of 135 nm/min

WHITE, J.G., and W.C. Roth, "Polarity of Gallium Arsenide Single Crystals," J. Appl. Phys., **30**, 346–47 (1959)
$HCl:HNO_3:H_2O$ (2:1:2); GaAs discrimination of (1 1 1)A from (1 1 1)B Surfaces

WHITNEY, P.S., and K. Uwai, "Compensation ratios in High Purity InP Using an Improved Hall Measurement," J. Appl. Phys., **63**(5), 1585–90 (1988)
$HBr:H_3PO_4:1N.K_2Cr_2O_7$ (2:2:1), dilute (1:1) with $H_2O$; Application: InP uniform thinning etch for incremental Hall measurements; etch rate ~300 Å/s

WIEDENSOHLER, A., H.-C. Hansson, I. Maximov, and L. Samuelson, "Nanometer Patterning of InP Using Aerosol and Plasma Etching Techniques," Appl. Phys. Lett., **61**(7), 837–39 (1992)
ECR etch; $CH_4/Ar/H_2$; InP nanometer size, Ag-masked features

WILLIAMSON, J.B., and K.W. Carey, "Dopant-type Selective Electroless Photoetching of Zn-diffused InP and InGaAs/InP Heterostructures," J. Electrochem. Soc., **140**(7), 2125–28 (1993)
$HCl:HNO_3:H_2O$ (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
$K_3Fe(CN)_6:KOH:H_2O$ (10 g:10 g:100 ml) comparison

WILLIAMS, J.O., P.D. Wright, M.A. Elmorsi, and S.E. Morsi, "Anodic Oxidation of InP and the Quaternary Alloy GaInAsP," J. Mater. Sci., **13**, 2292 (1978)
Anodization; InP and InGaAsP

WILLIAMS, P.J., A.P. Webb, I. H. Goodridge, and A.C. Carter, "Planar VPE Infill 1.3 μm Integrated Laser/monitor Photodiode with CARIBE Etched Facets," Electron. Lett., **22**, 472 (1986)
Reactive ion etch; chemically assisted; Application: InGaAsP/InP photodiode facet etch

WILLIAMS, R., "Dry Etching-Plasma, RIE, RIBE, Ion Milling," Chapter 9 of Modern GaAs Processing Methods (Artech House, Boston/London, 1990a), p. 173
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

WILLNER, A.E., D.V. Podlesnik, H.H. Gilgen, and R.M. Osgood, “InGaAsP/InP Buried-heterostructure Photobias Effect in Laser-controlled Etching of InP,” Appl. Phys. Lett., **53**(13), 1198–200 (1988)
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

WILLNER, A.E., M.N. Ruberto, D.J. Blumenthal, D. Podlesnik, and R.M. Osgood, “Laser Fabricated GaAs Waveguiding Structures,” Appl. Phys. Lett., **54**(19), 1839–41 (1989)
HF:$HNO_3$:$H_2O$ (4:1:50); Application: GaAs photoetch for waveguide fabrication; AlGaAs/GaAs Ar-laser-induced etch rate = 750 μm/min

WIPIEJEWSKI, T., and K.J. Ebeling, “In Situ Controlled Wet Chemical Etching of Layered AlGaAs Structures with Interferometric Accuracy,” J. Electrochem. Soc., **140**(7), 2028–33 (1993)
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

WISSMANN, H., T. Tran Anh, S. Rogaschewski, and M. von Ortenberg, “Self-organized MBE growth of II–Vi epilayers on patterned GaSb substrates,” J. Cryst. Growth, **201/202**, 619 (1999)
HCl:$H_2O_2$:$H_2O$ (1:1:2); anisotropic stripe pattern etch on GaSb (1 0 0) at 5°C

WOODWARD, J., G.T. Brown, B. Cockayne, and D.C. Cameron, “Substrate Effects on Performance of InP MOSFETs,” Electron. Lett., **18**(10), 415–17 (1982)
$H_2O$:$AgNO_3$:$CrO_3$:HF (2 ml:8 mg:1 g:1 ml); A–B etch; Application: InP dislocation etch pit delineation

WRICK, V., G.J. Scilla, L.F. Eastman, R.L. Henry, and E.M. Swiggard, “In Situ In Etching Technique for LPE InP,” Electron. Lett., **12**(16), 394–95 (1976)
Indium metal solution etch; Application: for InP LPE in situ substrate cleaning

