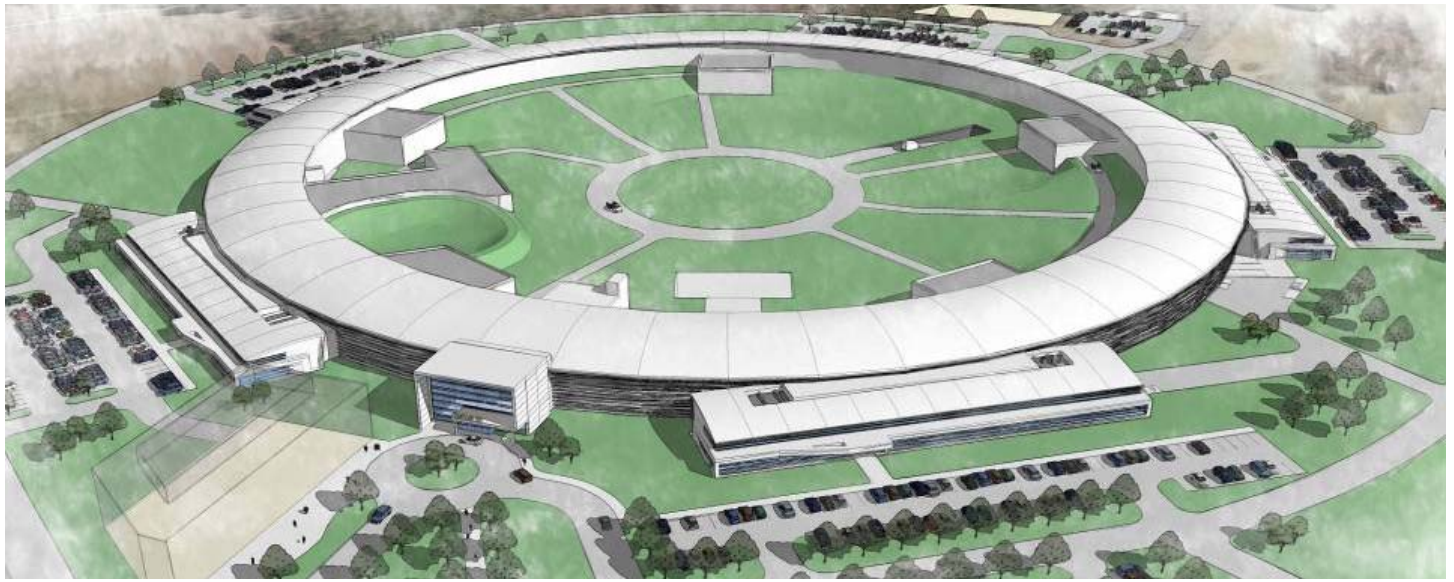
National Synchrotron Light Source II



Kinoform R+D update

K. Evans-Lutterodt
October 5th, 2007

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Outline for 1nm R&D

1) Reminder of issues to be addressed Kinoform R+D

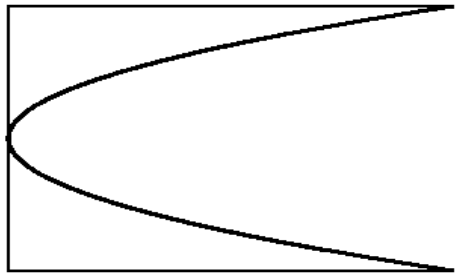
2) Progress towards 10nm testing station

3) Si Etching status

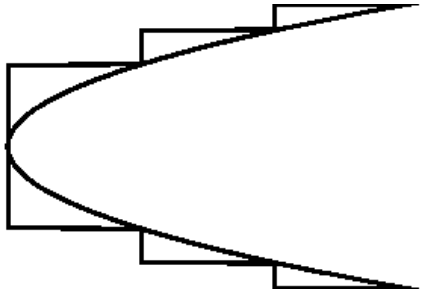
4) Diamond etching and lens

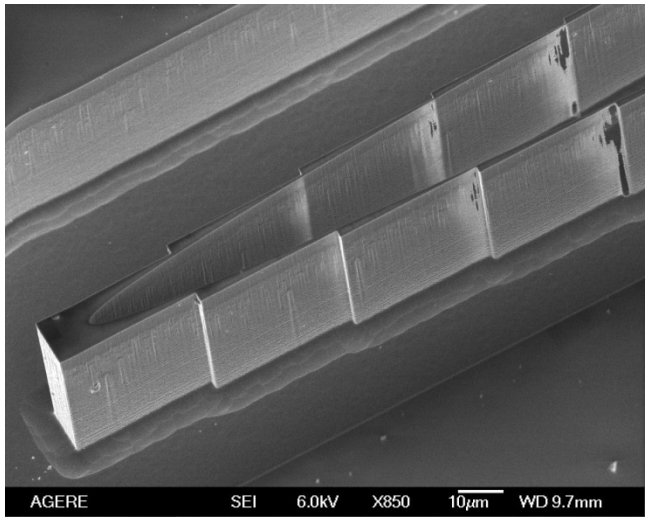
Kinoform Optics

Instead of solid refractive optic:



