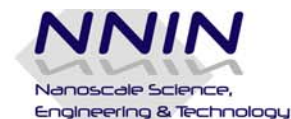


*NNIN Etch Workshop*  
**Cornell University**  
**May 21, 2013**

# Cornell NanoScale Facility Dry Etch Capabilities

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**CNF Research Staff**



## Dry Etch Systems

- High Density Plasma (ICP): PlasmaTherm Versaline DRIE  
Unaxis (PT) 770 DRIE  
PlasmaTherm 770  
Oxford PlasmaLab 100-380  
Trion Minilock III  
Oxford PlasmaPro 100 Cobra (6/2013)
- RIE (parallel plate):  
PlasmaTherm 720/740 (dual chamber)  
PlasmaTherm 72  
Oxford PlasmaLab 80 (2)

## Dry Etch Systems

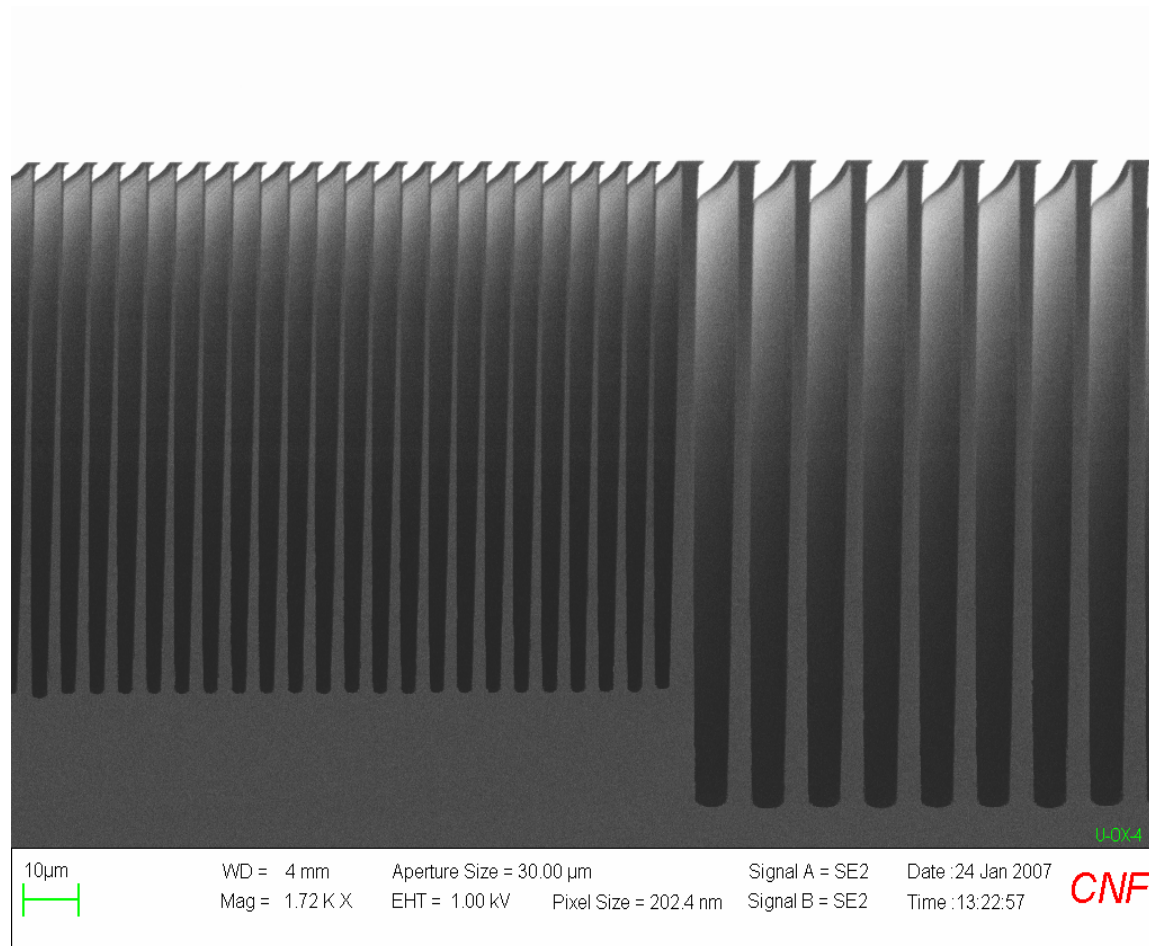
- Dry release: Xactix XeF2  
Primaxx uetch
- PR strip/ash: Aura 1000  
Branson barrel system  
Glenn 1000  
Yes CV200RFS
- Ion Milling: Veeco  
AJA custom system (9/2013)



## PlasmaTherm Versaline DRIE

- Timed multiplexed process (C<sub>4</sub>F<sub>8</sub>, SF<sub>6</sub>, Ar)
- SOI, HAR processes
- PR, SiO<sub>2</sub>, Al<sub>2</sub>O<sub>3</sub> (ALD) masks
- 110:1, 340:1, >1000:1 selectivity
- 50:1 AR (trench), 200:1 (lines)
- Typical etch rates ~ 8um/min
- 100 mm wafer size, clamped
- Endpoint works OES