WRIGHT, P.D., and R.J. Nelson, “High-efficiency Stripe-geometry InGaAsP DH Lasers (1.3 μm) with Chemically-etched Mirrors,” IEEE Electron Device Lett., **EDL-1**, 242 (1980a)
$Br_2$/methanol; Application: InGaAsP/InP laser mirror etch

WRIGHT, P.D., R.J. Nelson, and T. Cella, “High-gain InGaAsP Heterojunction Phototransistors,” Appl. Phys. Lett., **37**(2), 192–94 (1980b)
$Br_2$/methanol; Application: InGaAsP/InP non-selective mesa etch

WRIGHT, P.D., R.J. Nelson, and T. Cella, “InGaAsP Double Heterostructure Lasers (1.3 μm) with Etched Reflectors,” Appl. Phys. Lett., **36**(7), 518–20 (1980c)

$Br_2$/methanol (0.2%); Application: photolithography, InP vee-grooves; laser mirror etch with (1 1 1)A facets; very little mask undercutting

WRIGHT, P.D., R.J. Nelson, and R.B. Wilson, “Monolithic Integration of InGaAsP Heterostructure Lasers and Electro-optical Devices,” IEEE J. Quantum Electron., **QE-18**(2), 249–58 (1982)

$Br_2$/methanol; Application: InGaAsP/InP laser mirror etch
$H_2SO_4$:$H_2O_2$:$H_2O$ (10:1:1); InGaAsP selective etch from InP
HCl:$H_2O$ (4:1); InP selective etch from InGaAsP

WRIGHT, P.D., E.A. Rezek, and N. Holonyak, “Lattice-matching and Dislocations in LPE InGaPAs–InP Heterojunctions,” J. Cryst. Growth, **41**, 254–61 (1977)

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

WU, D., L. Liu, J. Marcano, Y. Darici, N. Paul, and S. Mergui, “Temperature studies of sulfur passivated GaAs(1 0 0) contacts,” Mater. Sci. Eng. B, **B46**, 61 (1997)

$P_2S_5$:$(NH_4)_2S$:$S_x$ solution; Application: sulfur passivation of GaAs
$(NH_4)_2S_x + 6\%$ S solution; Application: sulfur passivation of GaAs

WU, X.S., L.A. Coldren, and J.L. Merz, “Selective etching characteristics of HF for $Al_xGa_{1-x}As$/GaAs,” Electron. Lett., **21**(13), 558 (1985)

HF(48%); selective removal of $Al_xGa_{1-x}As$ from GaAs: $Al_xGa_{1-x}As$ etch rates versus $x$ at 80°C

XIAO, H.Z., N.-E. Lee, R.C. Powell, Z. Ma, L.J. Chou, L.H. Allen, and J.E. Greene, “Defect ordering in epitaxial a-GaN (0 0 0 1),” J. Appl. Phys., **76**(12), 8195 (1994)

$H_2SO_4$:$H_3PO_4$ (3:1); surface preparation of $Al_2O_3$ (0 0 0 1) substrates at 160°C for GaN growth by MBE

XING, Y.R., Z. Jamal, T.B. Joyce, T.J. Bullough, and C.J. Goodhew, P. J. Kiely, “Growth of High Quality Gallium Arsenide on HF-etched Silicon (0 0 1) by Chemical Beam epitaxy,” Appl. Phys. Lett., **62**(14), 1653–55 (1993)

HF:$H_2O$ (1:5); Silicon substrate contaminant removal step, 2 min; HCl:$H_2O_2$:$H_2O$ (3:3:5); Silicon substrate oxidation step, 2 min followed by HF:$H_2O$ step for three times prior to loading for CBE growth of GaAs

YABLONOVITCH, E., R. Bhat, C.E. Zhat, T.J. Gmitter, and M.A. Koza, “Nearly Ideal InP/InGaAs Heterojunction Regrowth on Chemically Prepared InGaAs Surfaces,” Appl. Phys. Lett., **60**(3), 371–73 (1992)

$Br_2$/methanol (1:2000); InGaAs best surface cleaning for InP OMVPE regrowth on patterned InGaAs, or alternative: Saturated $Br_2$ water:HBr:$H_2O$ (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