Use a kinoform:





K. E-L *et al.* (2003)

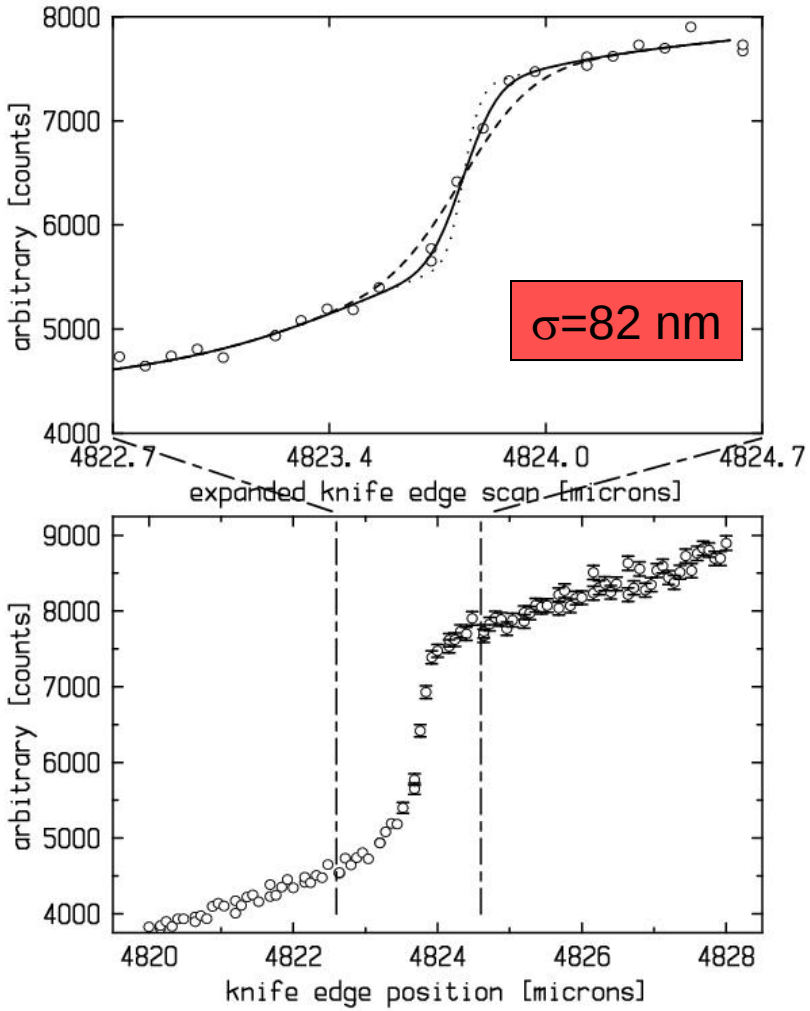
One can view the kinoform equivalently as

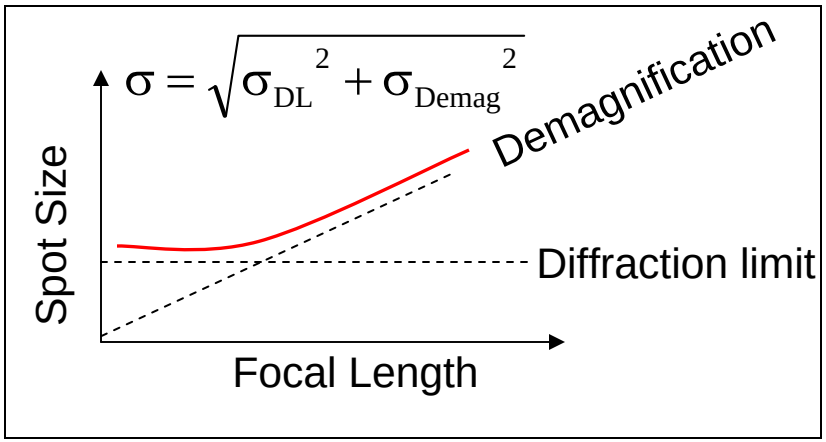
a) A blazed zone plate

b) An array of coherently interfering micro-lenses.

APS results as of last EFAC meeting 82nm

Kinoform results from 1st run at APS (BL 8IDI)





200 micron aperture used

300 micron aperture manufactured

Near diffraction limit.