## Versaline DSEIII-TMP deep silicon etch

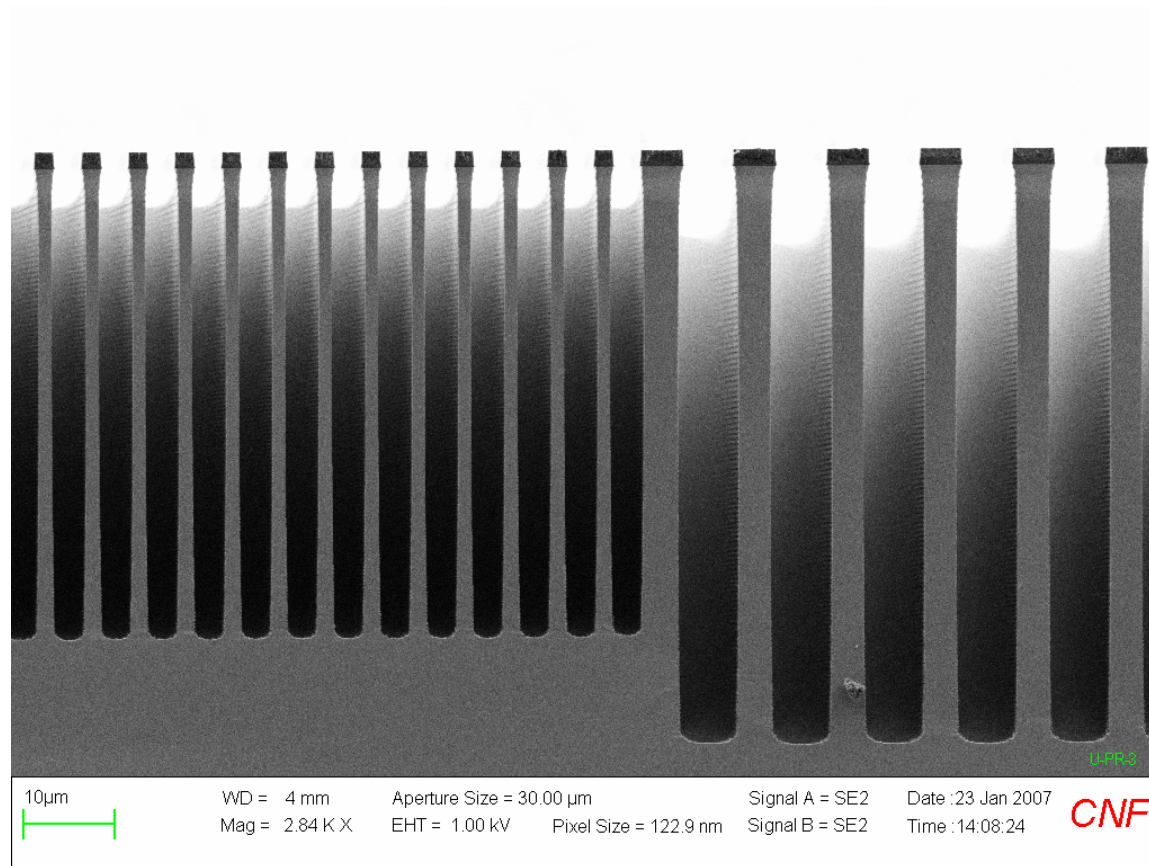
35:1 aspect ratio

Oxide selectivity = 333:1

Etch rate = 8µm/min



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## Versaline DSEIII-TMP deep silicon etch

PR mask selectivity 120:1

Etch rate 8µm/min



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## ALD alumina and Plasmatherm Versaline 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.

## Unaxis (Plasmatherm) 770 SLR DRIE

- Time multiplexed process  
(SF<sub>6</sub>, C<sub>4</sub>F<sub>8</sub>, Ar)
- SF<sub>6</sub> based release etch
- Mixed etch (SF<sub>6</sub>+C<sub>4</sub>F<sub>8</sub>+O<sub>2</sub>)  
aka “photonics etch”
- Typical etch rates ~ 2μm/min.
- PR and oxide masks with 50:1  
and 200:1 selectivity.
- Aspect ratios up to 20:1
- 100mm, 150mm clamped





