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Solar Wind Induced Substrate Alteration on Genesis Array Materials and H^+ Diffusion at L1

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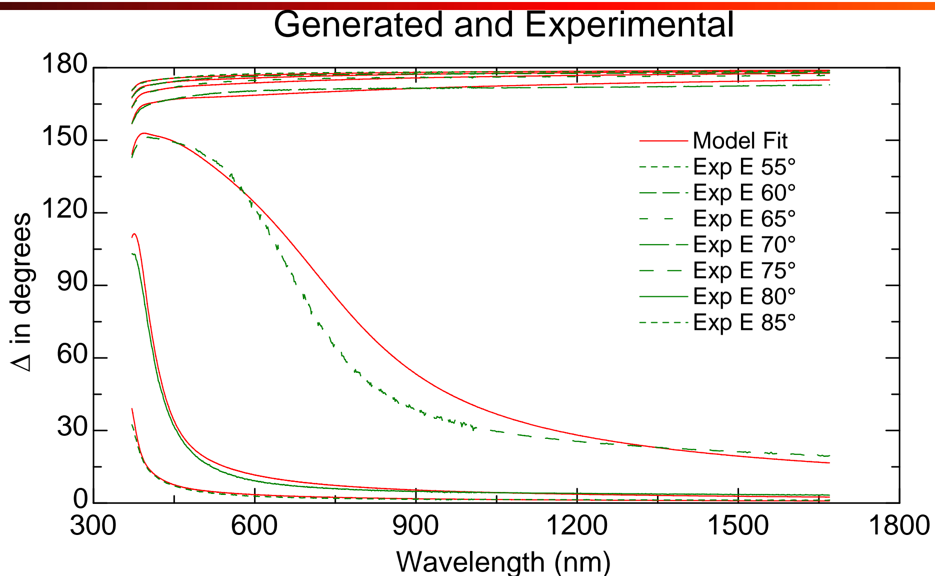
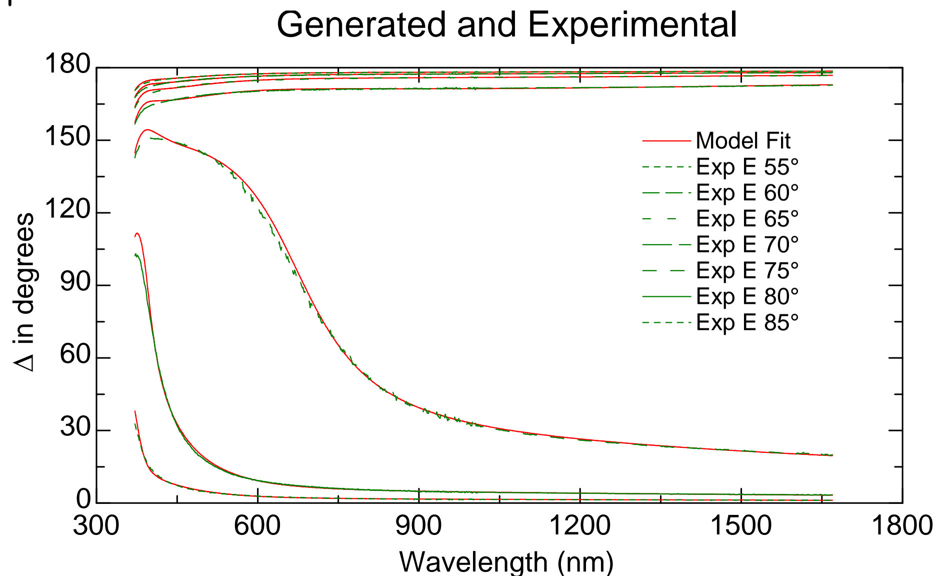
Review of Si Ellipsometry Results (Presented at 2006 LPSC)

- Effective Medium Approximation (EMA) Layer used to model lattice void spaces.
- EMA layer model suggests solar wind radiation zone depth.