Diffraction size 0.44λ/NA = 44nm

Demag size = 15nm

Net = 46nm

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Existing (Borrowed) Nano-positioners

+

25mm travel range
80nm step-size
Glass encoder on stage

100 micron range XYZ
1nm step size
Capacitance encoder for feedback

Integrated with 8IDI beamline programs
Performs satisfactorily down to 10nm stepping +-3nm
Borrowed hardware above; we are beginning procurement

Project owned nano-positioners

Key specifications
100nm encoded
Long range travel 35mm,70mm,150mm
Robust Z motion
Have been shipped to APS

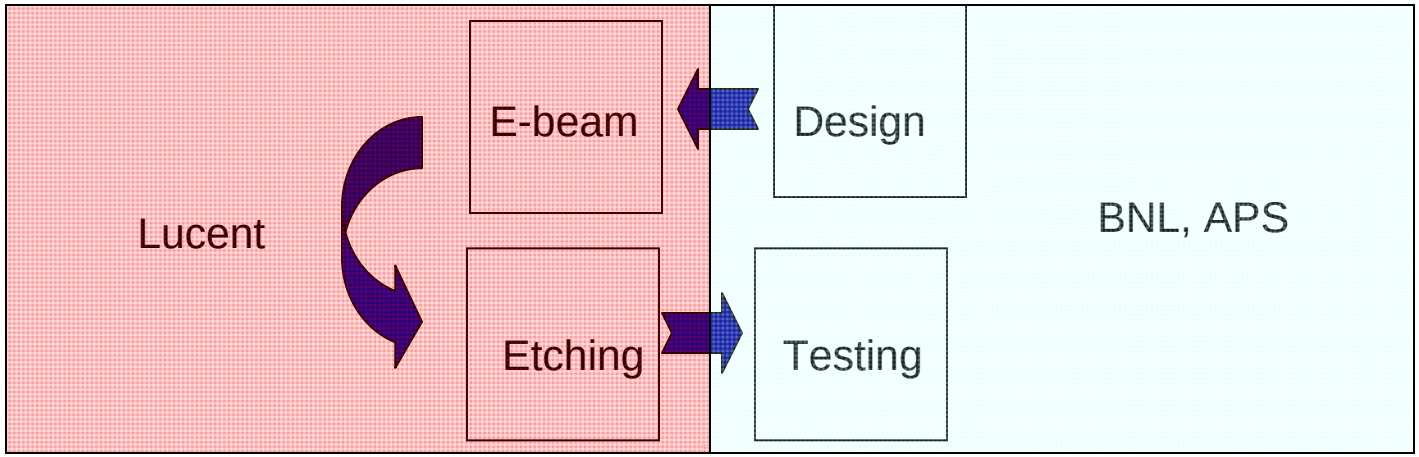
+

100 micron range XYZ
1nm step size
Capacitance encoder for feedback
Not yet arrived

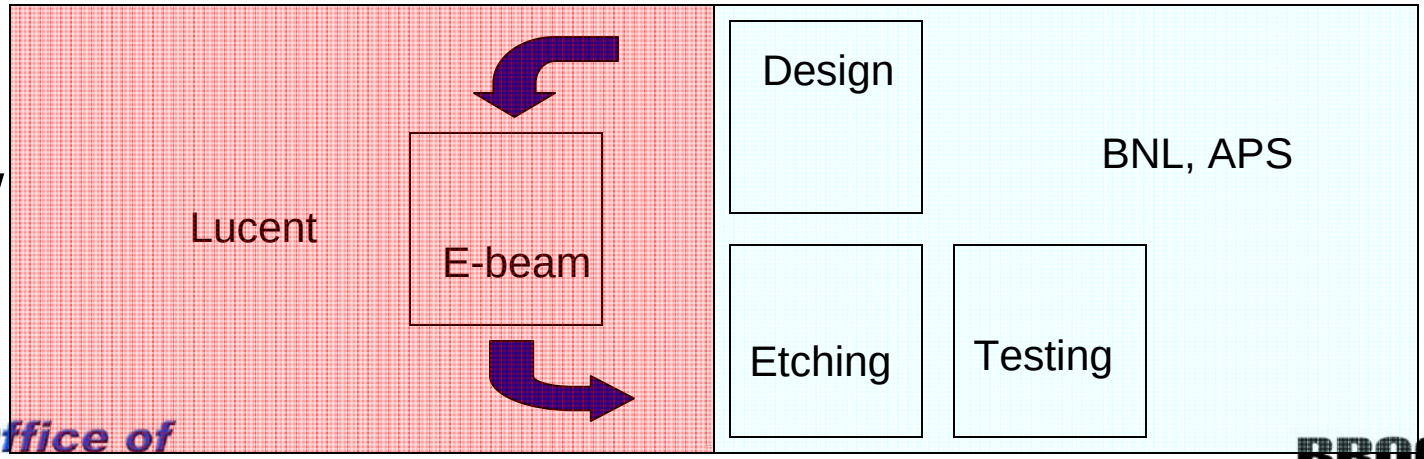
Kinoform Lens Fab

We have acquired a new skill at BNL; etching.