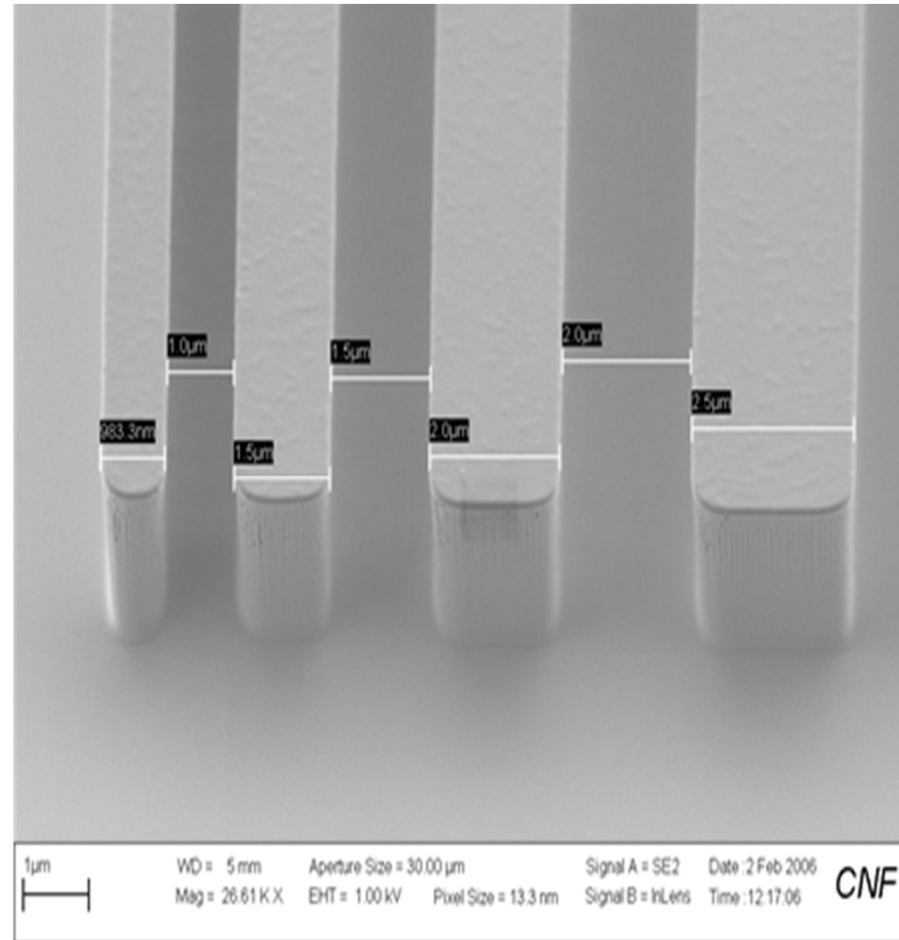
## Plasmatherm 770-ICP

- Dual chamber ICP
- Left chamber – shallow silicon (<10um), single xtal and polyxtalline.
  - Cl<sub>2</sub> 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, SiO<sub>2</sub>, Si<sub>3</sub>N<sub>4</sub>, and Ni masks.
  - 100mm clamped
  - non-heated electrode
  - Cl<sub>2</sub>, SiCl<sub>4</sub>, CH<sub>4</sub>, H<sub>2</sub>, SF<sub>6</sub>



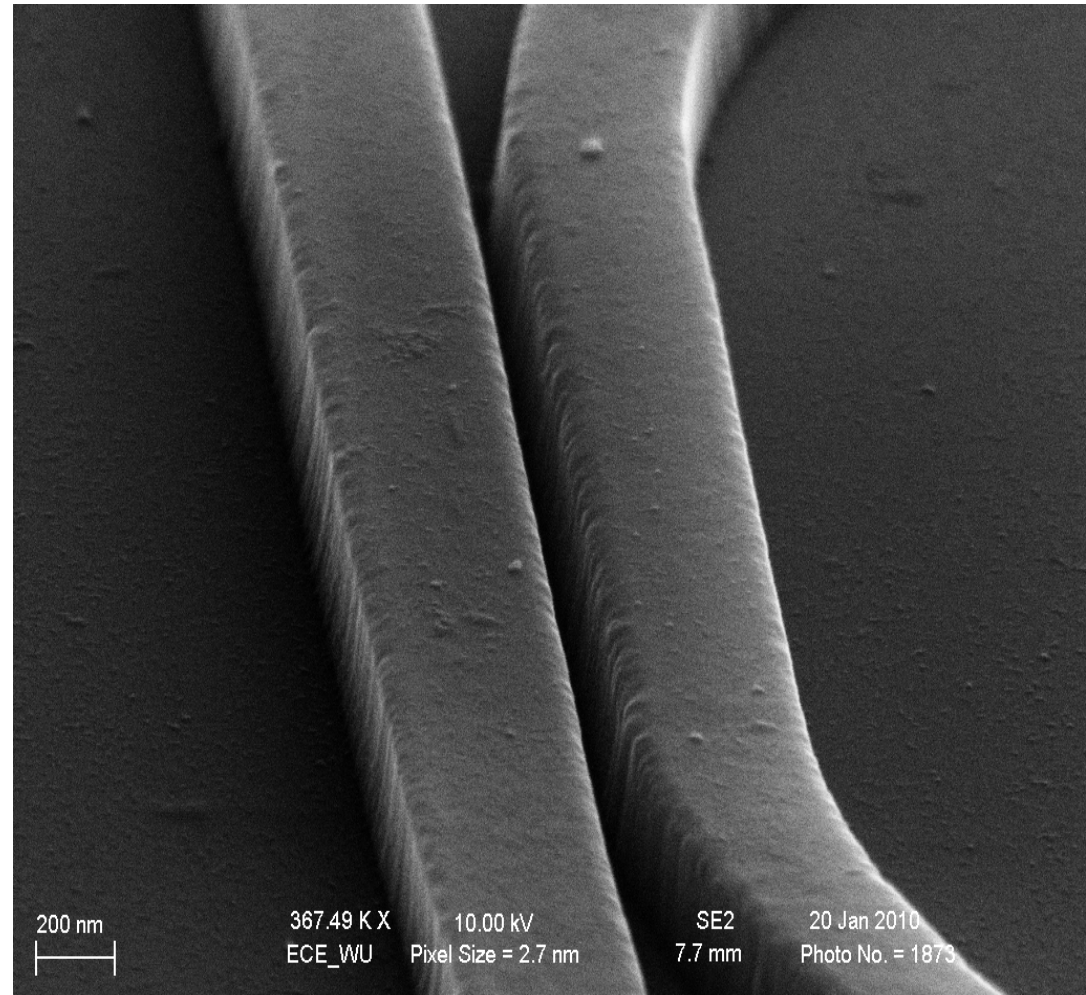
## Plasmatherm 770 ICP

GaAs etch using  $\text{BCl}_3$  chemistry  
with pecvd oxide mask.