1	sio2_jaw	37.36 Å
0	si_jaw	1 mm



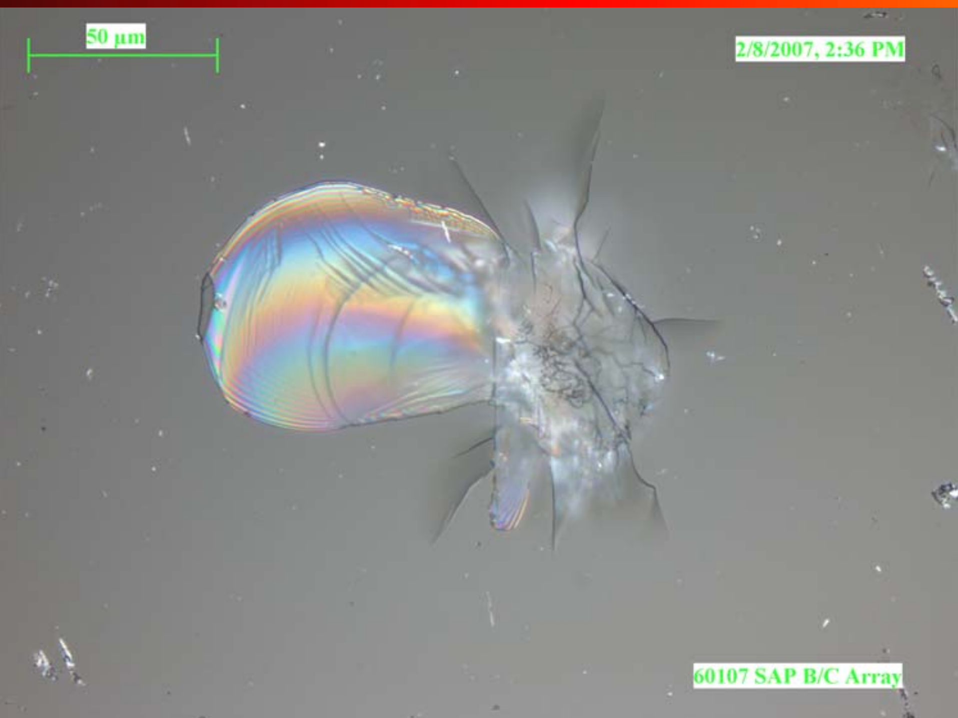
3	sio2_jaw	33.91 Å
2	EMA (si_jaw)/1.34% void	611.41 Å
1	si_jaw	0.00 Å
0	si_jaw	1 mm