OLD

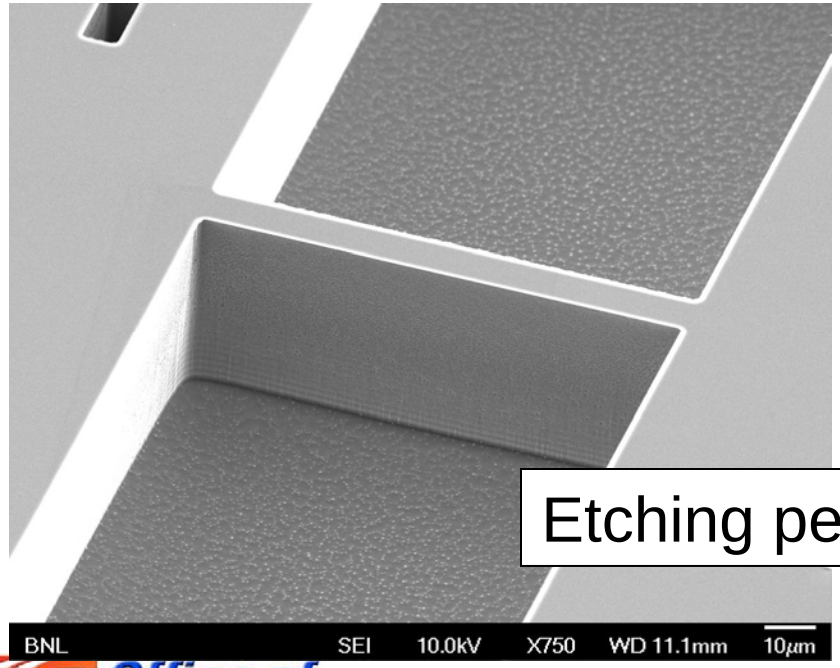


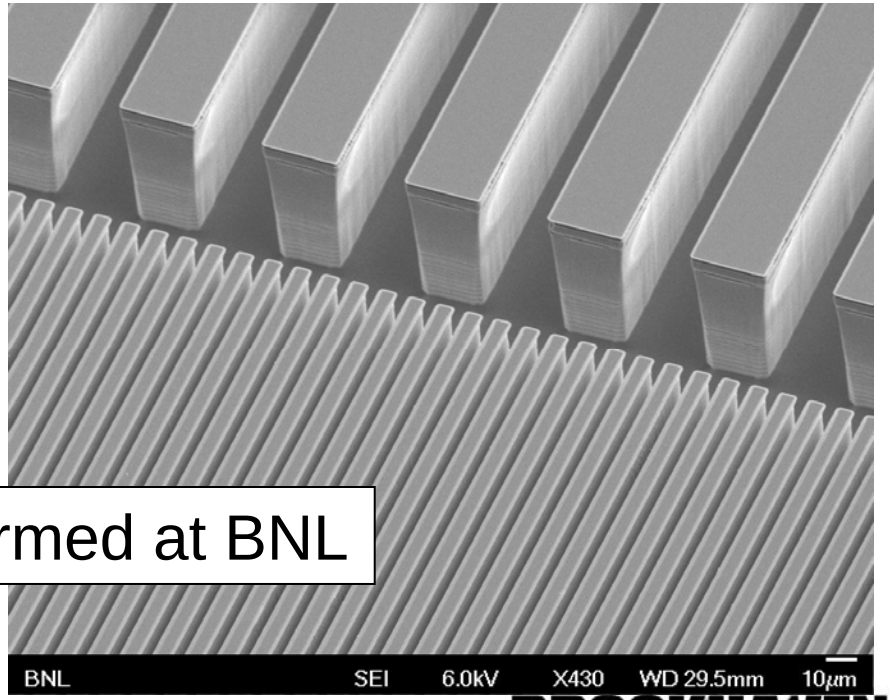
NEW



Status of Si etching; (Abdel Isakovic, Post-doc)

- Purchased machine was Cryo-process only.
- Home grown cyclical cryo-etch process developed;
- Better (deeper, but more vertical) than company-provided recipe.
- Manuscript in process