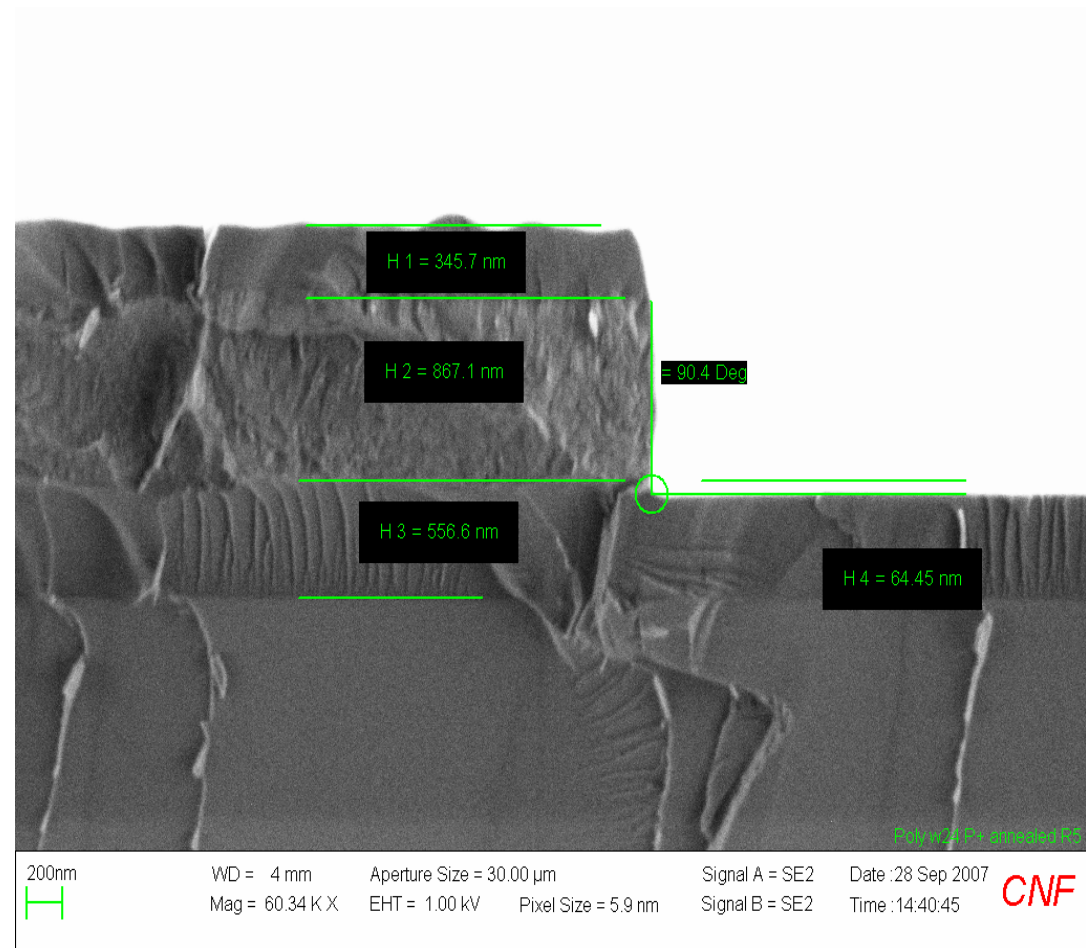
## Plasmatherm 770 ICP

Ebeam defined SOI waveguide structure using HSQ mask etched with  $\text{Cl}_2/\text{BCl}_3/\text{H}_2$  chemistry.



## Plasmatherm 770 ICP

Annealed P+ polysilicon on oxide  
etched in Cl<sub>2</sub>/BCl<sub>3</sub> chemistry with  
PECVD oxide mask.



## Trion Minilock III ICP

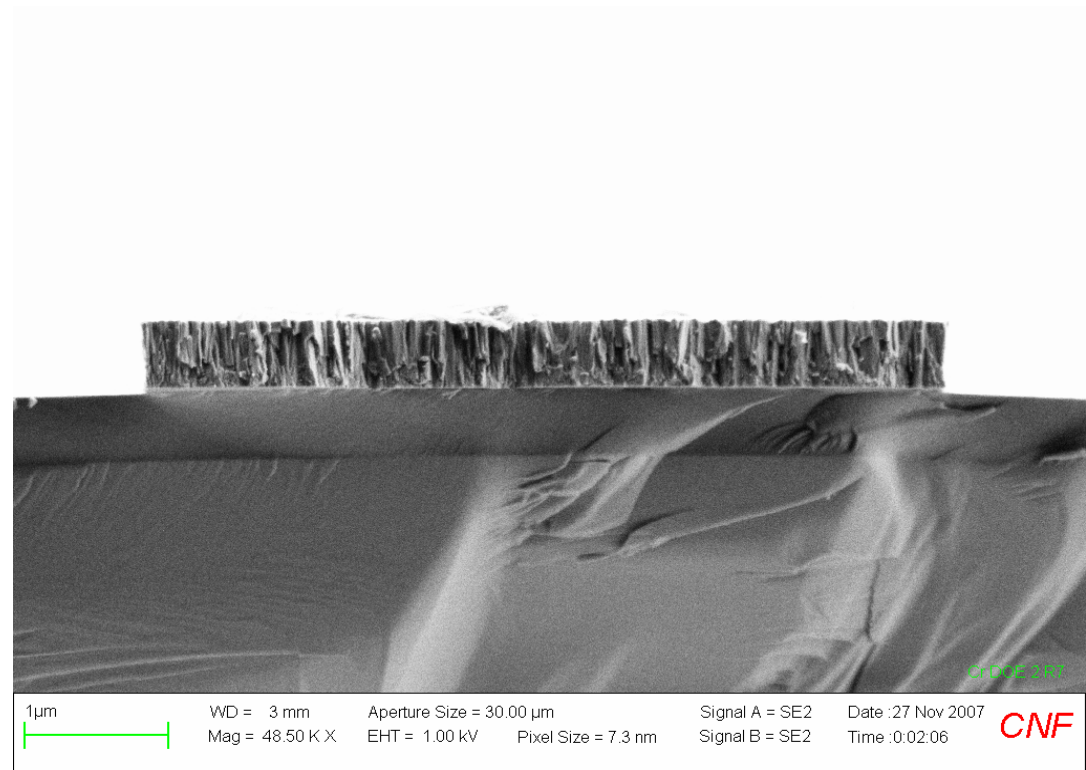
- Chrome etching only
- Cl<sub>2</sub>, O<sub>2</sub>, Ar based chemistry
- Up to 200mm wafers
- Up to 7" square mask plates
- Nanoimprint template fabrication (P-NIL)





