NNCI Etch Workshop
Cornell University
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Cornell NanoScale Facility Dry Etch Capabilities

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Cornell University
CNF Cornell NanoScale Science and Technology Facility
NNIN Nanoscale Science, Engineering & Technology
NYSTAR
NSF

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

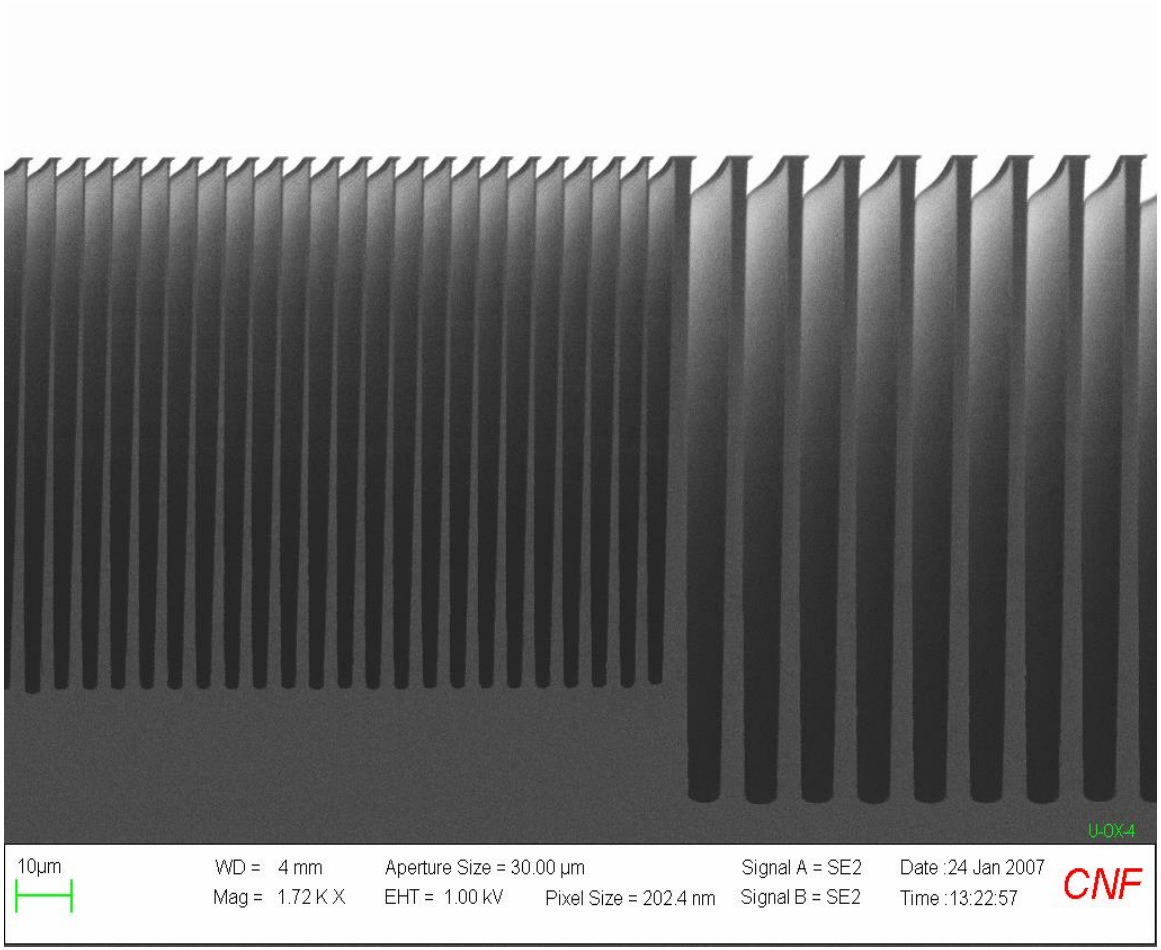
- Dry release: Xactix XeF2
  Primaxx uetch

- 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

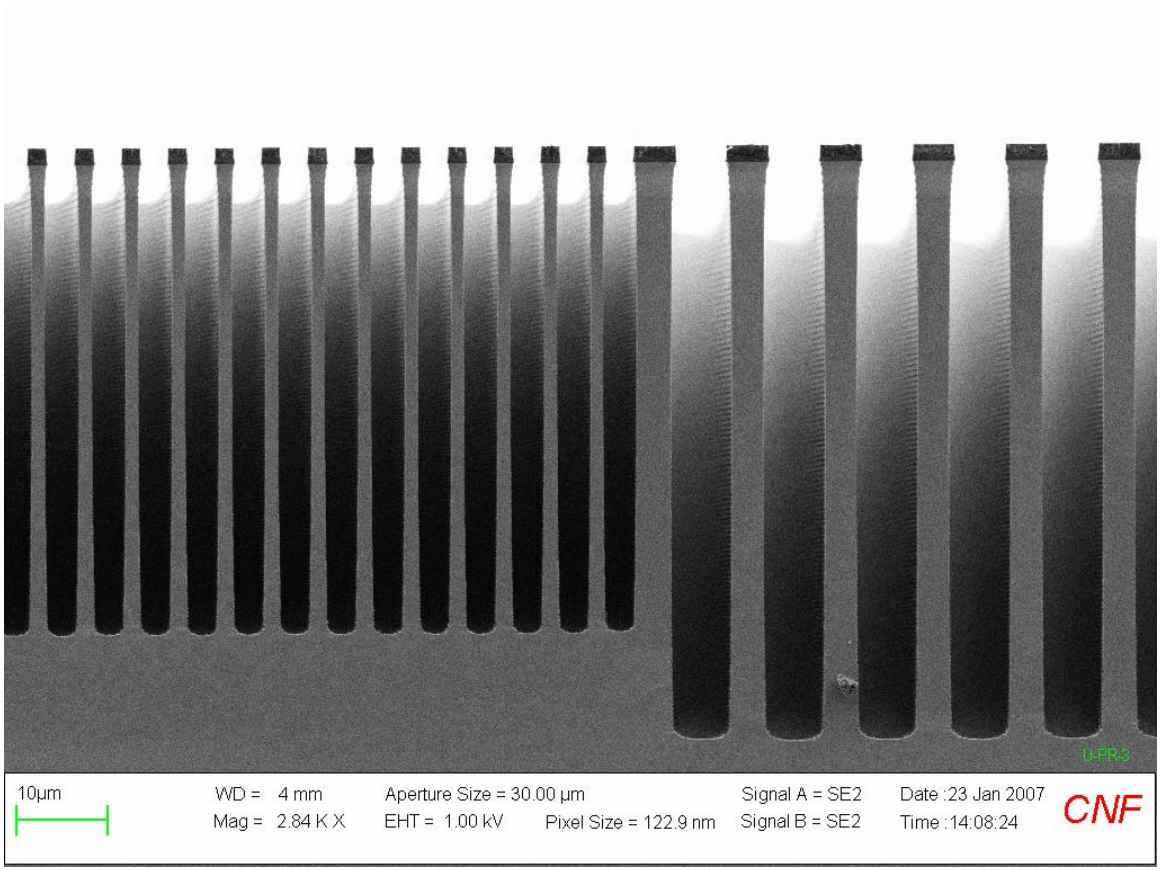


Versaline DSEIII-TMP deep silicon etch

35:1 aspect ratio

Oxide selectivity = 333:1

Etch rate = 8um/min



Versaline DSEIII-TMP deep silicon etch

PR mask selectivity 120:1

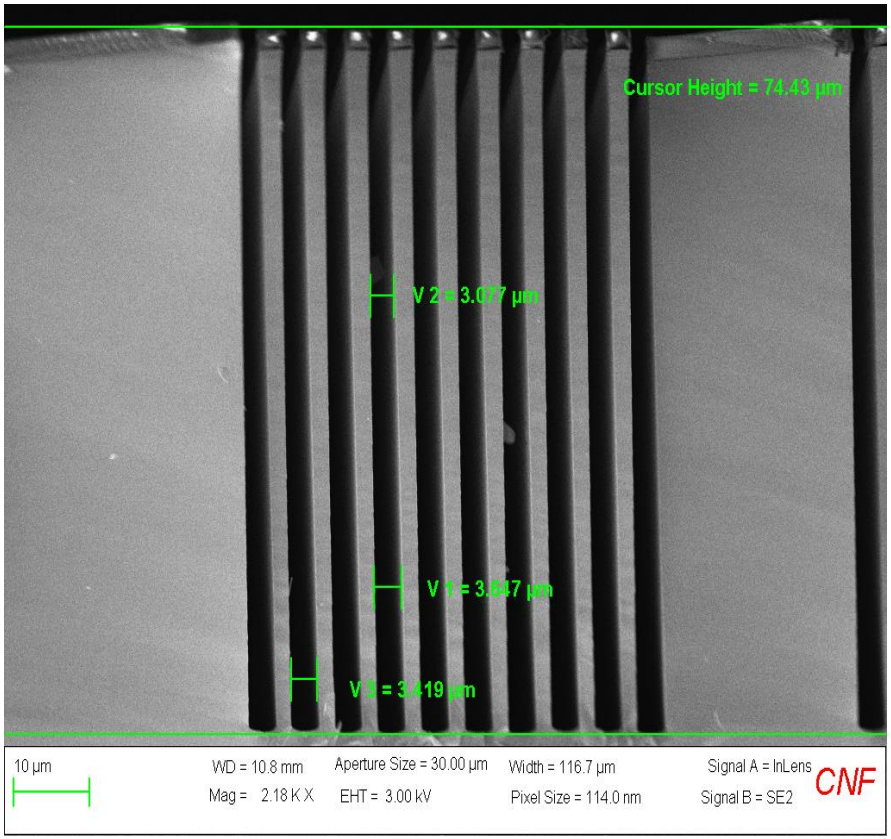
Etch rate 8um/min

ALD alumina and Plasmatherm Versaline Silicon DRIE etching

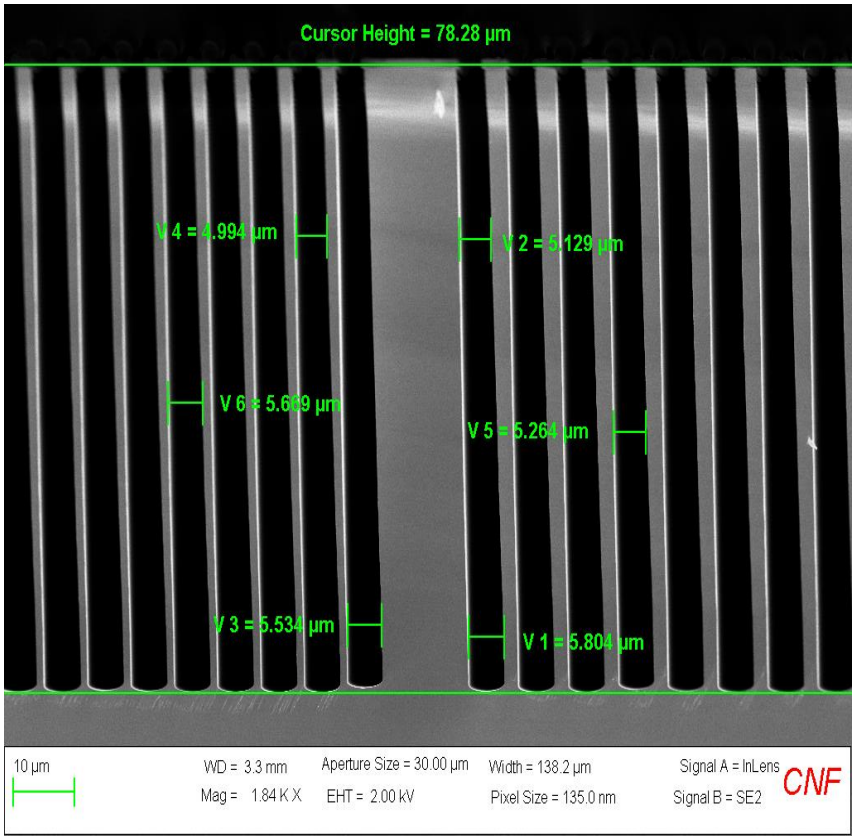
ALD alumina has shown to be a good etch mask for the new Versaline DRIE silicon etcher. The selectivity to silicon has been shown to be 2000:1. In the image above 15nm of ALD alumina was used to etch 25 microns into silicon. The alumina can be etched in a chlorine plasma or wet etched in basic developer.