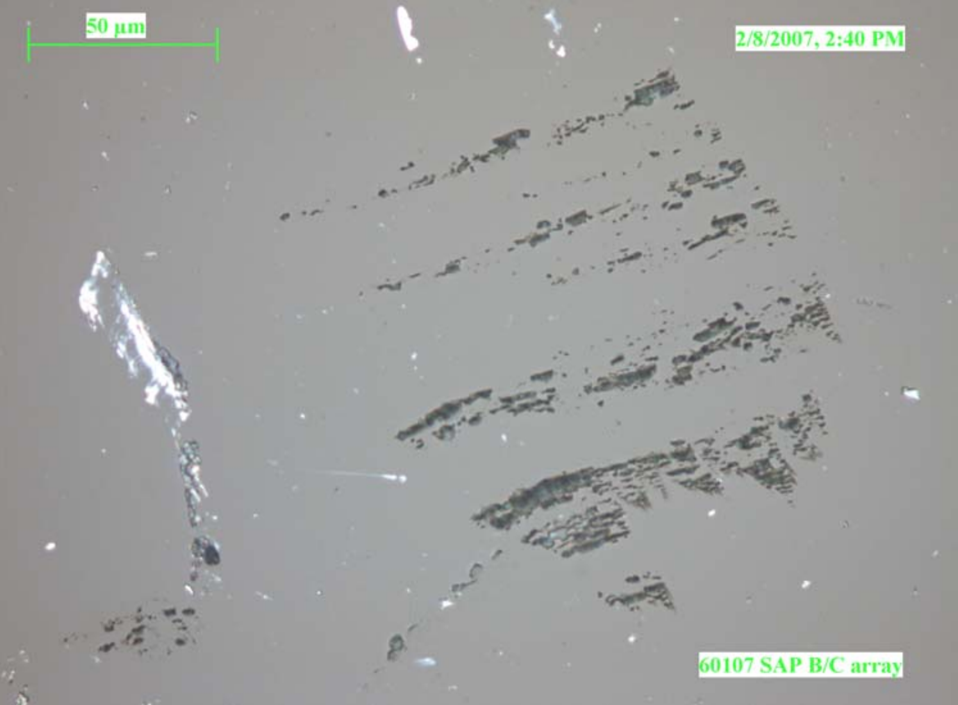


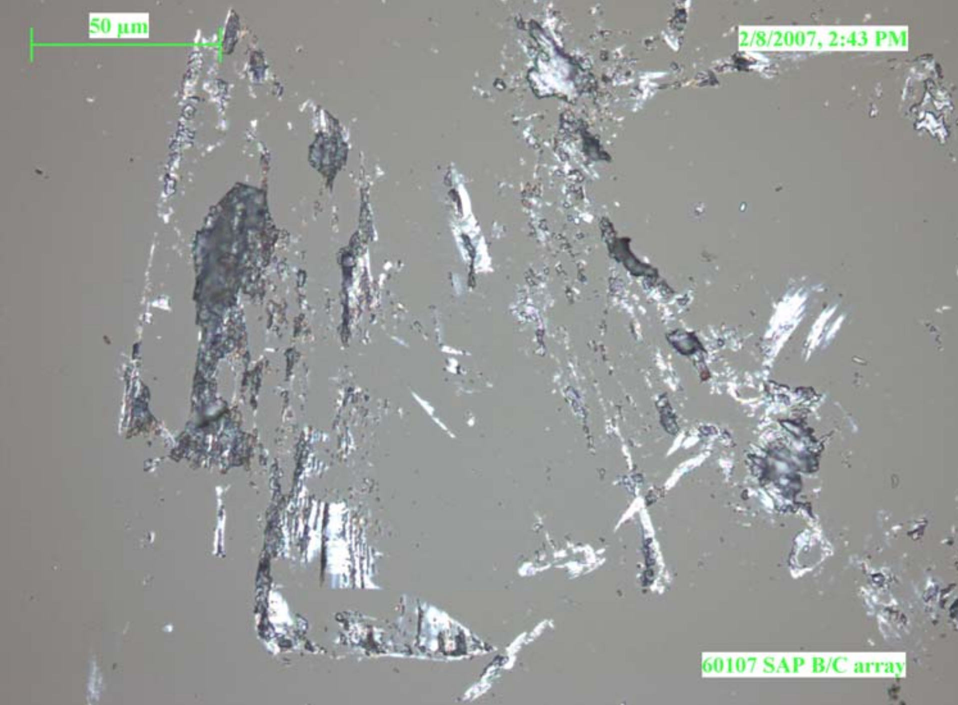
Sample 60208 Flown Genesis Si B/C array

Review of Surface Contamination after UPW/Megasonic Treatment

- Molecular Contamination (Brown stain remains)
- Very little surface particle contamination remains
- UPW treatment does remove some statically charged particles
- Impact Craters still have small particles around craters
- Melted and fused materials are not removed
- Fused materials are 90 % other wafer fragments
- Still Unknown Contamination