## Trion Minilock III ICP

Chrome etched with  $\text{Cl}_2/\text{O}_2/\text{Ar}$  on  $\text{SiO}_2$  underlayer using 1800 series resist (removed).





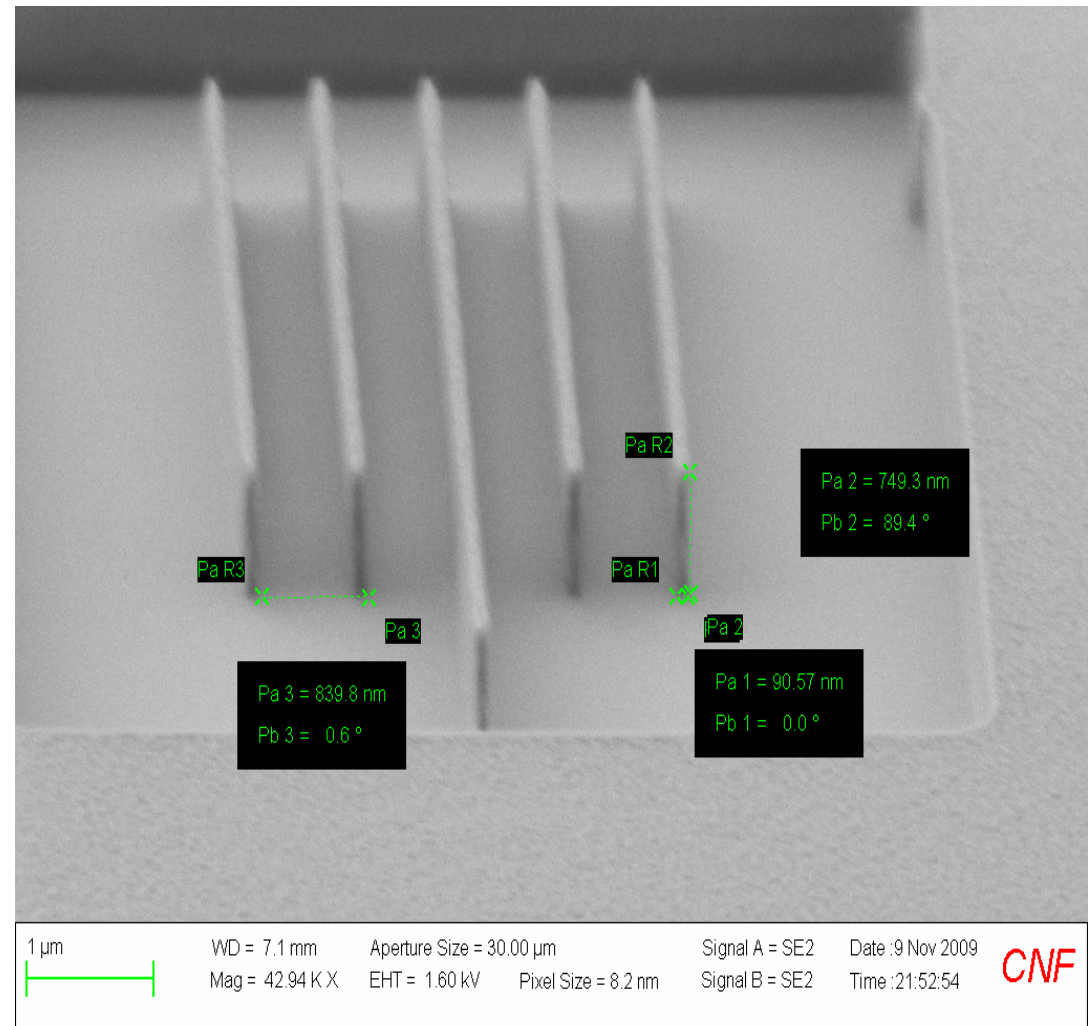
## Oxford Plasmalab 100-ICP

- 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 ( $C_4F_8$ ,  $C_2F_6$ ,  $C_4F_6$ ,  $CH_2F_2$ ,  $CHF_3$ )
- Other gases ( $CF_4$ ,  $SF_6$ ,  $O_2$ ,  $Ar$ ,  $N_2$ ,  $He$ )
- Switchable manifold for the showerhead or gas ring for low F/Cs.
- Enhanced selectivity to ebeam and deep UV