Plasmatherm Versaline DRIE
Germanium

Ge DRIE: PR mask
R7-IAT DOE: 4um/min



Ge DRIE: SiO2 mask
R5-IAT DOE: 3.5um/min



Plasmatherm Versaline

Ge DRIE with Al2O3 (70nm) mask

Unaxis (Plasmatherm) 770 SLR
DRIE

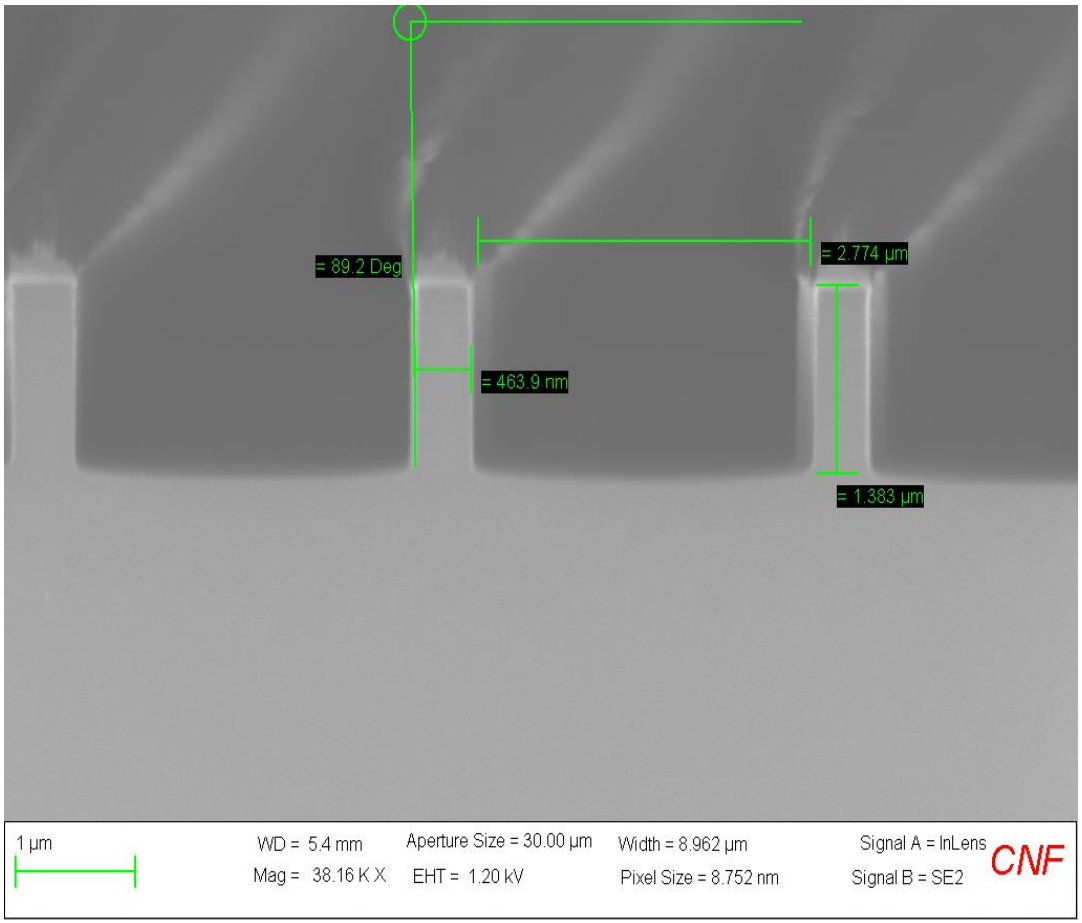
- Time multiplexed process (SF6, C4F8, Ar)
- SF6 based release etch
- Mixed etch (SF6+C4F8+O2) aka “photonics etch”
- Typical DRIE etch rates ~ 2um/min.
- PR and oxide masks with 50:1 and 200:1 selectivity.
- Aspect ratios up to 20:1
- 100mm, 150mm clamped

Unaxis 770

Photonics or “mixed etch” (SF6+C4F8) Silicon (100)

ASML DUV features

5:1 to UV210 PR



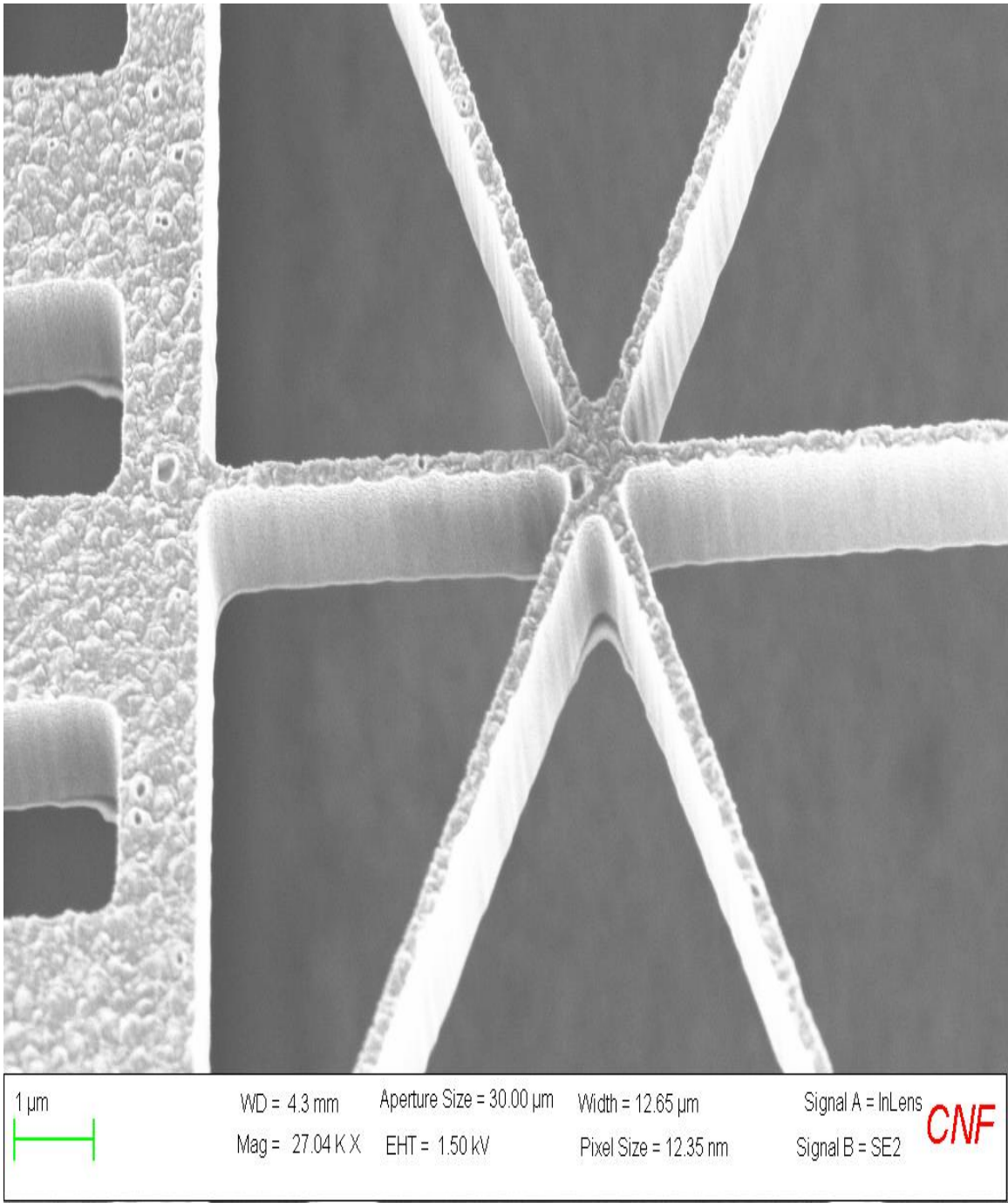
Unaxis 770

Photonics or mixed etch

SF6+C4F8

N+ polysilicon

200nm ASML lines

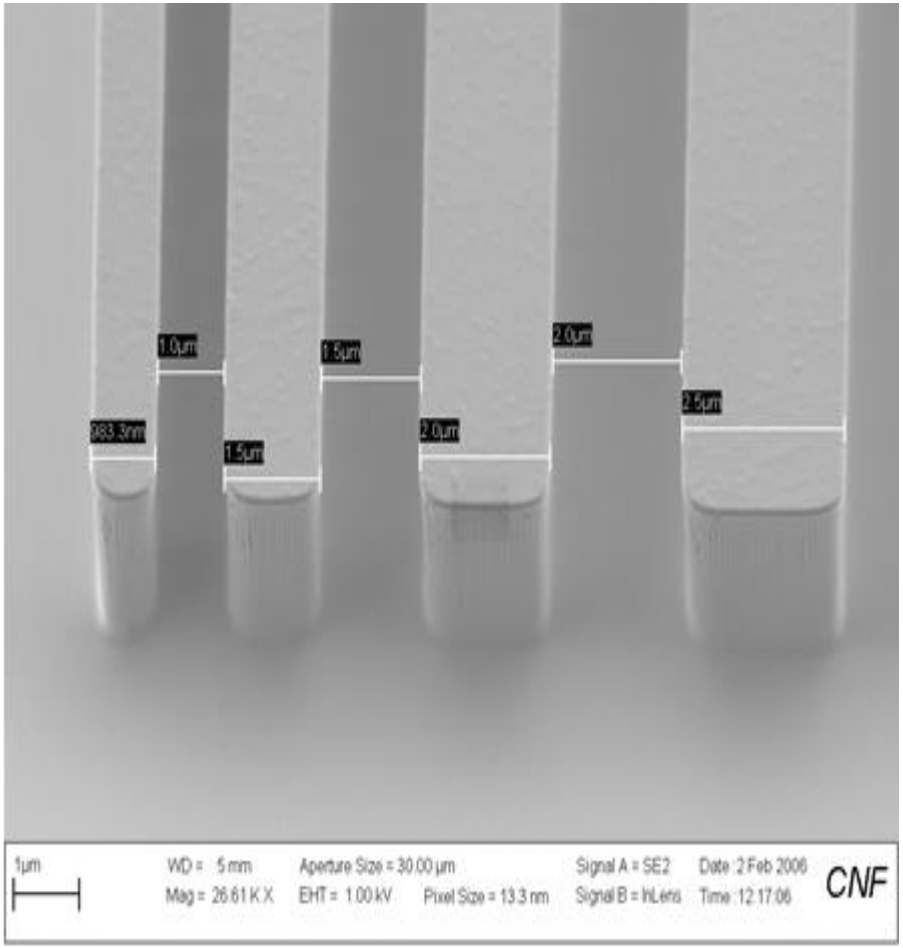


Plasmatherm 770-ICP

- Dual chamber ICP
- Left chamber – shallow silicon (<10um), 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

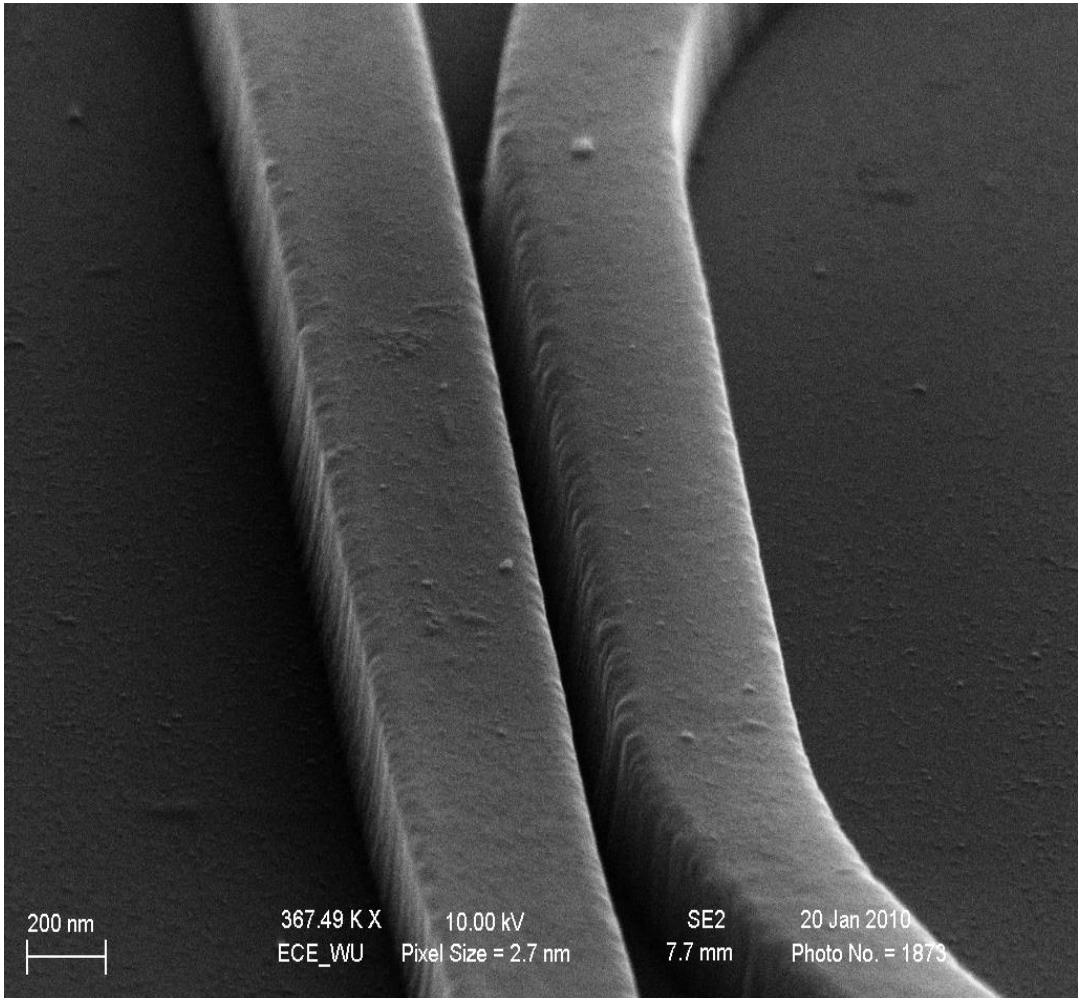
Plasmatherm 770 ICP

GaAs etch using BCl3 chemistry with pecvd oxide mask.