50 µm
2/8/2007, 2:40 PM
60107 SAP B/C array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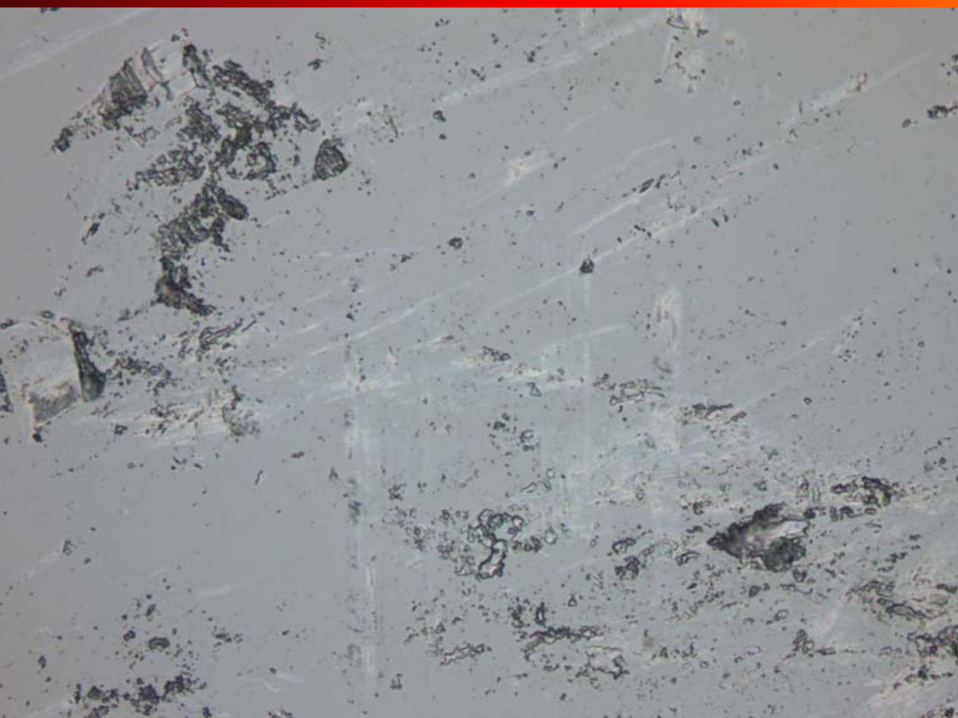