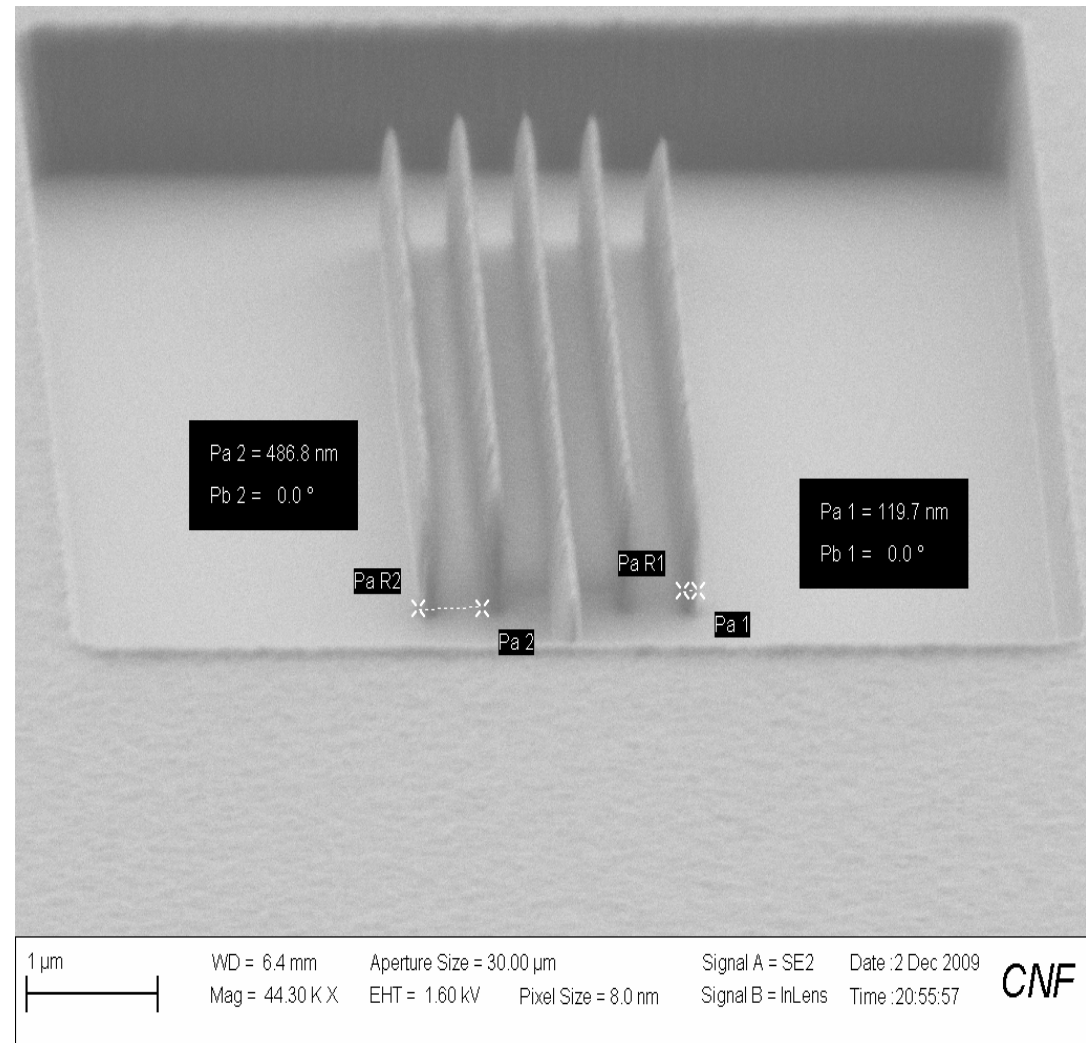
## Oxford 100 ICP

90nm linewidth ASML DUV  
(248nm) silicon nitride etched with  
CHF<sub>3</sub>/O<sub>2</sub>



## Oxford 100 ICP

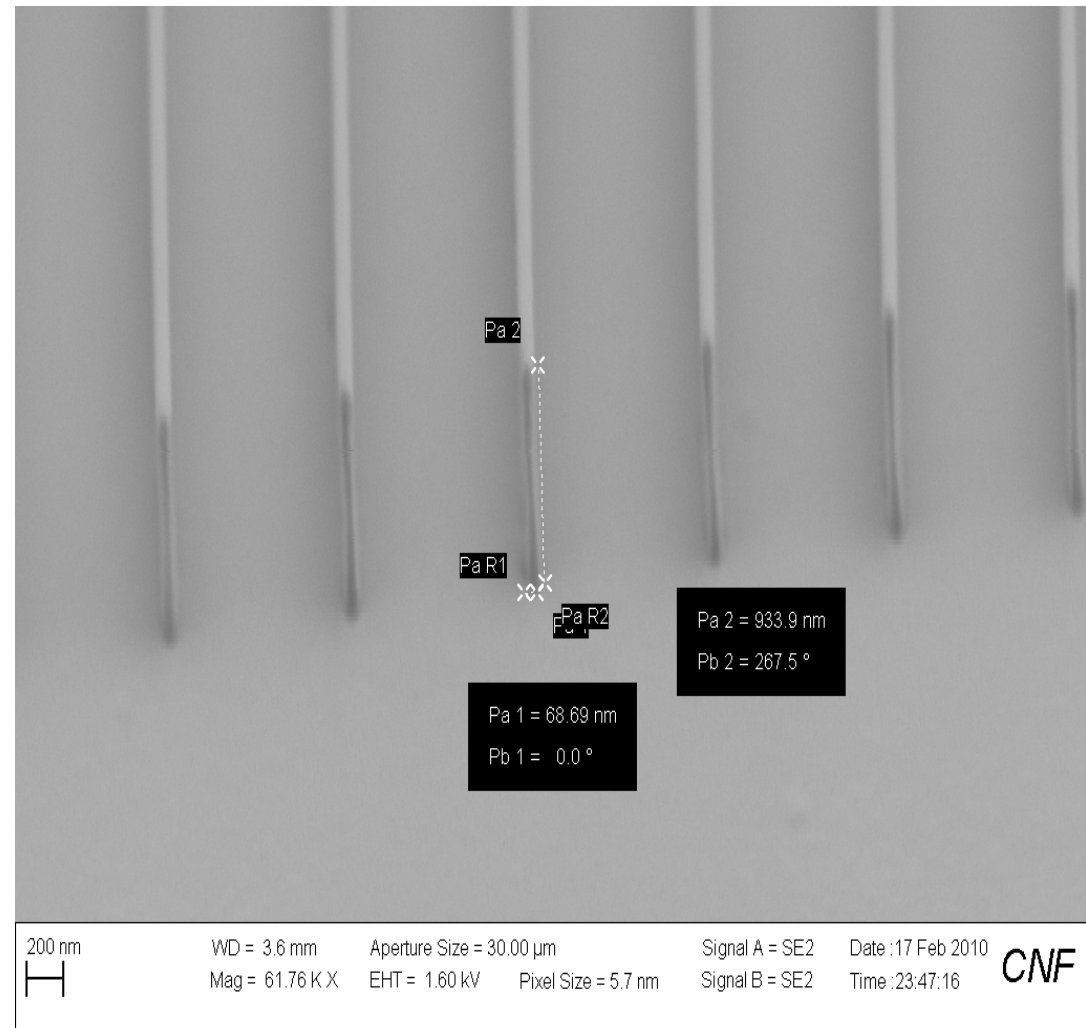
119nm linewidth ASML DUV  
(248nm) defined silicon dioxide  
etched with CHF<sub>3</sub>/O<sub>2</sub>.