$H_2SO_4$:$H_2O_2$:$H_2O$ (1:8:5000); etch rate = 20 Å/s; for 30 s; InGaAs surface cleaning
$H_2SO_4$:$H_2O_2$:$H_2O$ (1:8:500); $H_2SO_4$:$H_2O_2$:$H_2O$ (1:8:50)
{Compares surface recombination velocity of regrown InP/InGaAs for various cleaning methods.}

YABLONOVITCH, E., T. Gmitter, J.P. Harbison, and R. Bhat, "Extreme Selectivity in the Lift-off of Epitaxial GaAs Films," Appl. Phys. Lett., **51**(26), 2222–24 (1987)
HF (10%): AlAs selective etch lift-off of a AlGaAs/GaAs layer; selectivity of >107 between AlAs and $Al_{0.4}Ga_{0.6}As$; onset of etching occurs for compositions greater than 40–50% aluminum

YAMAGUCHI, K., and S. Tada, "Fabrication of GaAs microtips for scanning tunneling microscopy by wet etching," J. Electrochem. Soc., **143**(8), 2616 (1996)
$H_3PO_4$:$H_2O_2$:$H_2O$ (10:1:1); shaping of GaAs microtips for scanning tunneling microscopy; shape dependence on $H_3PO_4$ concentration and etch temperature. $(NH_4)_2S_x$ 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 by Electrochemical Etching Under Illumination.," J. Electrochem. Soc., **128**(5), 1095–100 (1981)
1 M NaOH is electrolyte; n-InP defect delineation electrochemical etch under illumination
$H_3PO_4$:HBr(2:1) {Huber etch}; defect delineation comparison

YAMAMOTO, A., and S. Yano, "Anodic Dissolution of n-type Gallium Arsenide Under Illumination," J. Electrochem. Soc., **122**(2), 260–67 (1975)
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 (RIE)," J. Cryst. Growth, **193**, 16 (1998)
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
$H_2SO_4$; treatment to remove RIE etch polymer by-products
$(NH_4)_2S_x$ (6.0–7.5% sulfur concentration); room temperature for 10 min; followed by $H_2SO_4$ treatment to reduce surface impurities; process acronym is (ACE); surface preparation of InP mesa devices for InP MOVPE regrowth; study of regrown interface quality

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 ($CH_4$) or ethane ($C_2H_6$) and hydrogen ($H_2$)," J. Vac. Sci. Technol., B, **15**(1), 103 (1997a)
Reactive ion etching; $CH_4/H_2$ & $C_2H_6/H_2$; electrical measurement study of InP surface damage

YAMAMOTO, N., K. Kishi, S. Matsumoto, Y. Kadoto, H. Okamoto, and H. Mawatari, "Electrical drift phenomena due to deep donor defects induced by reactive ion etching (RIE) using mixture of ethane ($C_2H_6$) and hydrogen ($H_2$)," Jpn. J. Appl. Phys. Pt. 2, **36**(6A), L654 (1997b)
Reactive ion etching; $C_2H_6/H_2$ of InP; electrical drift from etch-induced deep donor defects

YAMAMOTO, Y., and H. Kanbe, "Zn Diffusion in InGaAs with $ZnAs_2$ source," Jpn. J. Appl. Phys., **19**(1), 121–28 (1980)

$HF:H_2O_2:H_2O$ (1:1:10); Application: InGaAs diffused p–n junction cross-section delineation; 20–15 s under illumination

YAMAZOE, Y., T. Nishino, and Y. Hamakawa., "Electroreflectance Study of InGaAsP Quaternary Alloys Lattice Matched to InP," IEEE J. Quantum Electron., **QE-17**(2), 139–43 (1981)

$H_2SO_4:H_2O_2:H_2O$ (5:1:1); Application: InGaAsP surface preparation for Schottky contact

YANG, L.W., R.S. Brozovich, F. Ren, C.R. Abernathy, S. J. Pearton, J. R. Lothian, B.S. Mercer, and J.E. Spencer, "High Speed InGaP Emitter HBTs Fabricated with ECR Dry Etch Technique," InP and Related Material Conference Proceedings, 1994, (IEEE cat. no. 94CH 3369-6), paper $ThC_4$, pp. 563–66