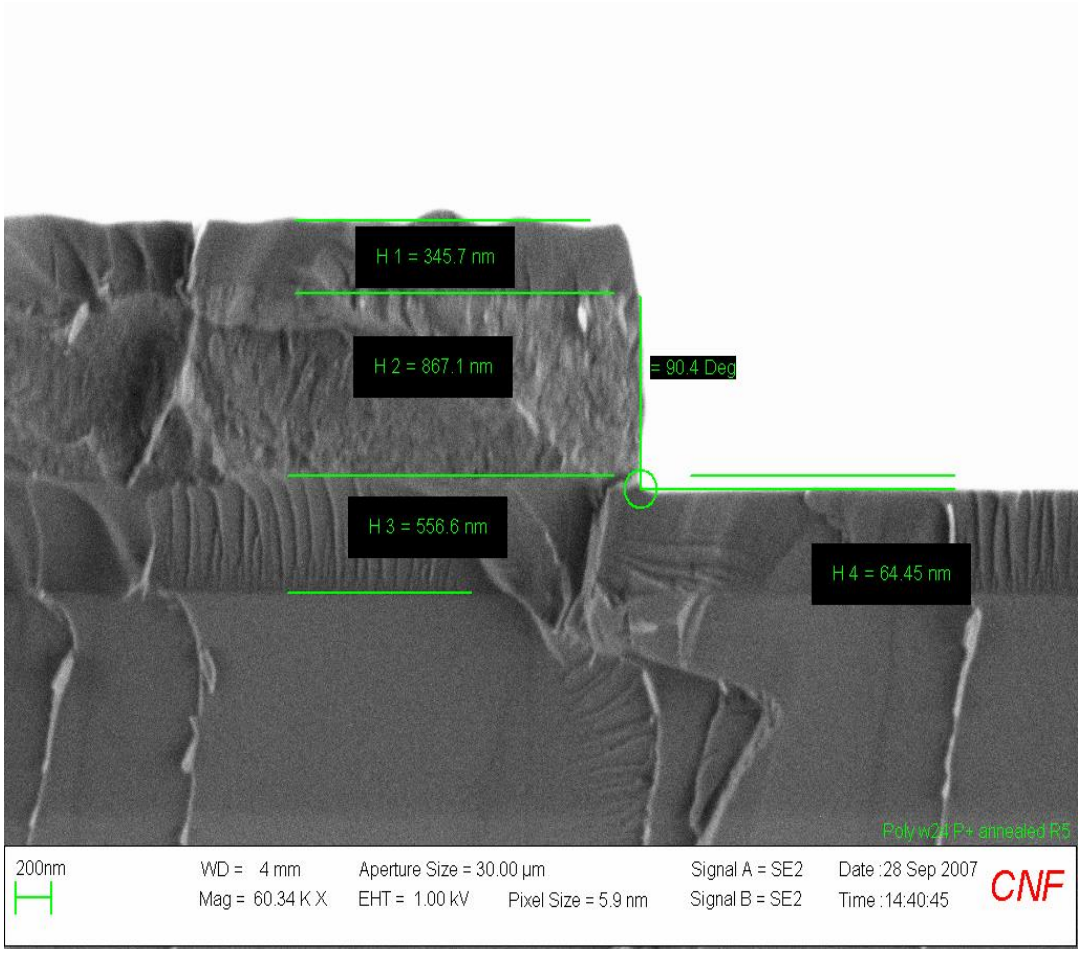
Plasmatherm 770 ICP

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.