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## Oxford 100 ICP

Ebeam lithographically defined  
68nm etched into fused silica with  
C<sub>4</sub>F<sub>8</sub>/CO<sub>2</sub> using chrome mask.



## Plasmatherm 720/740 RIE

- 720: Cl<sub>2</sub> based shallow silicon etch (single xtal or polycrystalline)
  - oxide mask only, 30:1 selectivity
  - up to 200mm wafers
  - etch rates up to 100nm/min
- 740: metal etching (mostly Al, but also Al<sub>2</sub>O<sub>3</sub>, Cr, Ta, and Nb)
  - Cl<sub>2</sub> based chemistry
  - CH<sub>4</sub> sidewall passivation
  - SF<sub>6</sub>/O<sub>2</sub> for post etch passivation PE mode.
  - up to 200mm wafers.



## Oxford Plasmalab 80s RIE

- Parallel plate conventional RIE
- Fluorine based chemistry:  $\text{CF}_4$ ,  $\text{CHF}_3$ ,  $\text{SF}_6$ .
- Additives: Ar,  $\text{O}_2$ ,  $\text{H}_2$
- 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.





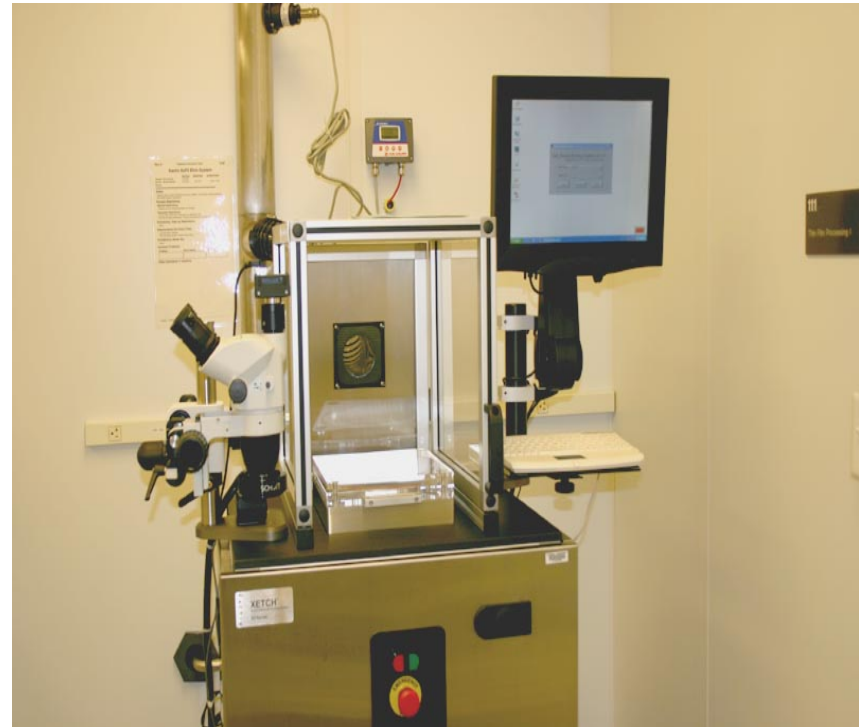
## Plasmatherm 72 RIE

- Conventional parallel plate RIE
- Fluorine based chemistry:  $\text{CF}_4$ ,  $\text{CHF}_3$ ,  $\text{SF}_6$ .
- Additive gases include  $\text{O}_2$  and  $\text{H}_2$ .
- 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 XeF<sub>2</sub> 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.