ECR plasma etch; $BCl_3/Ar$; GaAs

ECR plasma etc; $CH_4/H_2/Cl_2/Ar$; InGaP; Application InGaP/GaAs HBTs

YANG, Y.J., K.Y. Hsieh, and R.M. Kolbas, "Continuous Room-temperature Operation of an InGaAs–GaAs–AlGaAs Strained-layer Laser," Appl. Phys. Lett., **51**(4), 215–17 (1987)

Chlorox:$H_2O$ (1:4) {where Chlorox household bleach is 5.25% NaOCl solution}; Application: GaAs selective etch from AlGaAs

YAO, H., and K. Itaya, "Atomically resolved scanning tunneling microscopy images of InP(0 0 1), (1 1 1)A, and (1 1 1)B surfaces in sulfuric acid solution," J. Electrochem. Soc., **145**(9), 3090 (1998)

HCl (1 M); InP surface etch and oxide removal prior to STM study in sulfuric acid solution

YAP, D., Z.L. Liau, D.Z. Tsang, and J.N. Walpole, "High-performance InGaAsP/InP Buried-heterostructure Lasers and Arrays Defined by Ion-beam-assisted Etching," Appl. Phys. Lett., **52**(18), 1464–66 (1988a)

Ar ion beam assisted etch; $Cl_2$; Application: InGaAsP/InP laser mesa etch

Ar; 500 eV Ar beam, current density of 80 $\mu A/cm^2$, etching temperature = 190°C; at high temperature and low pressure, vertical wall is achieved; undercut may happen if etching temperature is too high

YAP, D., J.N. Walpole, and Z.L. Liau, "InGaAsP/InP Buried-heterostructure Lasers with Concurrent Fabrication of the Stripes and Mirrors," Appl. Phys. Lett., **53**(14), 1260–62 (1988b)

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)

$NH_4OH:H_2O_2:H_2O$ (20:7:1000); GaAs vee-grooves through a $Si_3N_4$ 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

YEATS, R., (Varian Report; Navy contract N66001-81-C-0346), (1982)
HCl:citric acid (4:5); InP photolithography; forms inverted sidewalls and flat bottoms

YENIGALLA, S.P., and C.L. Ghosh, “Fabrication of Via Holes in 200 μm Thick GaAs Wafers,” J. Electrochem. Soc., 1377–1378 (1982)
$H_3PO_4$:$H_2O_2$:$H_2O$ (3:4:1); GaAs; uniform, high, isotropic etch rate for etching via holes

YING, F., W.H. Juan, and S.W. Pang, “Etching of high aspect ratio microcavity structures in InP,” J. Vac. Sci. Technol., B, **15**(3), 665 (1997)
ECR plasma etch; $Cl_2$/Ar; InP etch profile dependence on $Cl_2$ concentration

YOH, K., H. Taniguchi, K. Kiyomi, M. Inoue, and R. Sakamoro, “Fabrication and Characterization if InAs Nanostructures from Standing Wires,” IEEE IEDM Technical Digest, **813** (1991)
Photoresist developer Microdeposit MF319 as etchant; GaSb and AlGaSb selective etch from InAs
$NH_4OH$ dilute; GaSb and AlGaSb selective etch from InAs. $H_3PO_4$ non-selective etch for InAs/GaSb/AlGaSb

YONENAGA, I., and K. Sumino, “Behavior of Dislocations in GaAs Revealed by Etch Pit Technique and X-ray Topography,” J. Cryst. Growth, **126**, 19–29 (1993)
$AgNO_3$:HF:$HNO_3$:$H_2O$ (40 mg:16 ml:24 ml:32 ml) {RC etch}; Application: GaAs dislocation propagation behavior study

YOO, B.-S., S.-J. Park., and K.-Y. Park, “Reactive Ion Etching-Induced Damage in GaAs/AlGaAs Quantum Well Structures and Recovery by Rapid Thermal Annealing and Hydrogen Passivation,” J. Vac. Sci. Technol., A, **13**(3), 931–34 (1995)
RIE etch damage; $CCl_2F_2$/He; GaAs/AlGaAs QW; annealing and $H_2$ passivation

YOON, H.J., M.H. Choi, and I.S. Park, “The Study of Native Oxide on Chemically Etched GaAs (1 0 0) Surfaces,” J. Electrochem. Soc., **139**(11), 3229–34 (1992)
Surface study by AES and XPS of GaAs etched with: $H_2SO_4$:$H_2O_2$:$H_2O$ (5:1:1) at 50°C for 1 min
NaOH (1N):$H_2O_2$ (1:1) at 30°C for 1 min