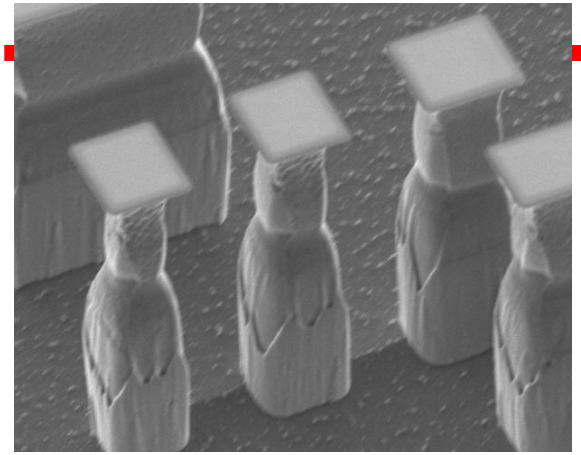




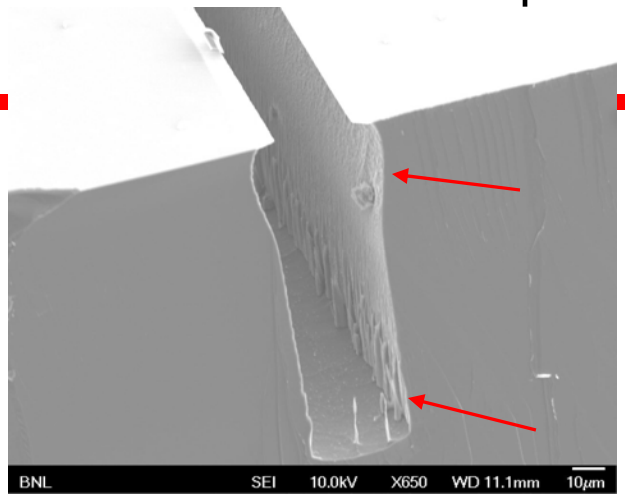
Etching performed at BNL

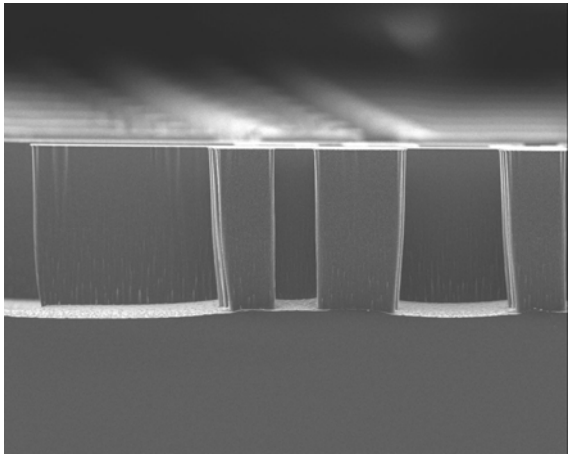
2.5microns/minute

Comparison of Locally Developed Etch Recipe with Manufaturers Recipe

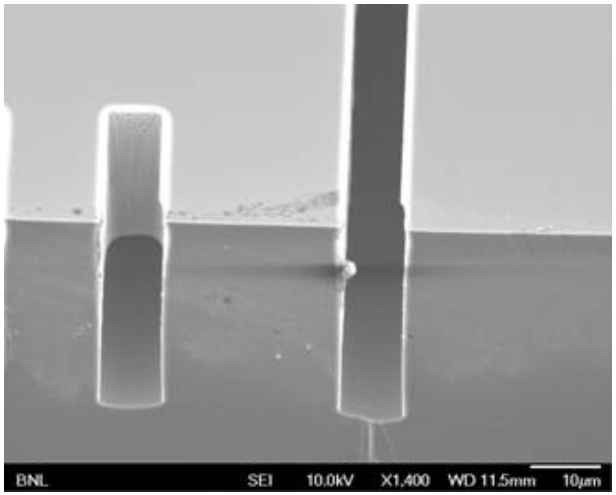


The best result for 80 microns etch with manufacturer's cryo recipe



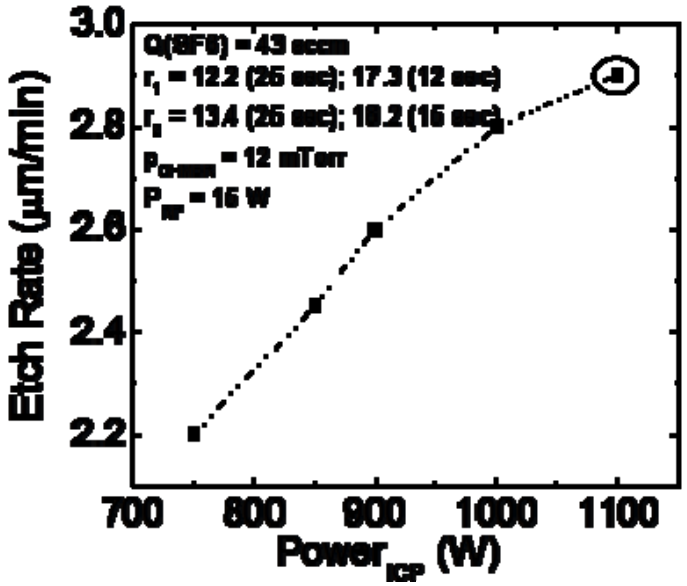


The result with our cyclic cryo etch



Undercut developed due to imbalance of O2 and SF6
Thus the need for optimization.