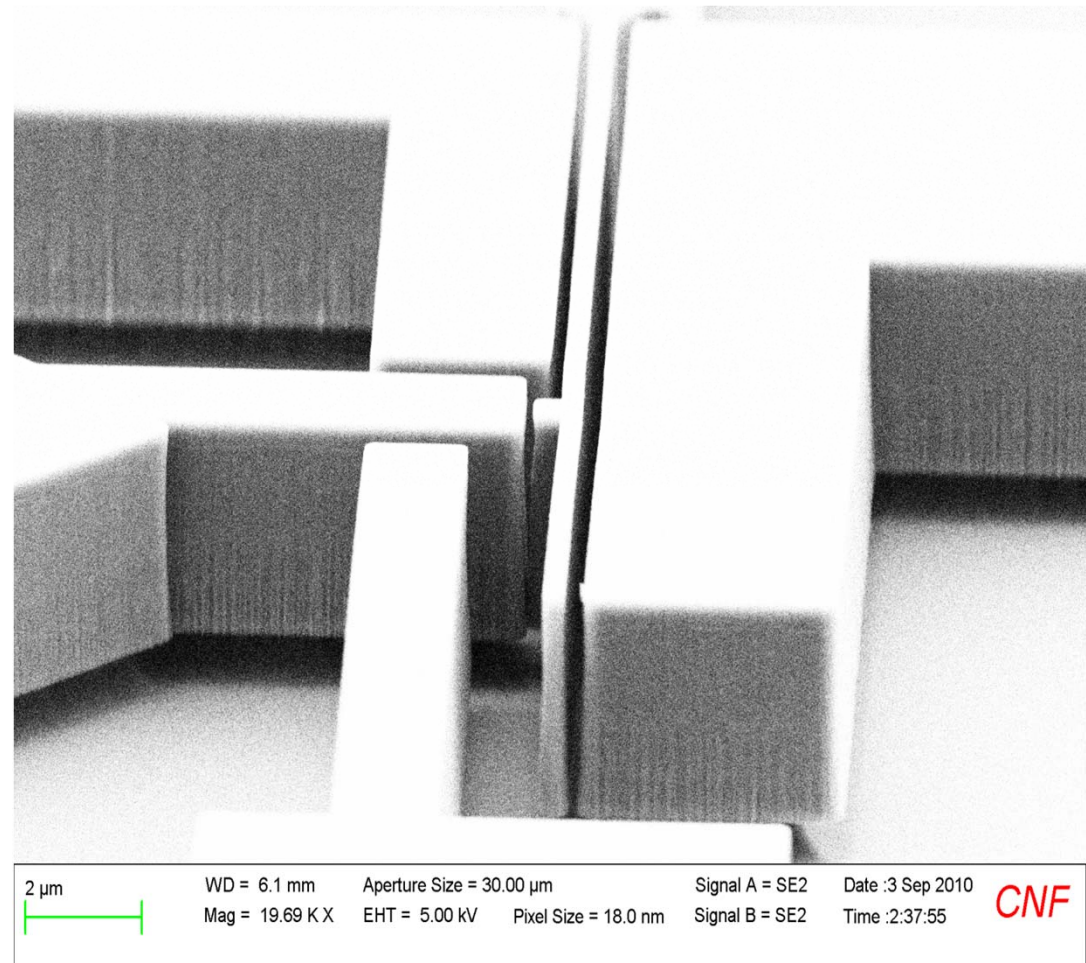
# Primaxx uetch vapor HF system

- 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, Al<sub>2</sub>O<sub>3</sub>, TiW, SiC and LPCVD low stress silicon nitride.
  - VHF, EtOH, and N<sub>2</sub> are reaction components.
  - Typical process pressures 50-150 torr.
  - Process temperature 45C.
  - Controlled thermal oxide etch rates up to 200nm/min.
  - Need to O<sub>2</sub> ash prior to etch to remove any CF<sub>x</sub> on surface acting as an inhibitor.
  - If Si<sub>3</sub>N<sub>4</sub> is present, need to hotplate bake at >160C to remove reaction product.
  - Small (few nm) particulate formation.
- HSiF<sub>x</sub>?



## Primaxx HF system

Successful release of silicon beams  
25 $\mu$ m in length, 500nm in width  
from SOI 2 $\mu$ m BOX layer.



## Plasma Ashing/Strip

- Aura 1000: downstream
  - 4" cassette to cassette
  - heating option
  - up to 4um/min rate
- Glenn 1000: multi-shelf electrode configuration.
  - powered, grounded, or floating.
  - strip or descum.
- Branson: barrel type system
  - heat, strip, and descum.
- YES CV200RFS: 40kHz plasma isolated by grounded perforated metal plate.
  - strip or descum
  - heated to 250C.
  - N2 and Ar are available.





## Veeco Ion Mill

- 10cm Kaufman Ar ion beam
- H<sub>2</sub>O cooled stage.
- 90 degree tilt with rotation.
- Up to 100mm wafers.





## Oxford Instruments PlasmaPro System 100 Cobra June 2013 delivery

- Newly designed Cobra ICP source
- Wide temperature range (-150C→400C) lower electrode
- Up to 150mm wafers-clamped system.
- 12 line gas pod initially populated for HBr, Cl<sub>2</sub>, BCl<sub>3</sub>, H<sub>2</sub>, CH<sub>3</sub>OH, SF<sub>6</sub>, O<sub>2</sub>, and Ar.
- Later additions would be NH<sub>3</sub>, CO, and C<sub>4</sub>F<sub>8</sub>.
- Low frequency (350kHz) bias to the lower electrode
- LN<sub>2</sub> auto changeover box for switches between cyro and chiller mode.
- Ocean Optics OES for endpoint and chamber condition monitoring.
- HBr based silicon etching
- Magnetic materials etching using CH<sub>3</sub>OH based chemistry.
- Alternative magnetic materials etching with NH<sub>3</sub>/CO based chemistry. (later)
- Deep silicon cryogenic based etch.
- Mixed silicon etch using SF<sub>6</sub>/C<sub>4</sub>F<sub>8</sub>. (later)