YORK, P.K., J.C. Connolly, N.A. Hughes, T.J. Zamerowski, J.H. Abeles, J.B. Kirk, J.T. McGuin, and K.B. Murphy, “MOCVD Regrowth Over GaAs/AlGaAs Grating for High Power Long-lived InGaAs/AlGaAs Lasers,” J. Cryst. Growth, **124**, 709–15 (1992)
$NH_4OH$:$H_2O$ (1:10–50); Application: GaAs patterned substrate cleaning prior to OMVPE regrowth; attacks primarily surface oxides
$H_3PO_4$:$H_2O_2$:$H_2O$; alternative etch attacks both GaAs and oxides

YOSHIDA, N., S. Chichibu, T. Akane, M. Totsuka, H. Uji, S. Matsumoto, and H. Higuchi, “Surface Passivation of GaAs using Excimer Laser in a $H_2S$ gas Ambient,” Appl. Phys. Lett., **63**(22), 3035–37 (1993)
$H_2S$ dry passivation of GaAs surface using excimer laser at room temperature

YOSHIDA, S., ‘‘Electrochemical etching of a conductive GaN crystal for patterning,’’ J. Cryst. Growth, **181**, 293 (1997)
KOH (5 g in 200 cc $H_2O$); electrolyte for electrochemical pattern etching of GaN and AlGaN

YOSHIKAWA, T., Y. Sugimoto, Y. Sakata, T. Takeuchi, M. Yamamoto, H. Hotta, S. Kohmoto, and K. Asakawa, ‘‘Smooth etching of various III/V and II/VI semiconductors by $Cl_2$ reactive ion beam etching,’’ J. Vac. Sci. Technol., B, **14**(3), 1764 (1996)
Reactive ion etch in $Cl_2$ of InP, GaAs, ZnSe and ZnTe; conditions for smooth etching and assessment of surface damage

YOUTSEY, C., and I. Adesida, ‘‘A comparative study of $Cl_2$ and HCl gases for the chemically assisted ion beam etching of InP,’’ J. Vac. Sci. Technol., B, **13**(6), 2360 (1995)
CAIBE: comparison of $Cl_2$/Ar and HCl/Ar for etching InP

YOUTSEY, C., I. Adesida, J.B.D. Soole, M.R. Amersfoort, H.P. LeBlanc, N.C. Andreadakis, A. Rajhel, C. Caneau, M.A. Koza, and R. Bhat, ‘‘Fabrication of InP-based wavelength multiplexing arrayed waveguide filters using chemically assisted ion beam etching,’’ J. Vac. Sci. Technol., B, **14**(6), 4091 (1996)
$Cl_2$ assisted Ar ion beam etch of InGaAsP/InP; optimum parameters for vertical sidewalls; at 250°C to accommodate low indium chloride volatility

YOUTSEY, C., G. Bulman, and I. Adesida, ‘‘Dopant-selective photoenhanced wet etching of GaN,’’ J. Electron. Mater., **27**(4), 282 (1998)
KOH (0.005–0.04 M); photoelectrochemical etch of n-GaN selectively from intrinsic GaN and p-GaN

YOUTSEY, C., R. Grundbacher, R. Panepucci, I. Adesida, and C. Caneau, ‘‘Characterization of chemically assisted ion beam etching of InP,’’ J. Vac. Sci. Technol., B, **12**(6), 3317 (1994)
CAIBE with Ar ion beam in $Cl_2$ ambient; InP patterning; comparison of mask materials: Cr/$SiO_2$, Ni, Ti, and hard baked photoresist

YU, D.G., C.-H. Chen, A.L. Holmes, E.L. Hu, and S.P. DenBaars, ‘‘Comparing ion damage in GaAs and InP,’’ Microelectron. Eng., **35**, 95 (1997a)
RIE Ar ion damage study; comparison of GaAs and InP

YU, D.G., C.-H. Chen, B.P. Keller, A.L. Holmes Jr., E.L. Hu, and S.P. Ben Baars, ‘‘Investigation of improved regrown material on InP surfaces etched with methane/hydrogen/argon,’’ J. Vac. Sci. Technol., B, **14**(6), 3674 (1996)
reactive ion etch, $CH_4$/$H_2$/Ar of InP; improved interfaces of regrown material due to hydrogen interaction with defects