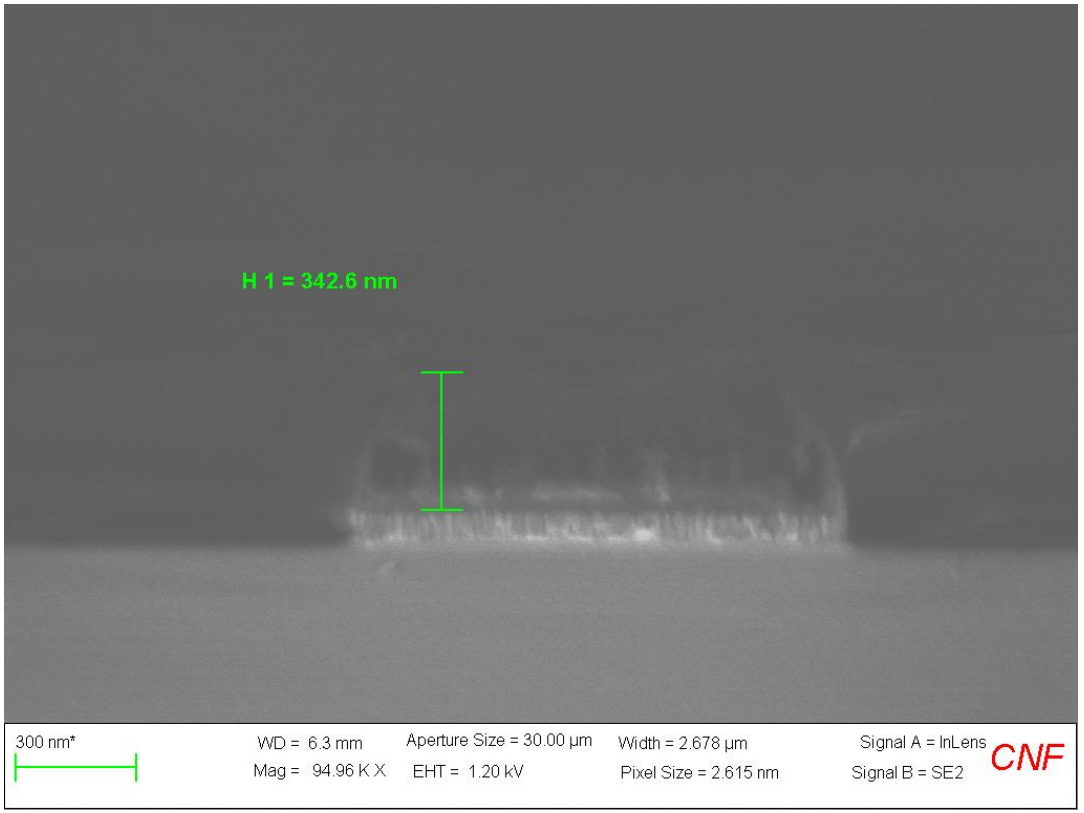


Trion Minilock III ICP

- 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

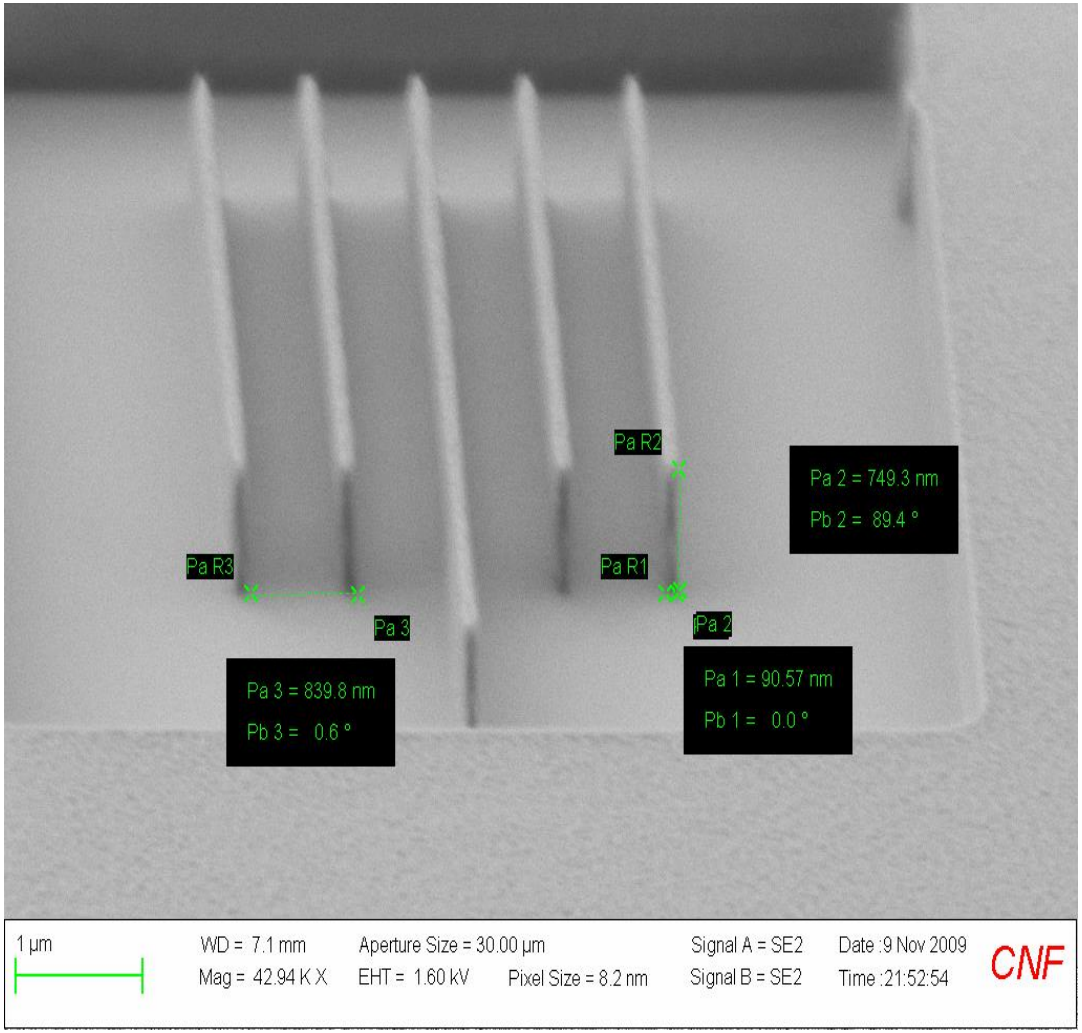


Oxford Plasmalab 100-ICP

- 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

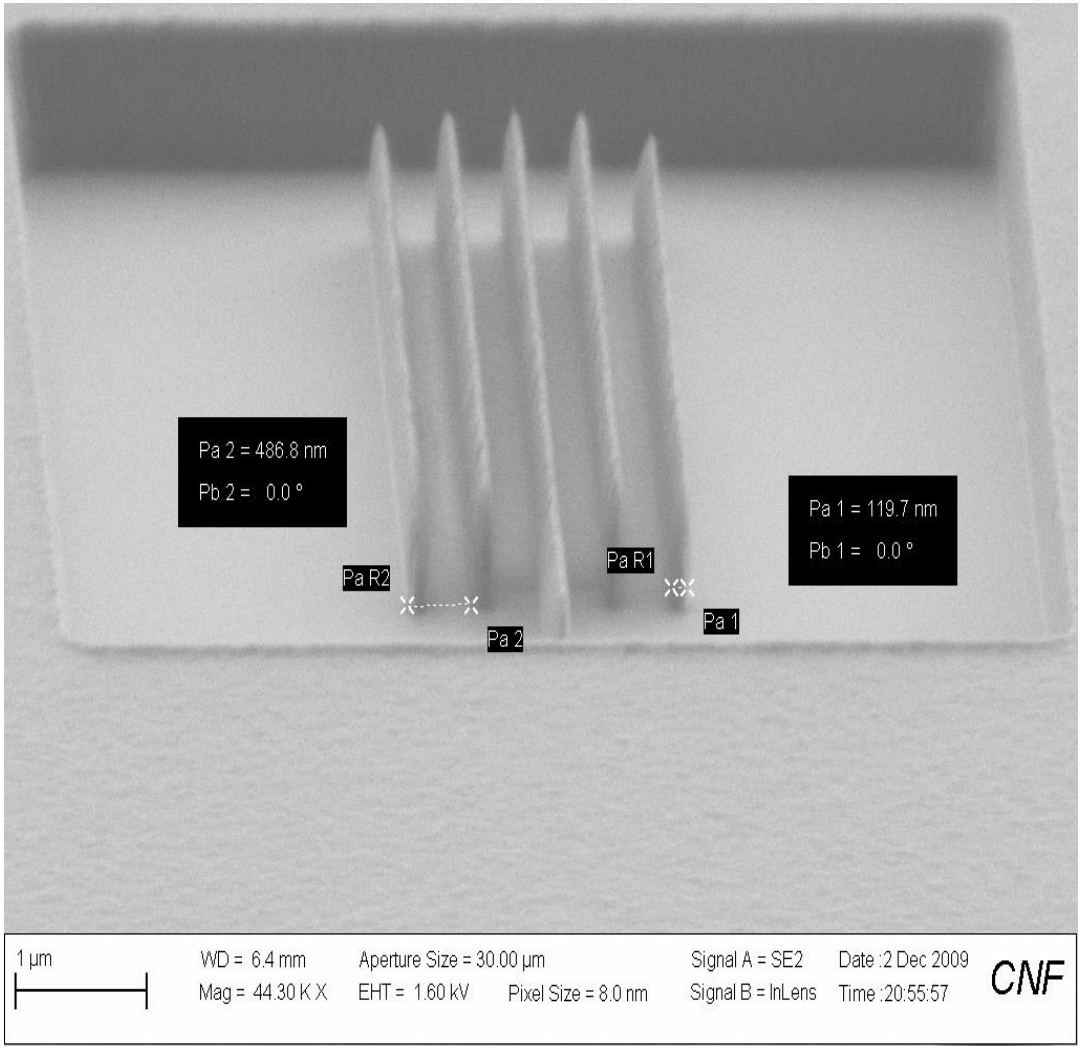
Oxford 100 ICP

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



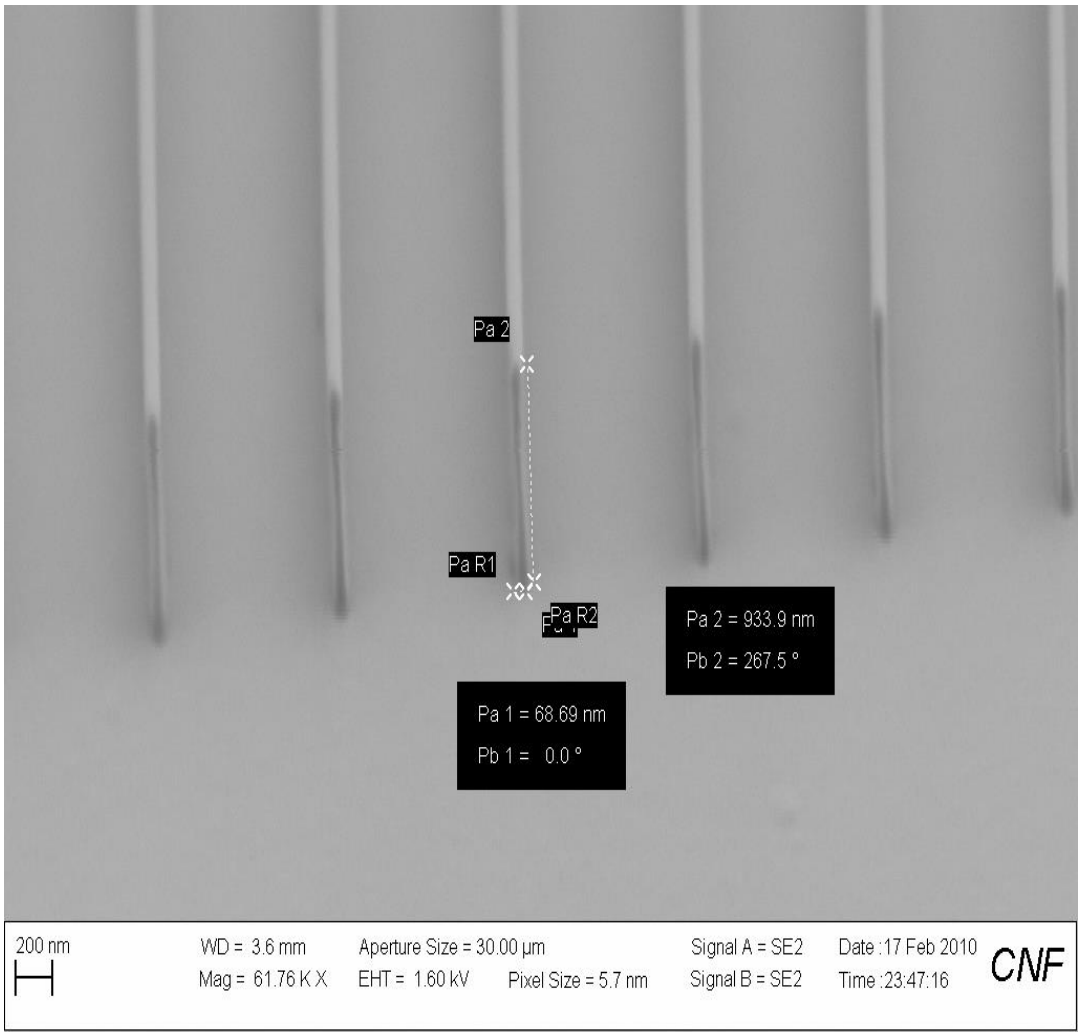
Oxford 100 ICP

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

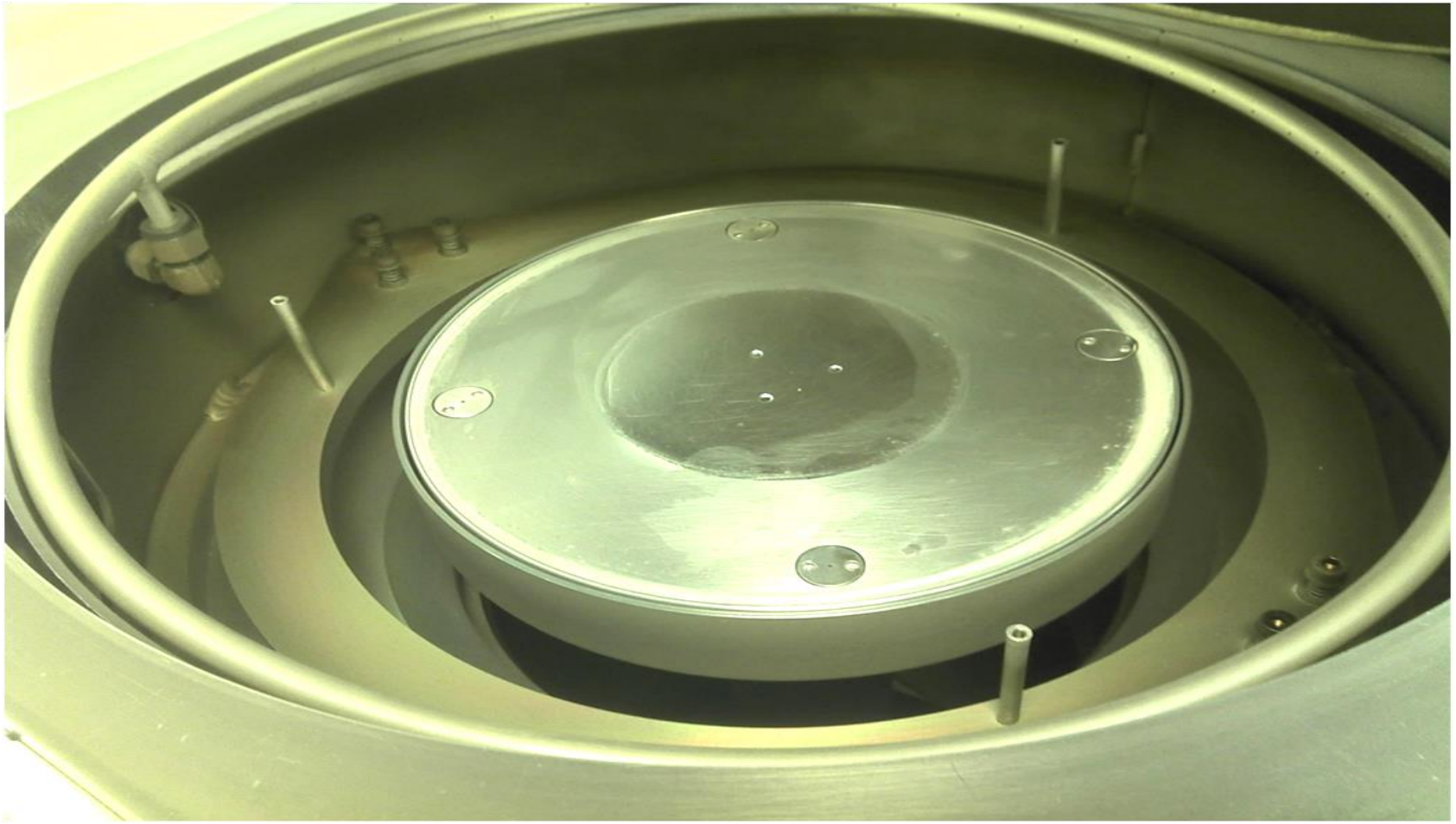


Oxford 100 ICP

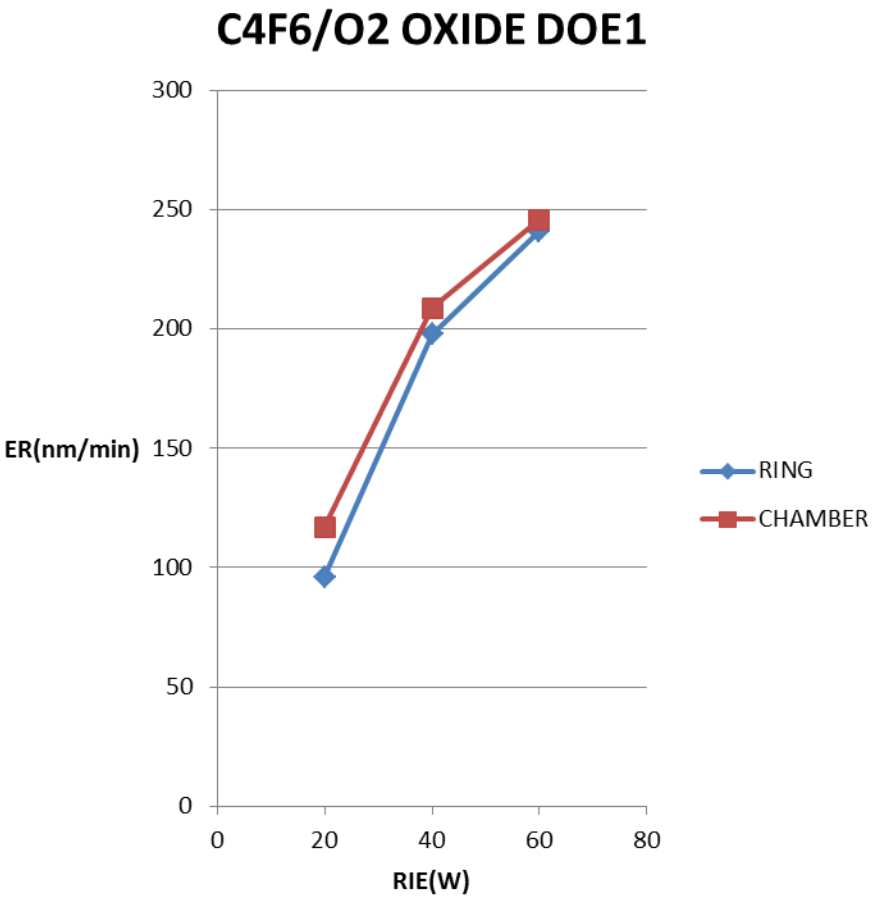
E-beam lithographically defined 68nm lines etched into fused silica with C4F8/CO2 using chrome mask.

