Cornell NanoScale Facility
Dry Etch Capabilities

Vince Genova
CNF Research Staff
Dry Etch Systems

- High Density Plasma (ICP): PlasmaTherm Versaline DRIE
  - Unaxis (PT) 770 DRIE
  - PlasmaTherm 770 (dual chamber)
  - Oxford PlasmaLab 100-380
  - Trion Minilock III
  - Oxford PlasmaPro 100 Cobra

- RIE (parallel plate):
  - PlasmaTherm 720/740 (dual chamber)
  - PlasmaTherm 72
  - Oxford PlasmaLab 80 (2)
Dry Etch Systems

- Dry release: Xactix XeF2
  Primaxx uetch

- PR strip/ash: Aura 1000
  Branson barrel system
  Glenn 1000
  Yes CV200RFS
  Anatech Resist Strip

- Ion Milling: AJA ion mill
PlasmaTherm Versaline DRIE

- Timed multiplexed process (C4F8, SF6, Ar)
- Si and Ge DRIE
- SOI, HAR processes
- PR, SiO2, Al2O3 (ALD) masks
- 110:1, 340:1, >1000:1 selectivity
- 50:1 AR (trench), 200:1 (lines)
- Typical etch rates ~ 6-8um/min
- 100 mm wafer size, clamped
- Endpoint works OES
Versaline DSEIII-TMP deep silicon etch

35:1 aspect ratio
Oxide selectivity = 333:1
Etch rate = 8um/min
Versaline DSEIII-TMP deep silicon etch

PR mask selectivity 120:1
Etch rate 8um/min
ALD alumina and Plasmatherm Versaline Silicon DRIE etching

ALD alumina has shown to be a good etch mask for the new Versaline DRIE silicon etcher. The selectivity to silicon has been shown to be 2000:1. In the image above 15nm of ALD alumina was used to etch 25 microns into silicon. The alumina can be etched in a chlorine plasma or wet etched in basic developer.
Plasmatherm Versaline DRIE
Germanium

Ge DRIE: PR mask
R7-IAT DOE: 4μm/min

Ge DRIE: SiO2 mask
R5-IAT DOE: 3.5μm/min
Plasmatherm Versaline
Ge DRIE with Al2O3 (70nm) mask
Unaxis (Plasmatherm) 770 SLR DRIE

- Time multiplexed process (SF6, C4F8, Ar)
- SF6 based release etch
- Mixed etch (SF6+C4F8+O2) aka “photonics etch”
- Typical DRIE etch rates ~ 2μm/min.
- PR and oxide masks with 50:1 and 200:1 selectivity.
- Aspect ratios up to 20:1
- 100mm, 150mm clamped
**Unaxis 770**

Photonics or “mixed etch” (SF6+C4F8) Silicon (100)  
ASML DUV features  
5:1 to UV210 PR
Unaxis 770
Photonics or mixed etch
SF6+C4F8
N+ polysilicon
200nm ASML lines
Plasmatherm 770-ICP

- Dual chamber ICP
- Left chamber – shallow silicon (<10µm), single xtal and polyxtalline.
  - Cl2 based chemistry
  - silicon oxide mask only (20:1)
  - 200nm/min etch rate
  - 100mm clamped
- Right chamber – III-V’s (Ga and In based materials) including ternaries and quaternaries.
  - PR, SiO2, Si3N4, and Ni masks.
  - 100mm clamped
  - non-heated electrode
  - Cl2, BCl3, SiCl4, CH4, H2, SF6, O2
Plasmatherm 770 ICP
GaAs etch using BCl3 chemistry with pcvd oxide mask.
Plasmatherm 770 ICP

Ebeam defined SOI waveguide structure using HSQ mask etched with Cl2/BCl3/H2 chemistry.
**Plasmatherm 770 ICP**

Annealed P+ polysilicon on oxide etched in Cl2/BCl3 chemistry with PECVD oxide mask.
Trion Minilock III ICP

- Chrome etching only
- Cl2, O2, Ar based chemistry
- Up to 200mm wafers
- Up to 7” square mask plates
- Nanoimprint template fabrication (P-NIL)
**Trion Minilock III ICP**