YU, D.G., C.-H. Chen, A.L. Holmes, S.P. DenBaars, and E.L. Hu, ‘‘Role of defect diffusion in the InP damage profile,’’ J. Vac. Sci. Technol., B, **15**(6), 2672 (1997b)
Dry etch ion damage in InP; diffusion of defects; modeling of diffusion

YU, K.L., U. Koren, T.R. Chen, P.C. Chen, and A. Yariv, "Groove GaInAsP Laser on Semi-insulating InP," Electron. Lett., **17**(21), 790–92 (1981)
Iodic acid:$H_2O$ (10% solution); Application: InP groove etch with $Si_3N_4$ mask

YU, S., P. Heard, B. Cakmak, R.V. Penty, and I.H. White, "Surface diagnostics of dry etched III–V semiconductor samples using focused ion beam and secondary ion mass spectrometry," J. Vac. Sci. Technol., B, **17**(6), 3080 (1999)
Reactive ion etch of InP using $H_2/CH_4$; surface study using focused Ga+ ion beam-SIMS

YUBA, Y., K. Gamo, H. Toba, X.G. He, and S. Namba, "Ion Beam Etching of InP: I. Ar Ion Beam Etching and Fabrication of Grating for Integrated optics," Jpn. J. Appl. Phys., **22**, 1206–10 (1983)
Ar ion beam etch; InP for grating fabrication

YUBA, Y., K. Gamo, H. Toba, X.G. He, Y.S. Zhang, and S. Namba, "Ion Beam Etching of InP: II. Reactive Ion Etching with Halogen-based Source Gases," Jpn. J. Appl. Phys., **22**(7), 1211–14 (1983)
Reactive ion etch; Cl, $CCl_2F_2$, $CHF_3$; InP and GaAs (1 0 0) for grating fabrication

ZAKNOUNE, M., O. Schuler, F. Mollot, D. Théron, and Y. Crosnier, "Non-selective wet chemical etching of GaAs and AlGaInP for device applications," J. Vac. Sci. Technol., B, **16**(1), 223 (1998)
HCl:$HIO_3$:$H_2O$ (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:$KIO_3$ (1:1) with $KIO_3$ 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:$K_2Cr_2O_7$; non-selective etchant for GaAs/AlGaInP; similar to HCl:$KIO_3$

ZALM, P.C., "Ion-beam Assisted Etching of Semiconductors," Vacuum, **36**(11–12), 787–97 (1986)
Review: ion beam assisted etching of semiconductors

ZARGAR'YANTS, M.N., V.V. Krapukhin, I.A. Krykanov, and N.B. Kagan, "Ion Etching of InP–InGaAsP Heterostructures," Sov. Phys. Tech. Phys., **27**(10), 1291–92 (1983)
Ar ion etch; InGaAsP/InP cross-section interface layer delineation

ZAVIEH, L., C.D. Nordquist, and T.S. Mayer, "Optimization of $In_{0.53}Ga_{0.47}As$ reactive ion etching with $CH_4/H_2$ using design of experiment methods," J. Vac. Sci. Technol., B, **16**(3), 1024 (1998)
Reactive ion etch; $CH_4/H_2$ of InGaAs; optimization

ZENGERLE, R., H.J. Brückner, B. Hüber, and W. Weiershausen, "Low-Loss Beamwidth Transformers on InP with Reduced Requirements on Lithographic Resolution," J. Vac. Sci. Technol., B, **11**(6), 2641–44 (1993)
ECR plasma etch; $CH_4/H_2 + Ar$; Application: InGaAsP tapered stripes using anisotropy dependence on bias voltage; $Al_2O_3$ or Ti masks

ZHANG, A.P., G. Dang, F. Ren, X.A. Cao, H. Cho, E.S. Lambers, S.J. Pearton, R.J. Shul, L. Zhang, A.G. Baca, R. Hickman, and J.M. Van Hove, "$Cl_2$/Ar high-density-plasma damage in GaN Schottky diodes," J. Electrochem. Soc., **147**(2), 719 (2000)
Inductively coupled plasma etching of GaN using $Cl_2$/Ar; damage in Schottky diodes