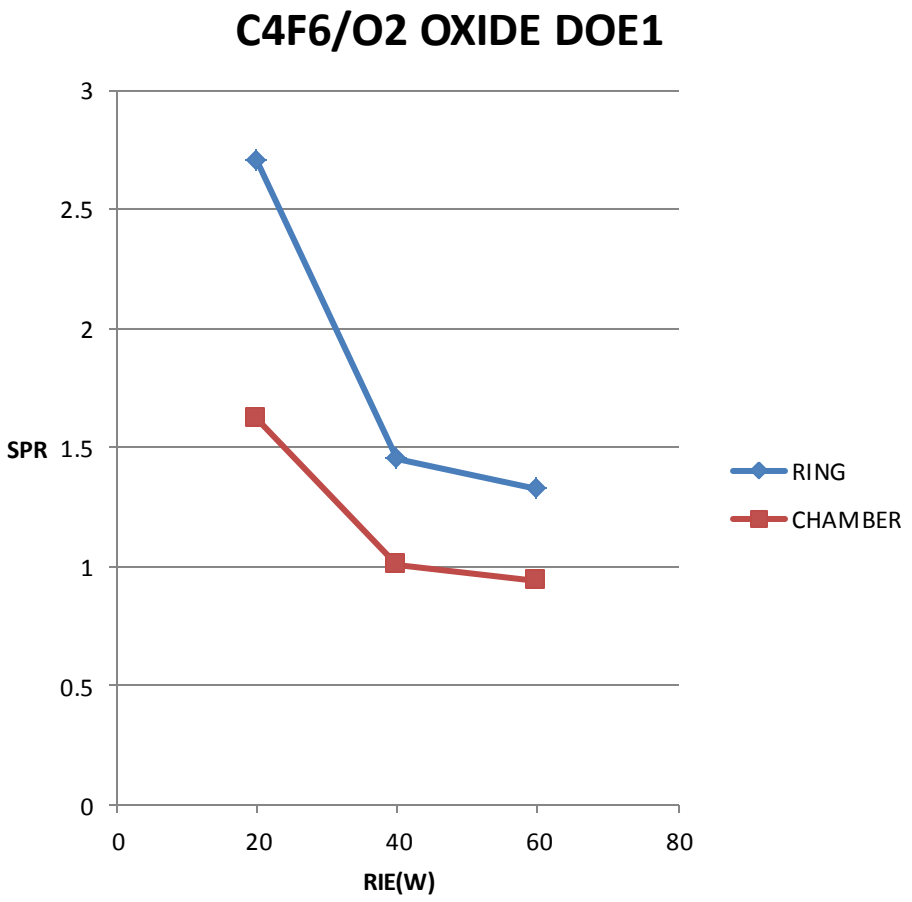


Oxford Instruments Plasma-Lab 100-380 ICP with Gas Ring

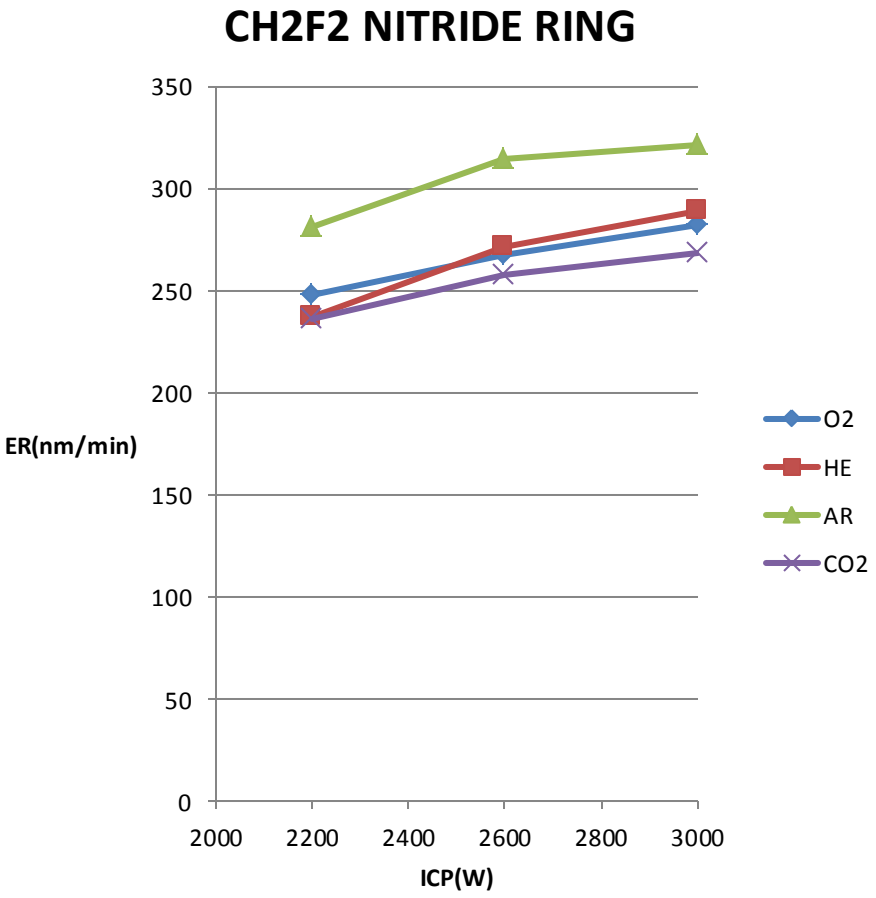


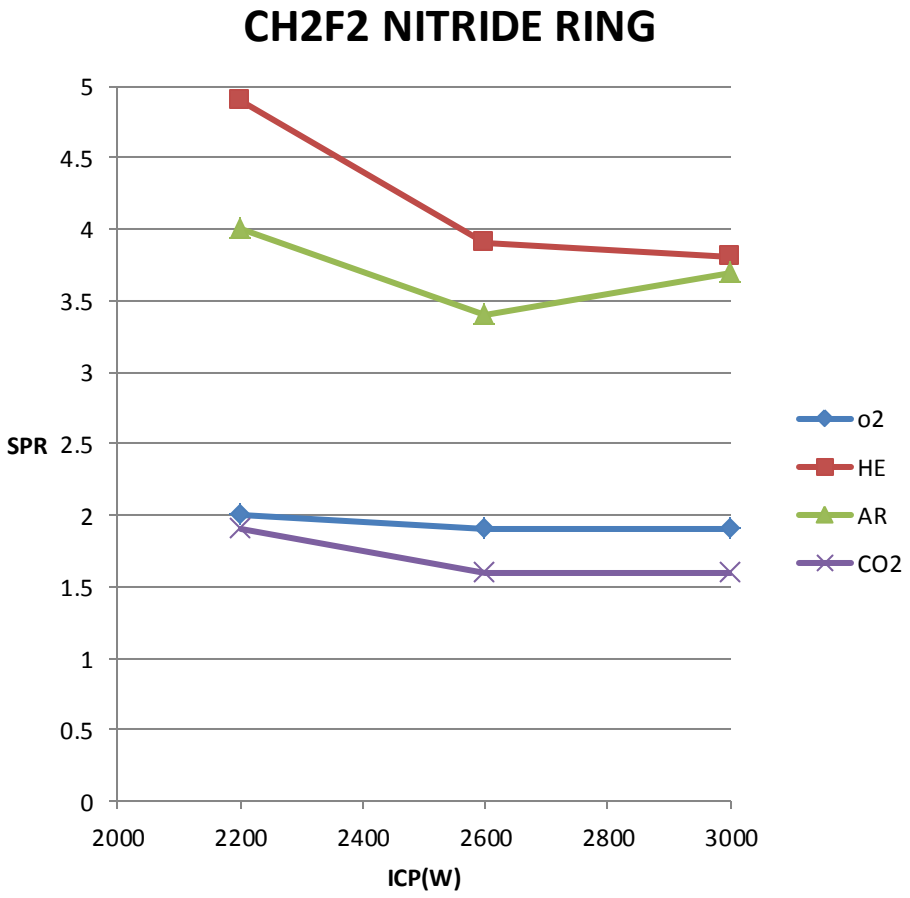
C4F6/O2 SiO2 chamber/ring DOE





CH2F2 nitride additive ring DOE

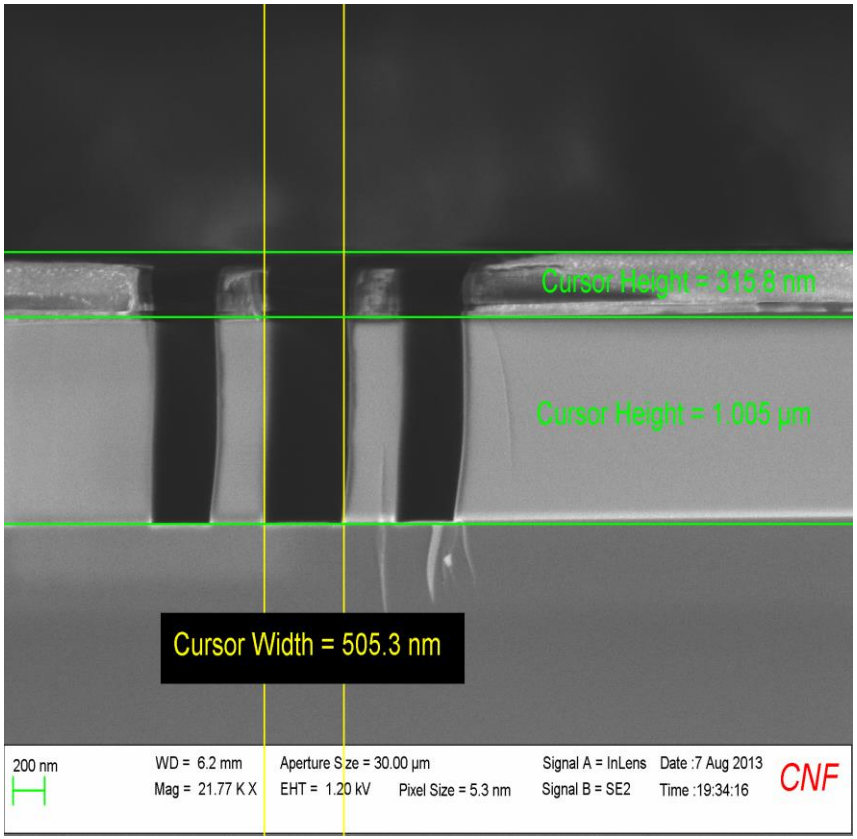




CH2F2/HIGH He OXIDE ETCH (RING)
CH2F2/He=20/80, 3000/60W, 4mT
Oxford 100-380 ICP

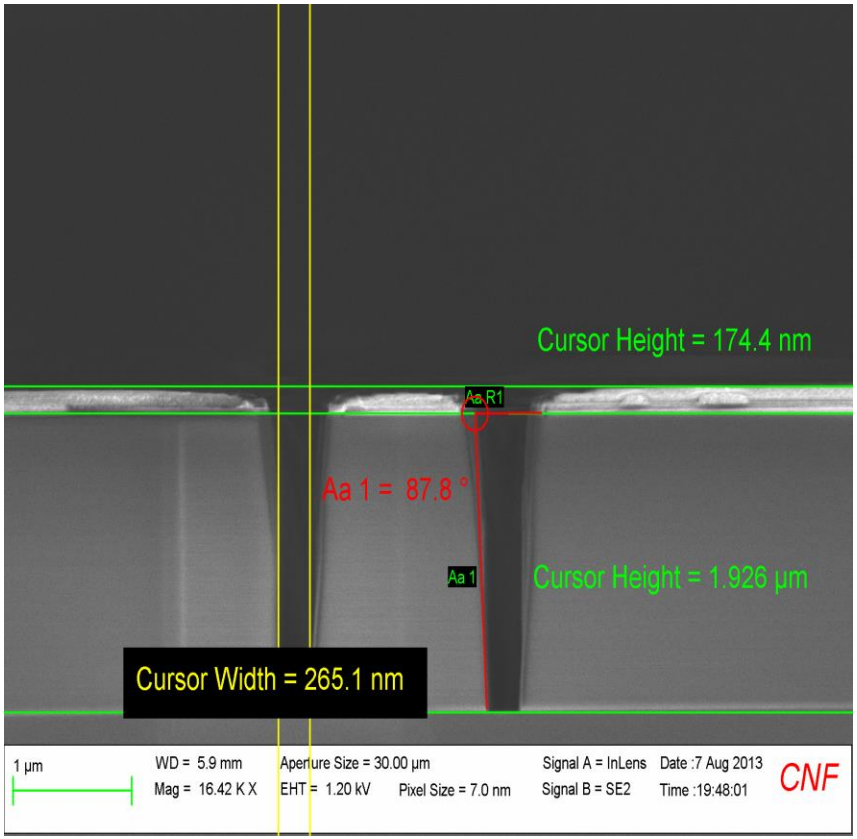
1um oxide, 155nm/min, SPR=4.4:1

UV210



2um oxide 155nm/min SPR=5.8 AR=7.3