Chrome etched with Cl2/O2/Ar
Oxford Plasmalab 100-ICP

- Silicon based dielectric etching (oxide, nitride, low stress nitride)
- Quartz and fused silica etching (no borofloat, Pyrex, etc)
- Recent upgrade to 12 line gas pod and installation of gas ring in close proximity to the substrate.
- Low F/C ratio gas chemistries (C4F8, C2F6, C4F6, CH2F2, CHF3)
- Other gases (CF4, SF6, O2, Ar, N2, He)
- Switchable manifold for the showerhead or gas ring for low F/Cs.
- Enhanced selectivity to ebeam and deep UV resists
Oxford 100 ICP

90nm linewidth ASML DUV (248nm) silicon nitride etched with CHF3/O2
Oxford 100 ICP

119nm linewidth ASML DUV (248nm) defined silicon dioxide etched with CHF3/O2.
Oxford 100 ICP

E-beam lithographically defined 68nm lines etched into fused silica with C4F8/CO2 using chrome mask.
Oxford Instruments Plasma-Lab 100-380 ICP with Gas Ring
C4F6/O2 SiO2 chamber/ring DOE

C4F6/O2 OXIDE DOE1

ER (nm/min)

RIE(W)

RING
CHAMBER

C4F6/O2 OXIDE DOE1

SPR

RIE(W)

RING
CHAMBER
**CH2F2 nitride additive ring DOE**

**CH2F2 NITRIDE RING**

![Graph showing the relationship between ER (nm/min) and ICP (W) for different gases (O2, HE, AR, CO2).]

**CH2F2 NITRIDE RING**

![Graph showing the relationship between SPR and ICP (W) for different gases (O2, HE, AR, CO2).]
CH2F2/HIGH He OXIDE ETCH (RING)
CH2F2/He=20/80, 3000/60W, 4mT
Oxford 100-380 ICP

1um oxide, 155nm/min, SPR=4.4:1
UV210

2um oxide 155nm/min SPR=5.8  AR=7.3
UV210
CH$_2$F$_2$(ring)/high He thick(10um) SiO$_2$ etch
Oxford 100-380 ICP

CH$_2$F$_2$/He(20/80), 3000/60W, 4mT
160nm/min, SPR=5.75:1 (i-line PR)

Note: minimal RIE-LAG effects
Plasmatherm 720/740 RIE

- 720: Cl2 based shallow silicon etch (single xtal or polycrystalline)
  - oxide mask only, 30:1 selectivity
  - up to 200mm wafers
  - etch rates up to 100nm/min
  - 2D materials (WSe2, NbSe2, GaSe)

- 740: metal etching (mostly Al, but also Al2O3, Cr, Ta, W and Nb)
  - Cl2 based chemistry
  - CH4 sidewall passivation
  - SF6/O2 for post etch passivation PE mode.
  - up to 200mm wafers.
Plasmatherm 720/740
Tantalum etch SF6/N2
ASML UV210
Tungsten Etch PT740

ASML UV210 PR mask: SF6/N2=40/12, 100W, 10mTorr

ASML UV210 PR mask: SF6/N2=40/12, 100W, 10mTorr
Tungsten Etch PT740

SiO2 mask
SF6/N2=40/25 10mTorr, 125W

SiO2 mask
SF6/O2=40/12, 10mTorr, 125W
Oxford Plasmalab 80s RIE

- Parallel plate conventional RIE
- Fluorine based chemistry: CF4, CHF3, SF6.
- Additives: Ar, O2, H2
- Primarily used to etch silicon based materials.
- 2 plasmalab 80 systems: 82 is limited to CMOS approved materials, while 81 includes other substrates such as III-V materials.
- DUV ARC (AR3) etch is available on both systems.
- Up to 200mm wafers.
Plasmatherm 72 RIE

- Conventional parallel plate RIE
- Fluorine based chemistry: CF4, CHF3, SF6.
- Additive gases include O2 and H2.
- Used mostly to etch silicon based materials, but other materials such as W and Ta are etched as well.
- Very few material restrictions, III-V materials ok
- Up to 200mm wafers.
Xactix XeF2 vapor phase etch system

- Chemical isotropic etch of silicon, poly silicon, and amorphous silicon
- Large loading effect with respect to the amount of exposed silicon.
- Noticeable RIE-LAG aperture effect.
- Highly selective to silicon oxide, silicon nitride, resist, and metals such as Cr and Al. Not those metals that react with atomic fluorine.
- Ability to add nitrogen as a buffer gas to enhance nitride selectivity and to lessen surface roughness.
- Up to 150mm wafers.
Primaxx uetch vapor HF system