ZHANG, C., D. Lubyshev, T.N. Jackson, D.L. Miller, and T.S. Mayer, "The effect of $Al_{0.7}Ga_{0.3}As$ etch stop removal on the preparation of wafer-bonded compliant substrates," J. Electrochem. Soc., **146**(4), 1597 (1999)
citric acid:$H_2O_2$; selective removal of GaAs substrate from $Al_{0.7}Ga_{0.3}As$ etch stop layer
$NH_4OH$:$H_2O_2$; selective removal of GaAs substrate from $Al_{0.7}Ga_{0.3}As$ etch stop layer
HF; selective removal of $Al_{0.7}Ga_{0.3}As$ etch stop layer from GaAs layer
HCl:$H_2O$ (1:1); selective removal of $Al_{0.7}Ga_{0.3}As$ etch stop layer from GaAs layer
Alternate $H_2O_2$ 1 min soak followed by HCl:$H_2O$ (1:1) 1 min soak (3 cycles) of GaAs surface to reduce roughness after AlGaAs layer removal

ZHANG, J., O.P. Naji, P. Steans, P. Tejedor, T. Kaneko, T.S. Jones, and B.A. Joyce, "Modulated-beam studies of the layer-by-layer etching of GaAs(0 0 1) using $AsBr_3$: identification of the reaction mechanism," J. Cryst. Growth, **175/176**, 1284 (19970)
Thermochemical etch; $AsBr_3$; GaAs reaction mechanism study; rate is limited by formation/desorption of GaBr

ZHANG, J., K. Sugioka, S. Wada, H. Tashiro, and K. Midorikawa, "Study on high speed deep etching of GaN film by UV laser ablation," J. Cryst. Growth, **189/190**, 725 (1998)
UV laser ablation etch; GaN patterns
HCl; second step following UV laser ablation etch of GaN to remove accumulated Ga drops from surface

ZHANG, L., L.F. Lester, R.J. Shul, C.G. Willison, and R.P. Leavitt, "Inductively coupled plasma etching of III–V antimonides in $BCl_3$/Ar and $Cl_2$/Ar," J. Vac. Sci. Technol., B, **17**(3), 965 (1999)
ICP etching of GaSb and AlGaAsSb using $BCl_3$/Ar and $Cl_2$/Ar

ZHOU, B., and W.F. Ramirez, "Kinetics and modeling of wet etching of aluminum oxide by warm phosphoric acid," J. Electrochem. Soc., **143**(2), 619 (1996)
$H_3PO_4$ (14.61 M); study of etching $Al_2O_3$ dielectric films; etch rate dependence on temperature and concentration

ZHU, Y., Y. Komatsu, Y. Takeda, and A. Sasaki, "Fabrication and Characterization of AlGaAs Heterojunction Phototransistors with Wide Gap Windows," IEEE Trans. Electron Devices, **38**(6), 1310–14 (1991)
$H_2SO_4$:$H_2O_2$:$H_2O$ (3:1:1); Application: AlGaAs mesa etch at 50°C
$K_3Fe(CN)_6$:KOH:$H_2O$ (8:12:100 by weight); AlGaAslGaAs layer delineation

ZILKO, J.L., "Effect of Mesa Shape on the Planarity of InP Regrowths Performed by Atmospheric Pressure and Low Pressure Selective Metalorganic Vapor Phase Epitaxy," J. Cryst. Growth, **109**, 264–71 (1991)

$HBr:H_2O_2:H_2O$; InP pattern etch for OMVPE regrowth; for normal and reentrant sidewall profiles
$Br_2$/methanol (1%); InP; reentrant [1 0 0} direction profiles
$HBr:H_3PO_4:H_2O_2:H_2O$; InP; reentrant [1 0 0} direction profiles

ZOU, J., D. J.H. Cockayne, and B.F. Usher, "Misfit Dislocations and Critical Thickness in InGaAs/GaAs Heterostructure Systems," J. Appl. Phys., **73**(2), 619–26 (1993)
HF (10%); Application: AlAs selective etch from GaAs; used for lift-off of InGaAs/GaAs layer for TEM analysis

ZUBRZYCKI, W.J., G.A. Vawter, and J.R. Wendt, "High-aspect-ratio nanophotonic components fabricated by $Cl_2$ reactive beam etching," J. Vac. Sci. Technol., B, **17**(6), 2740 (1999)
$Cl_2$ reactive ion beam etching of $Al_{0.4}Ga_{0.6}As$ to form trench grating for distributed Bragg reflectors