Comparison of locally developed cyclic cryo-etch with conventional Bosch process



Process → Parameter	Cyclic Cryogenic	Bosch ®
Process gasses	**SF_6 and O_2**	**SF_6 and CF_4**
Etch rate	**2.2-3.2 μm/min**	**> 2 μm/min**
Selectivity (PR)	**40:1 – 80:1**	**> 60:1**
Uniformity variation	**~ 3-6 % over 3" wafer**	**< 5%**
Profile control	**Down to 100 μm: 1°**	**1°**

Etching Resources

•The CFN had purchased the oxford plasma with cryo-etch, but not Bosch process license and hardware add-ons.

•Last EFAC meeting: PO has been signed.

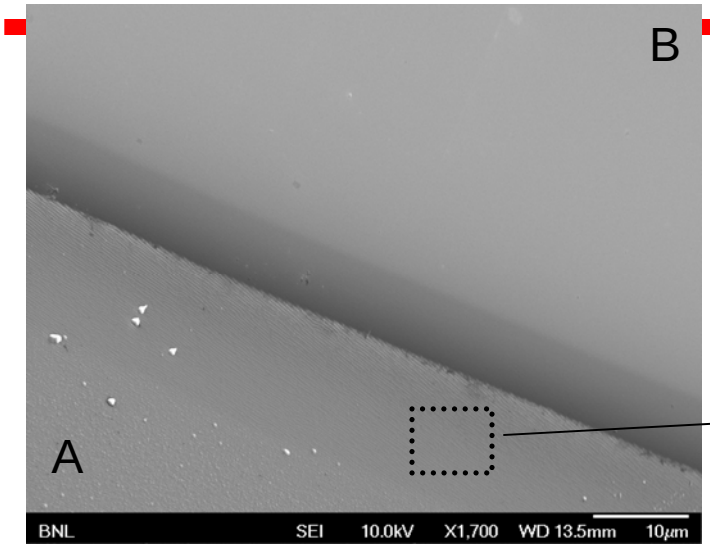
•Status. Etcher has been taken off-line to make the upgrades

•Last EFAC meeting: Diamond etching started; industrial and electronic grade 0.65nm/minute, comparable surface finish.

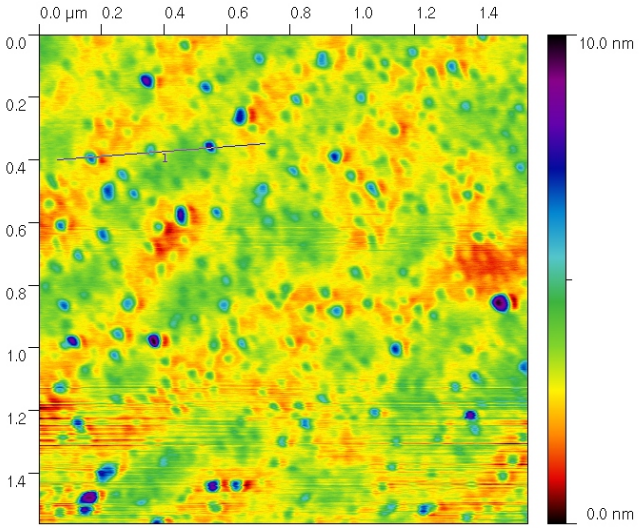
•Status: Diamond lens fabricated

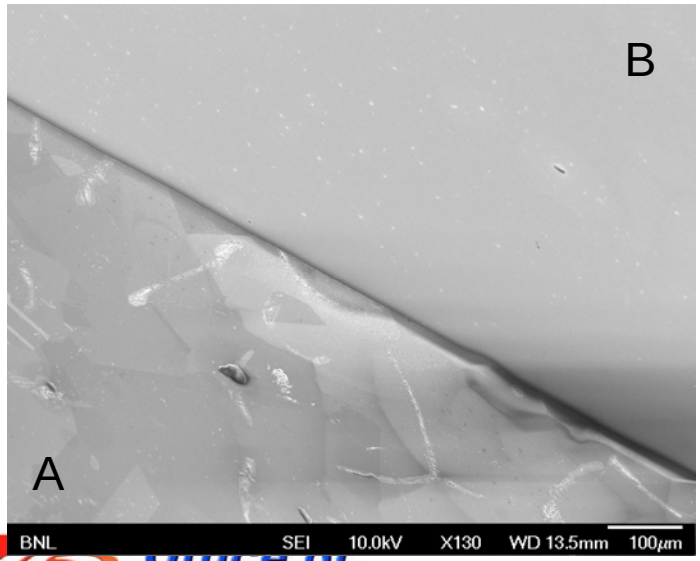
Etching Diamond

AFM test of *rms* surface roughn.