- Vapor phase isotropic etch of silicon oxide.
- Thermal, PECVD, and TEOS oxides.
- No doped oxides such as BSG, BPSG, PSG, due to formation of acids/corrosion.
- No resist masking.
- Selective to silicon, Al, Al2O3, TiW, SiC and LPCVD low stress silicon nitride.
- VHF, EtOH, and N2 are reaction components.
- Typical process pressures 50-150 torr.
- Process temperature 45C.
- Controlled thermal oxide etch rates up to 200nm/min.
- Need to O2 ash prior to etch to remove any CFx on surface acting as an inhibitor.
- If Si3N4 is present, need to hotplate bake at >160C to remove reaction product.
Primaxx HF system
Successful release of silicon beams 25um in length, 500nm in width from SOI 2um BOX layer.
Plasma Ashing/Strip

- Aura 1000: downstream
  - 4” cassette to cassette
  - heating option
  - up to 4um/min rate

- Anatech SCE-110-RF resist strip
  - ICP
  - 1000W
  - O2/N2
  - Bosch polymer removal

- Glenn 1000: multi-shelf electrode configuration.
  - powered, grounded, or floating.
  - strip or descum.

- YES CV200RFS: 40kHz plasma isolated by grounded perforated metal plate.
  - strip or descum
  - heated to 250C.
  - N2 and Ar are available.
AJA Ion Mill

- 22cm Kaufman RF-ICP Ar ion source
- Water cooled stage
- Up to 180 degree tilt with rotation up to 25 rpm
- Wafer sizes up to 150mm
- Beam energies up to 1000eV
Oxford Cobra NGP ICP

- Wide temp. electrode (-150C->400C)
- 100mm wafers, mechanically clamped
- Low frequency (350kHz) bias on electrode
- Ocean optics OES
- 12 line gas pod
- Current gases: HBr, Cl2, BCI3, H2, CH3OH, SF6, O2, and Ar
- Later additions: NH3, CO, C4F8
- Current processes: HBr silicon etch and CH3OH/Ar magnetics etch
- Deep silicon cryogenics etch
- Later: mixed silicon etch SF6/C4F8 and NH3/CO magnetics etch
Oxford Cobra NGP ICP Magnetics Etch

- CH3OH/Ar Magnetics Etch
- Ni, Fe, Co ferromagnetic based alloys
- Magnetic tunnel junctions MTJs (Cu, Ru, MgO, PtMn…)
- Generation of volatile carbonyl compounds
- Highly selective to Ta, Ti, Al2O3
- Ability to stop on thin (few nm) interfaces
- Non-corrosive chemistry
- Slow etch rates < 10nm/min
- No sidewall redeposition
- Suitable for nanoscale patterning
**Oxford Cobra NGP ICP**

**HBr silicon etch**

- HBr/Ar=20/10sccm, 40/1500W, 8mTorr
- PR mask: 177nm/min, SPR=3.3:1

- HBr=20, no Ar, 40/1500W, 8mTorr
- SiO2 mask: 227nm/min, SOX=22:1
Oxford Cobra NGP ICP
HBr silicon etch

HBr/Ar=20/7sccm, 30/1500W, 11mTorr
PR mask: 133nm/min, SPR=4.2:1

HBr/Ar=20/7sccm, 30/1500W, 11mTorr
ZEP mask: 75nm gaps 95nm/min, S-ZEP=3:1
Ultra-nanocrystalline diamond thin films are increasingly used in MEMS sensors and actuators (high biocompatibility).

UNCD films composed of nanograins (less than tens of nanometers) that can lead to large surface roughness.

Addition of a small percentage of SF6 (1.5 sccm) to an O2/Ar (50/5 sccm) leads to smooth etch morphology.

SF6 assists in the preferential etching of amorphous carbon at intergrain boundaries.

Aluminum used as an etch mask.

Etch rates of 270 nm/min with selectivity to Al of 40:1 with etch parameters of 2800 W/50 W at 5 mTorr.
Future Plans for the Etch Area

- Retrofit the Plasmatherm 770L from a Cl2 based Si etch ICP chamber to a Cl2 based metal etch chamber.
- Recommission the chlorine based Plasmatherm 720/740 system for more exotic materials such as selenides, etc.
- Add C4F8 to the Oxford Cobra ICP so that the mixed (SF6+C4F8) “photonics etch” can be moved, making the Unaxis(PT)770 a dedicated Bosch DRIE system.
- Make the HBr Si etch in the Oxford Cobra ICP the premier nanophotonics etch process (especially with the enhanced SOI process capability).
- Wish list: a dedicated photomask ICP etch system for high resolution ASML DUV masks.