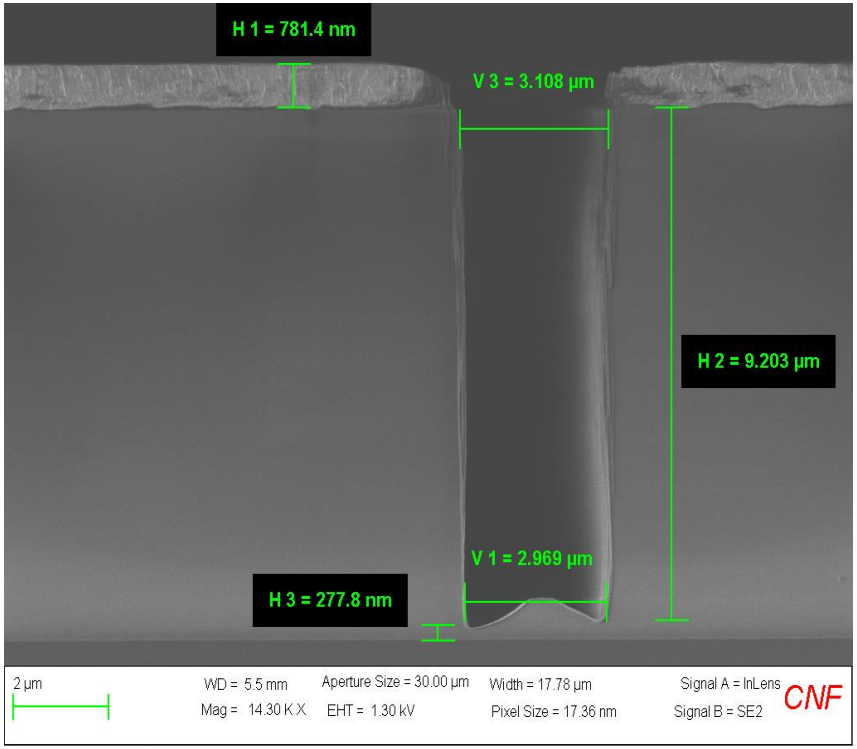
UV210

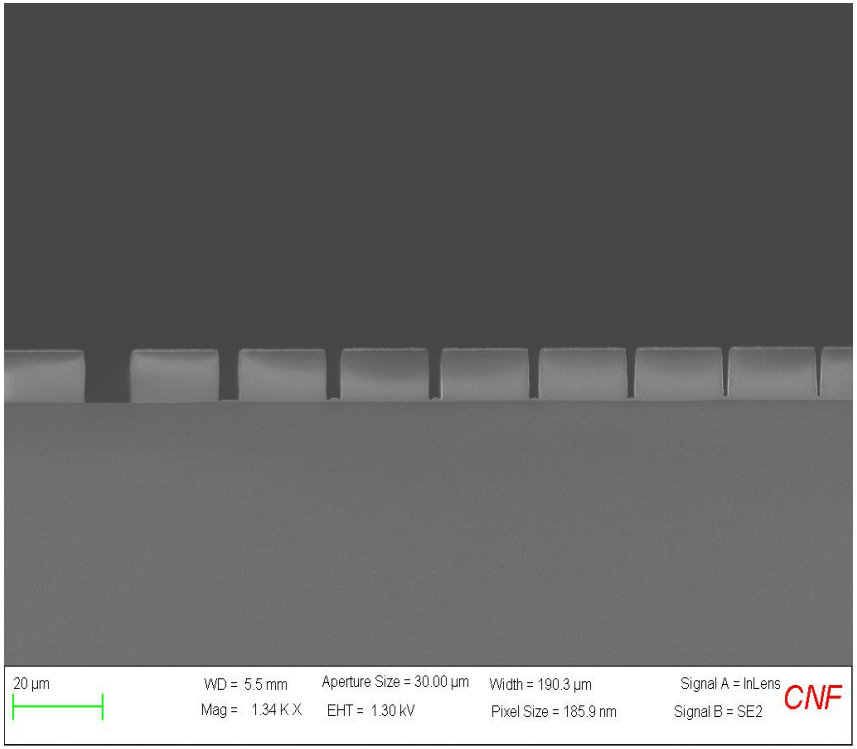


CH2F2(ring)/high He thick(10um) SiO2 etch
Oxford 100-380 ICP

CH2F2/He(20/80), 3000/60W, 4mT
160nm/min, SPR=5.75:1 (i-line PR)

Note: minimal RIE-LAG effects



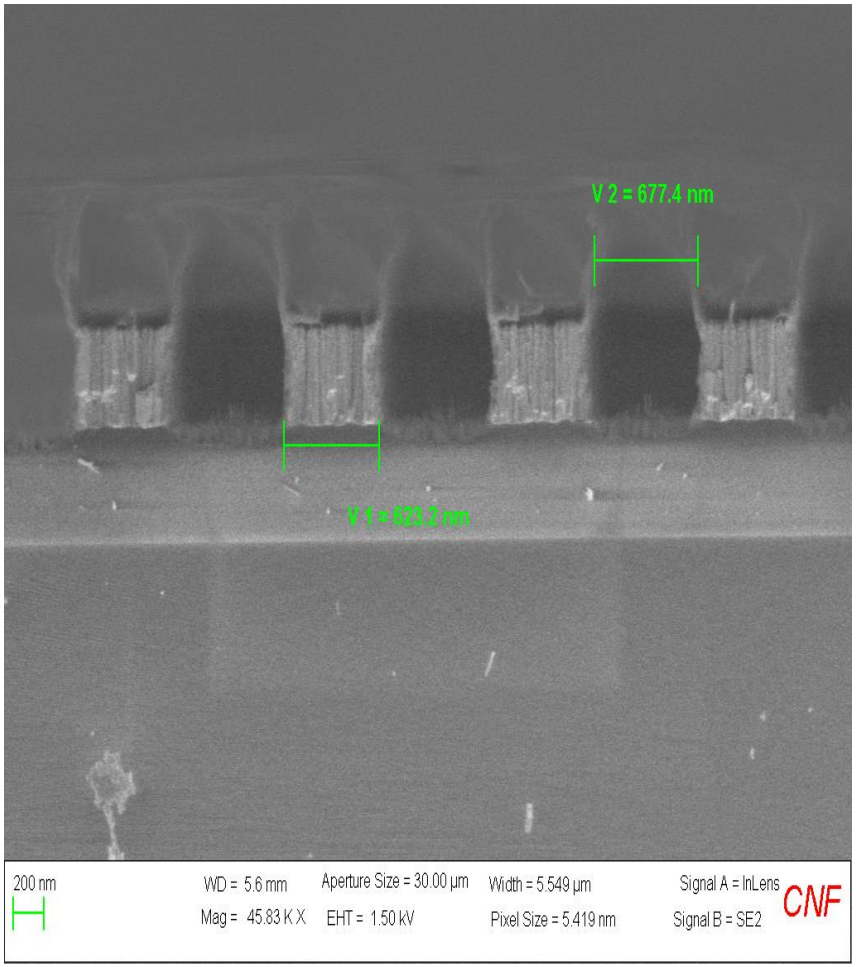


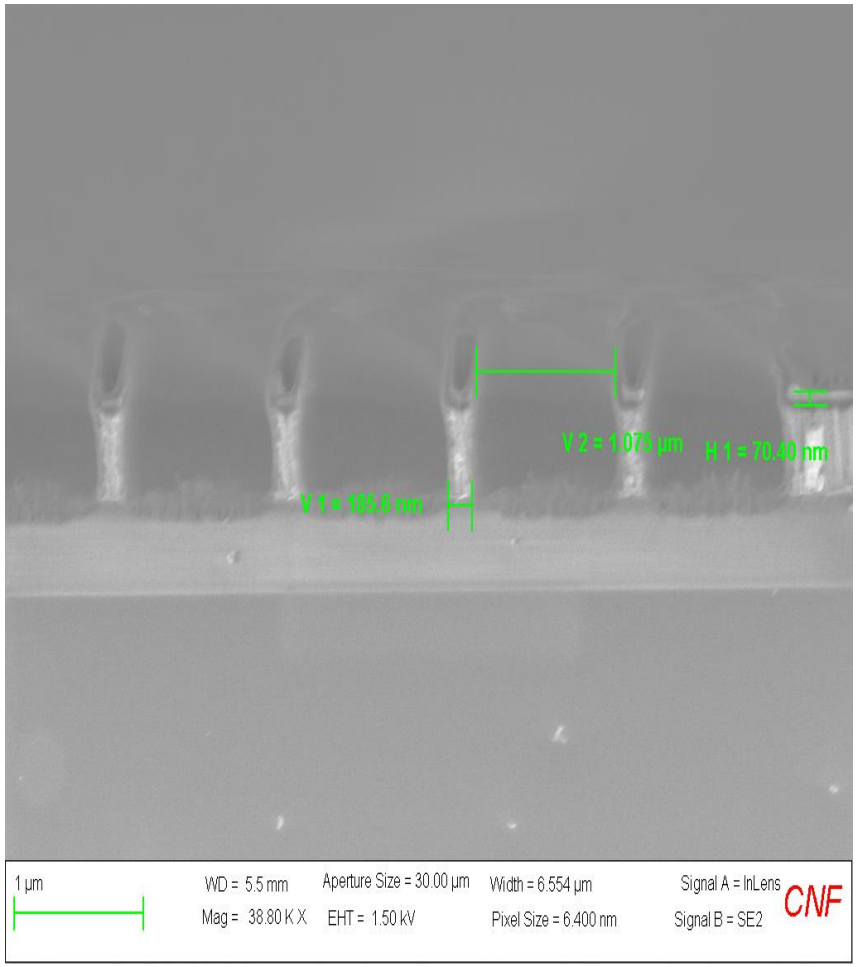
Plasmatherm 720/740 RIE

- 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.

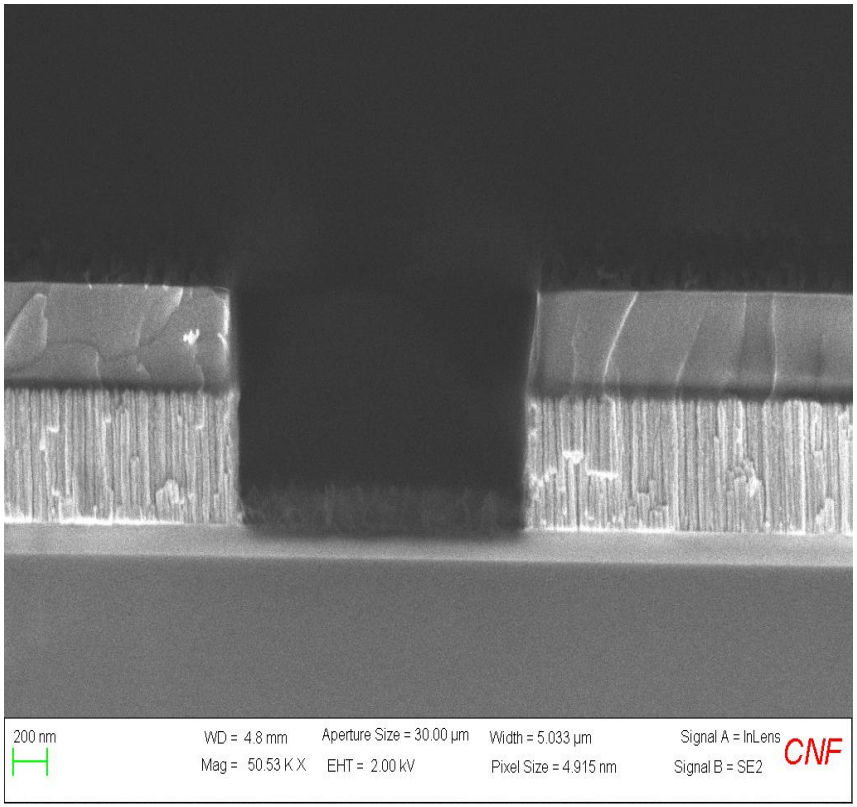
Plasmatherm 720/740
Tantalum etch SF6/N2
ASML UV210