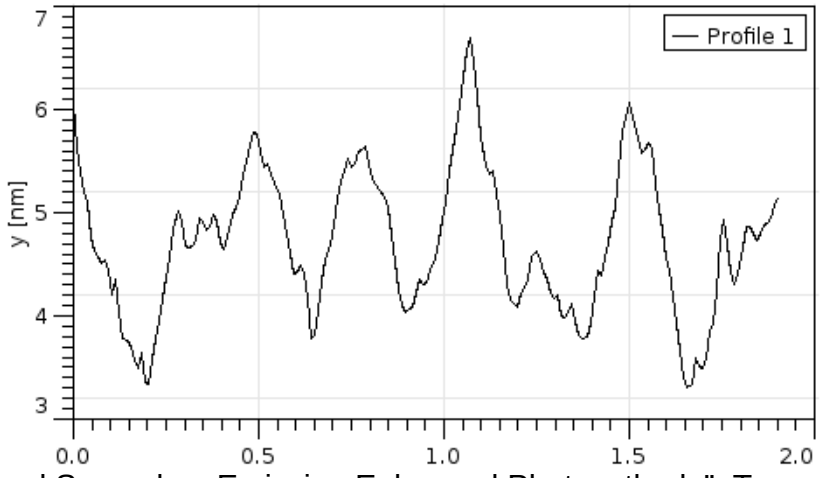


4 microns/1 hour



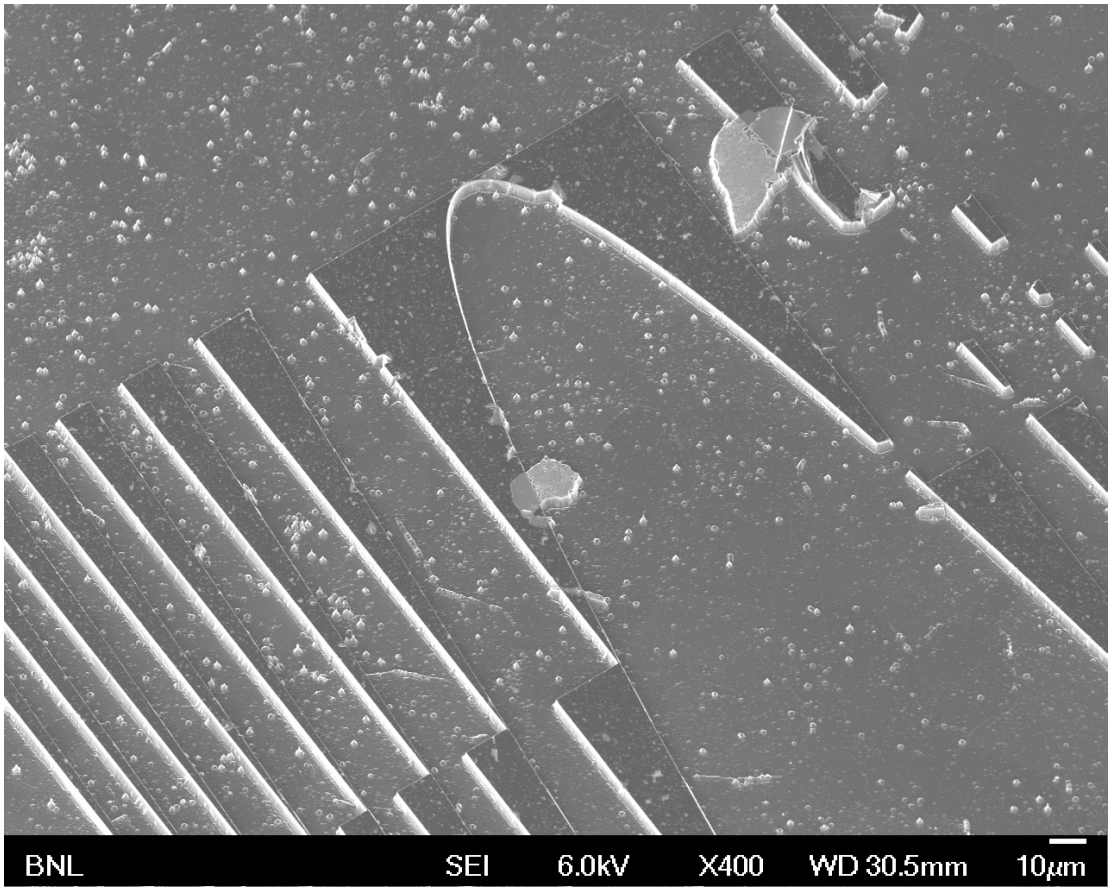


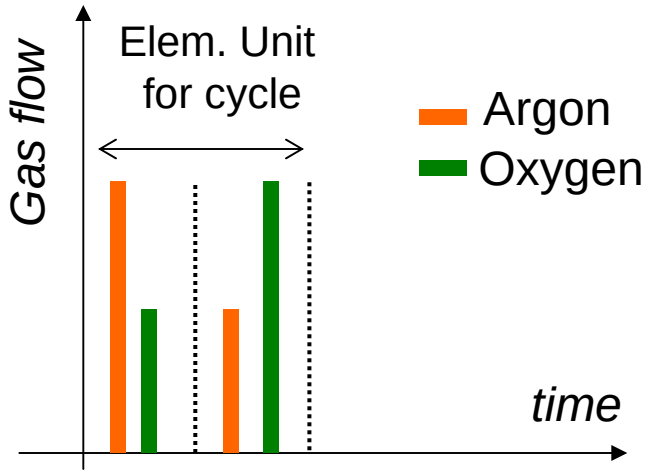
A - etched, B - protected



"Status of Diamond Secondary Emission Enhanced Photocathode", T. Rao, I. Ben-Zvi, X. Chang, J. Grimes, R. Grover, A. F. Isakovic, J. Smedley, R. Todd, J. B. Warren, Q. Wu, J. Bohon, D. Fischer, D. Dimitrov; Proceedings of ERL workshop 2007

A Diamond Lens!





$Q(O_2)$ = 40 sccm; Q(Ar) = 5 sccm (30 sec)
$Q(O_2)$ = 8 sccm; Q(Ar) = 40 sccm (15 sec)
P_{ICP} = 900 W; P_{RF} = 20 W; p_{CHMBR} = 12 mTorr

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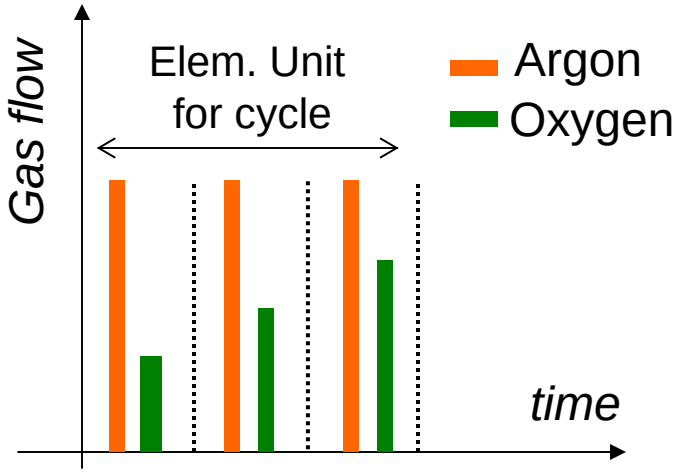
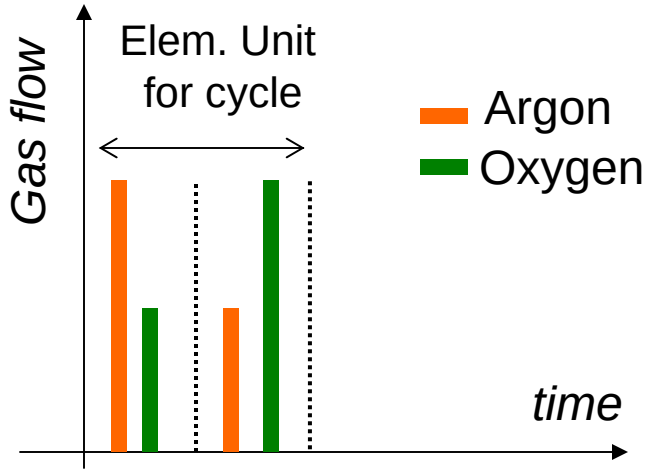
Future directions in Diamond

Faster diamond etch; cyclical Argon/Oxygen mixture



First approach (slow increase of one gas with constant another)



Second approach (cycling with switches in relative flows)

<u>Non Etching alternatives to Diamond sculpting</u>

Laser cutting+ ICP smoothing

Focused Ion beam cutting

Timelines for Kinoform(Lehman,12/06)

FY07

- ✓ Introduce etching RD program
- • Measure 60nm lenses
- ✓ Improve theoretical underpinning
- ✓ Improve measurement techniques to enable lens characterization

FY08

- • Develop Deep Vertical Si etching
- • Optimized E-beam Si process to allow many lens writes
- ✓ Develop etches for InSb, C, Si.
- • Test Compound Si lens sub 40nm

FY09

- • Develop E-beam for alternate materials
- • Test Alternate materials lens in xray
- • Test sub 20nm lens in xray

FY10

- • Test sub 10nm lens

FY 11

- • Test sub 5nm lens

FY12

- • Test 1nm lens

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Short term lens testing needs

- Beamtime – 2 days a month APS
- Can we improve NSLS X13B stability? Will a different mono do it.?
- Test bench stages (5 -10nm resolution), enclosed, temperature stable
  - Design
  - Procure
- Analysis
- Begin developing other methods: Phase retrieval methods (Fienup)

1nm R&D Summary

- Progress in kinoform.
- Characterisation tools acquired
- Collaborations started: 8ID, Fienup