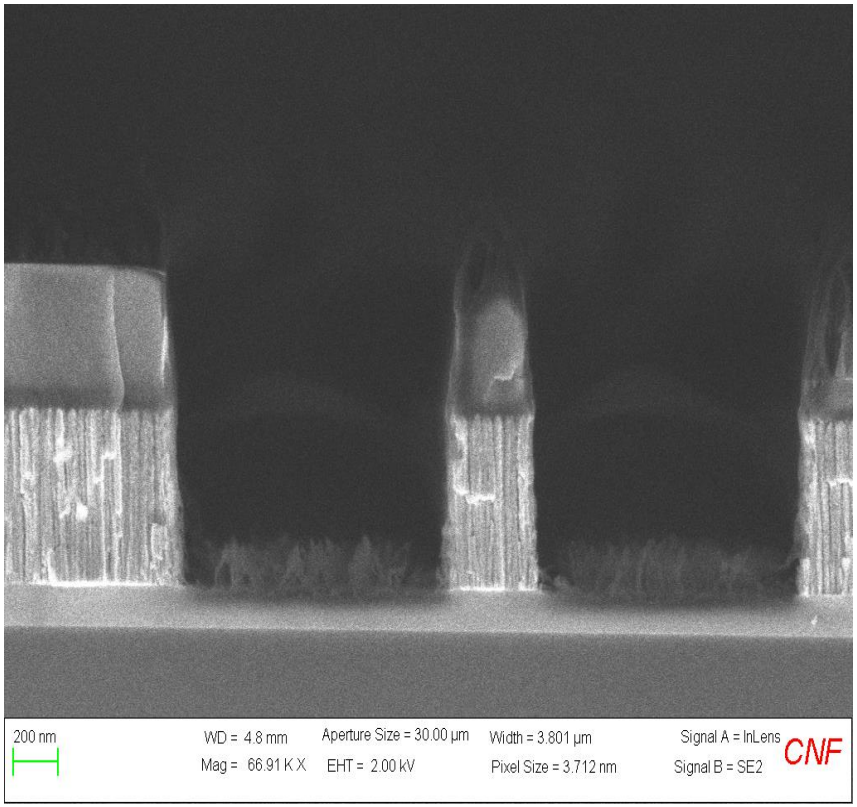


Tungsten Etch PT740

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

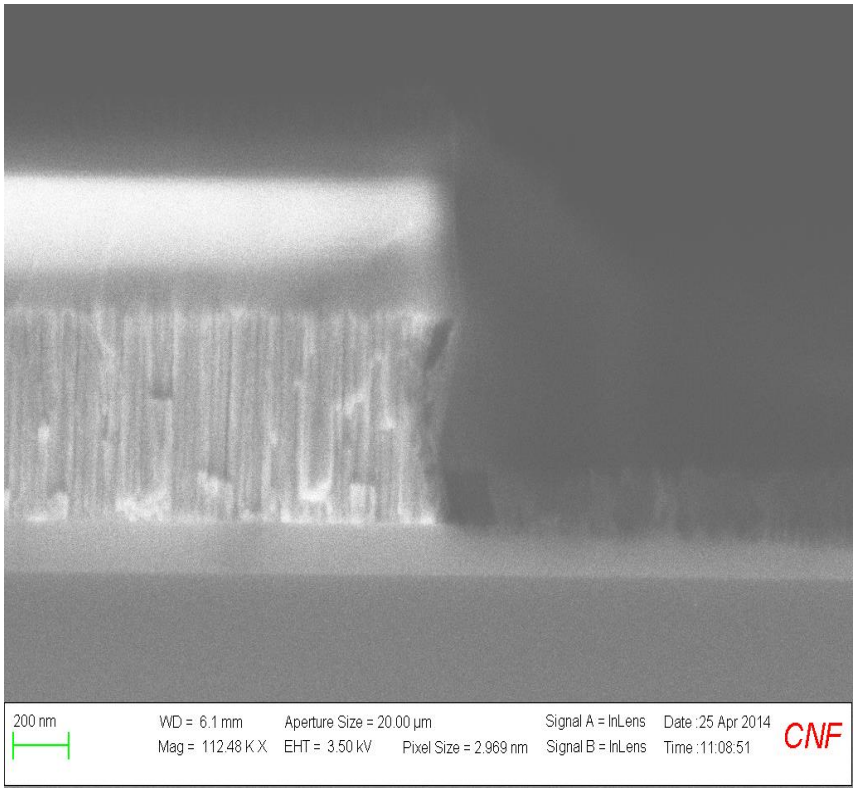


ASML UV210 PR mask:
SF6/N2=40/12, 100W, 10mTorr

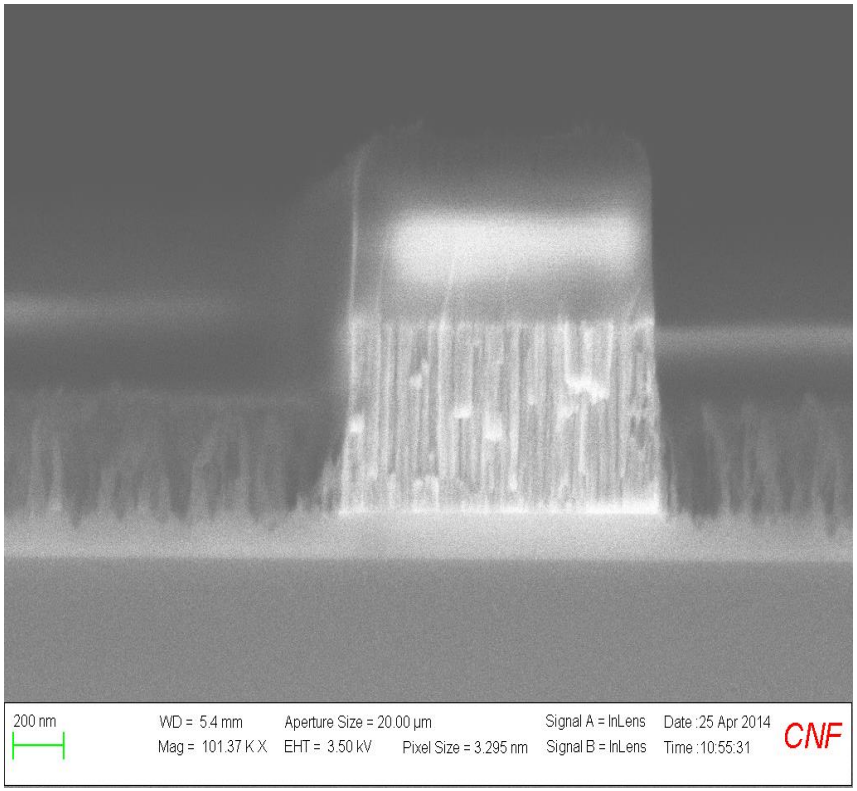


Tungsten Etch PT740

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



SiO2 mask
SF6/O2=40/12, 10mTorr, 125W



Oxford Plasmalab 80s RIE

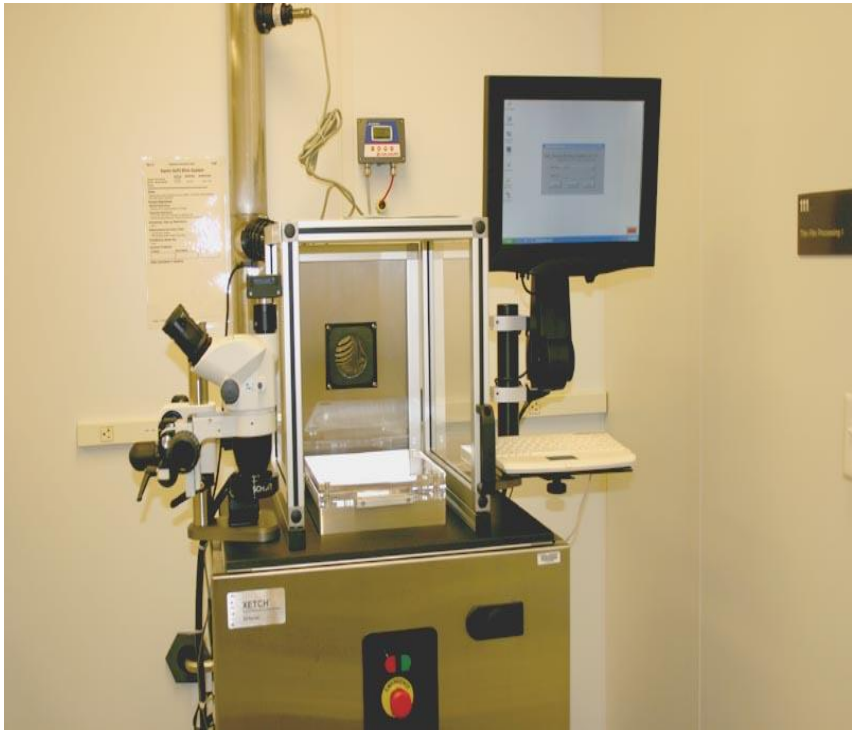
- Parallel plate conventional RIE
- Fluorine based chemistry: CF4, CHF3, SF6.
- Additives: Ar, O2, H2
- Primarily used to etch silicon based materials.
- 2 plasmalab 80 systems: 82 is limited to CMOS approved materials, while 81 includes other substrates such as III-V materials.
- DUV ARC (AR3) etch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

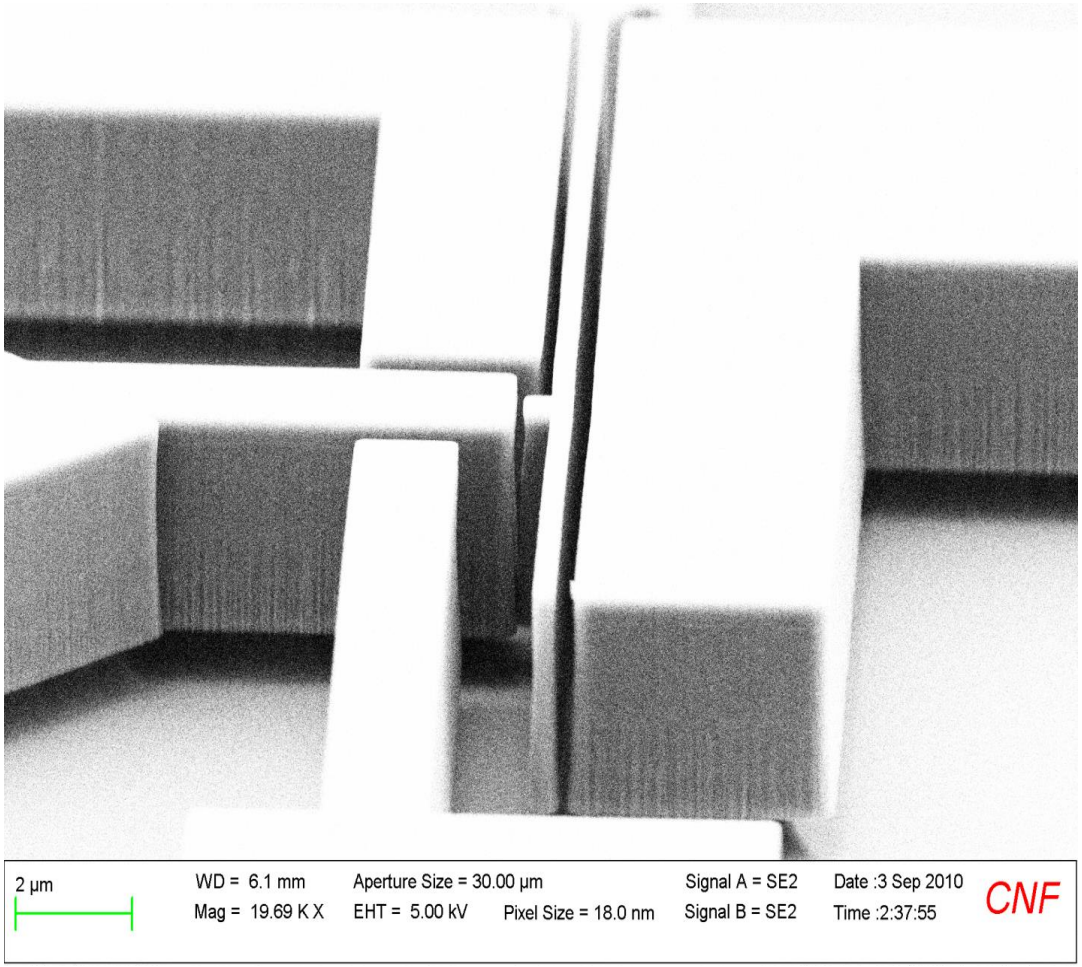


Primaxx uetch vapor HF system

- 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

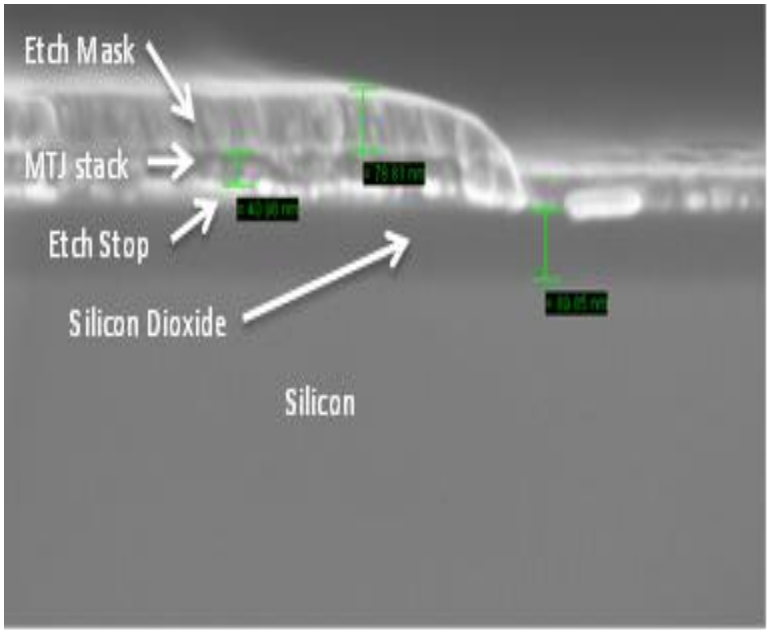
- 22cm Kaufman RF-ICP Ar ion source
- Water cooled stage
- Up to 180 degree tilt with rotation up to 25 rpm
- Wafer sizes up to 150mm
- Beam energies up to 1000eV

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, BCl3, 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

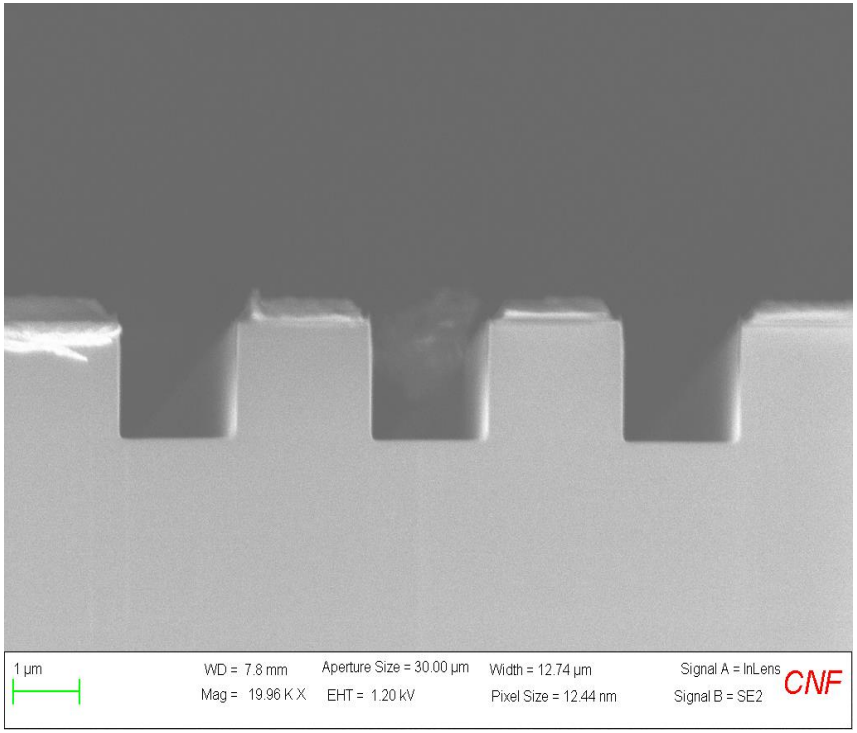
Oxford Cobra NGP ICP
Magnetics Etch

- 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

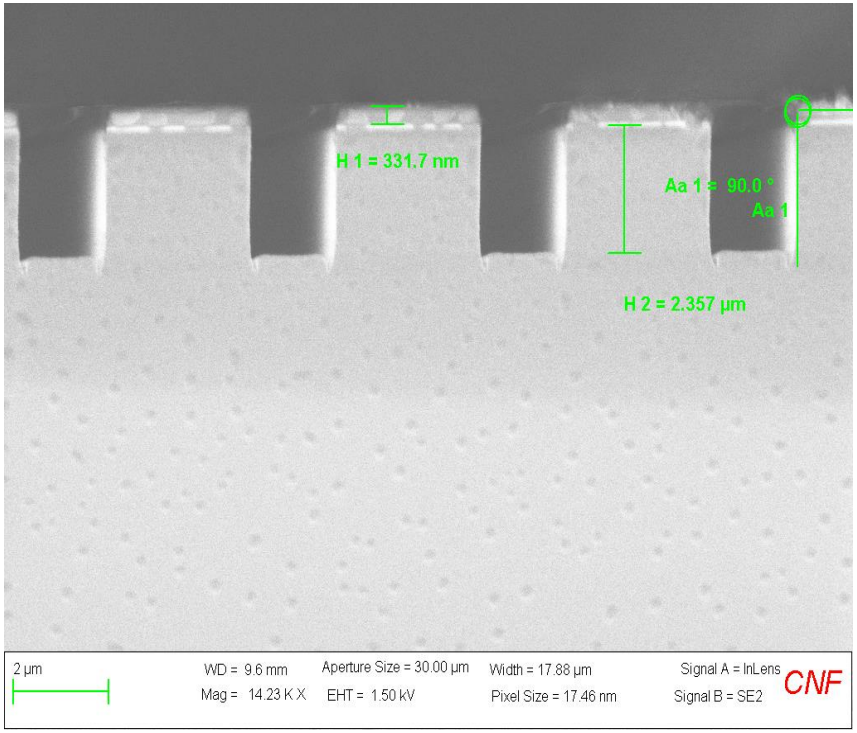


Oxford Cobra NGP ICP
HBr silicon etch

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

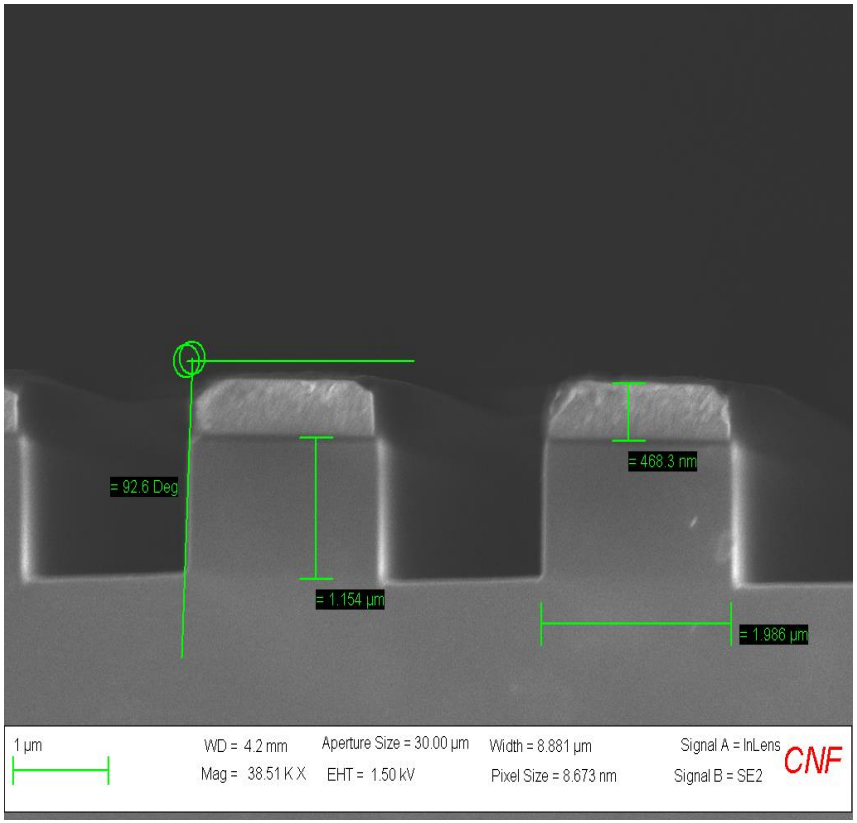


HBr=20, no Ar, 40/1500W, 8mTorr
SiO2 mask: 227nm/min, SOX=22:1

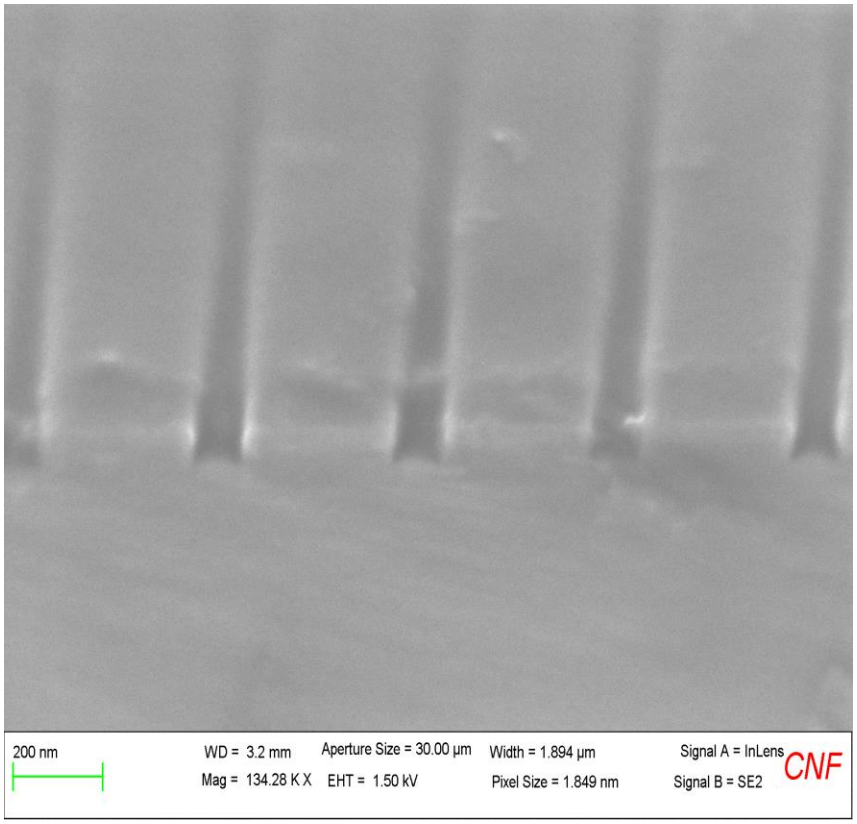


Oxford Cobra NGP ICP
HBr silicon etch

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

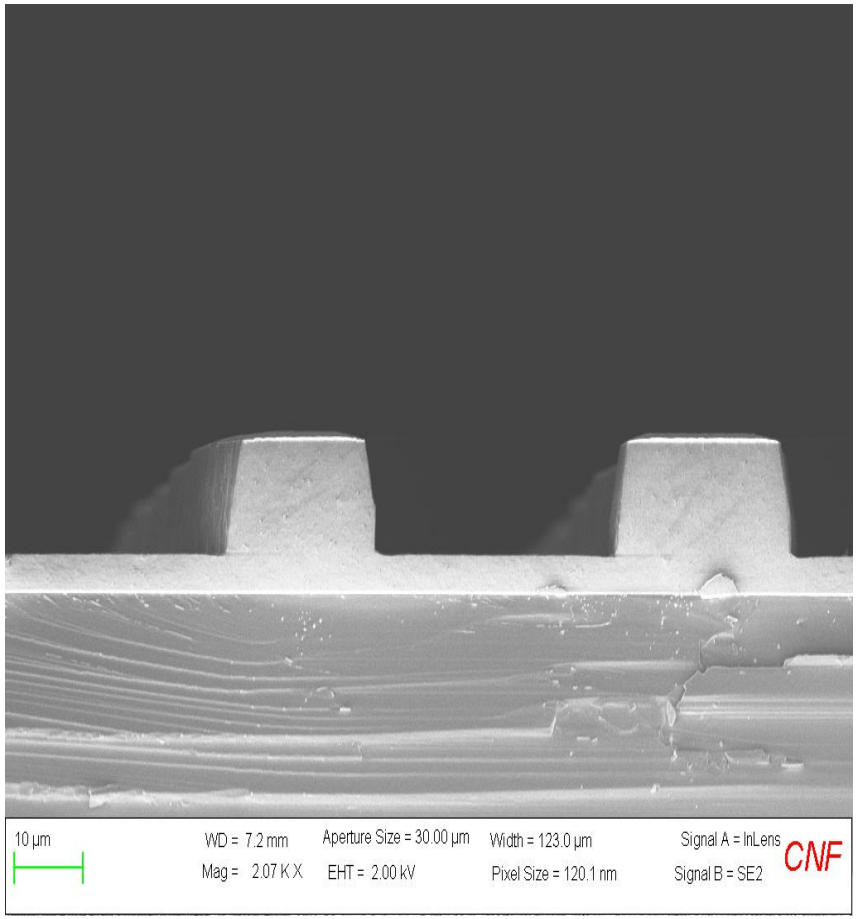


HBr/Ar=20/7sccm, 30/1500W, 11mTorr
ZEP mask: 75nm gaps 95nm/min, S-ZEP=3:1



Oxford Cobra NGP ICP
Ultra-Nanocrystalline Diamond (UNCD) Etch

- 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(1.5sccm) to an O2/Ar (50/5sccm) 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 270nm/min with selectivity to Al of 40:1 with etch parameters of 2800W/50W at 5mTorr.



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.