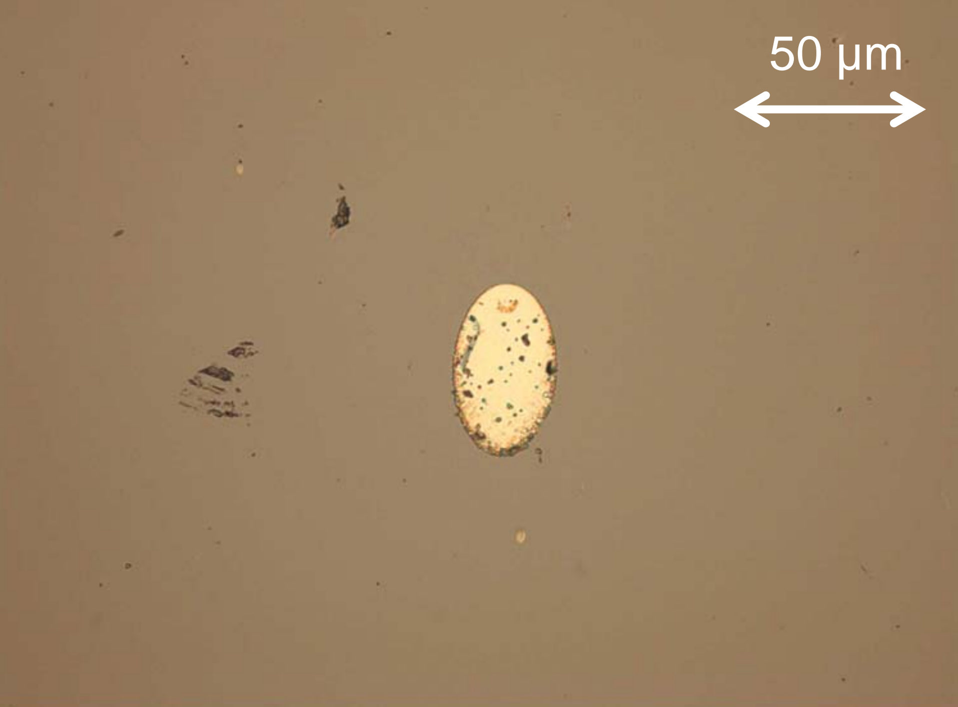
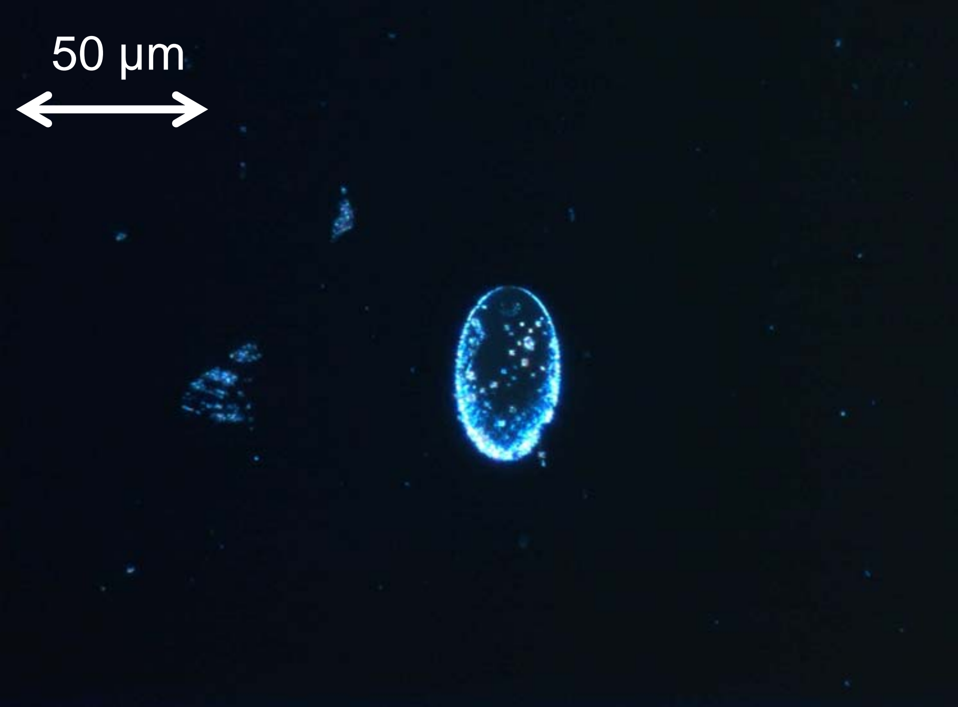
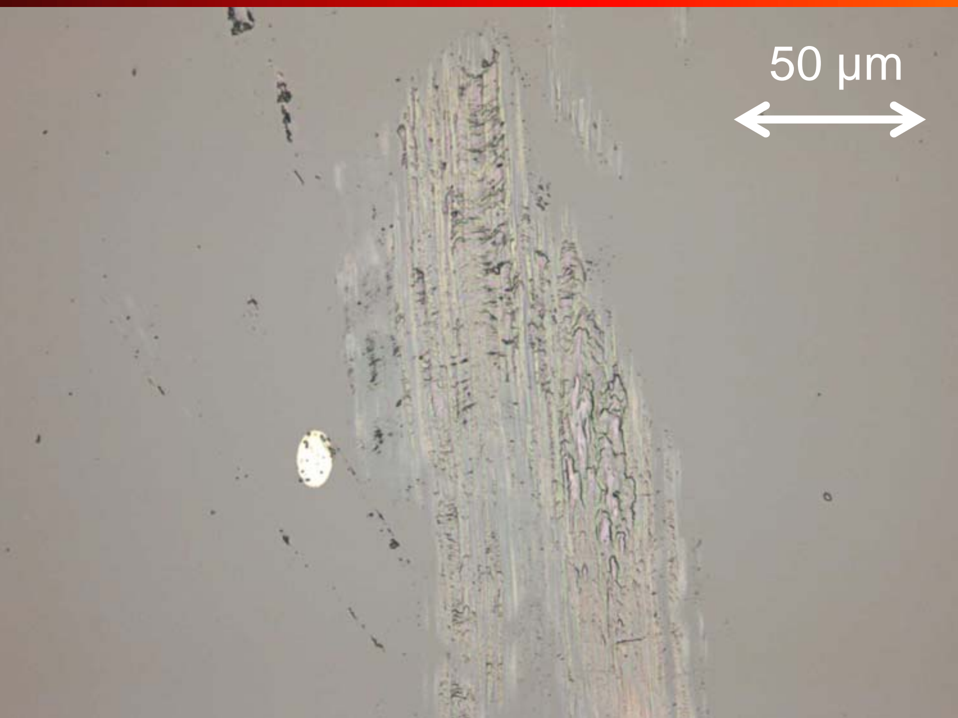
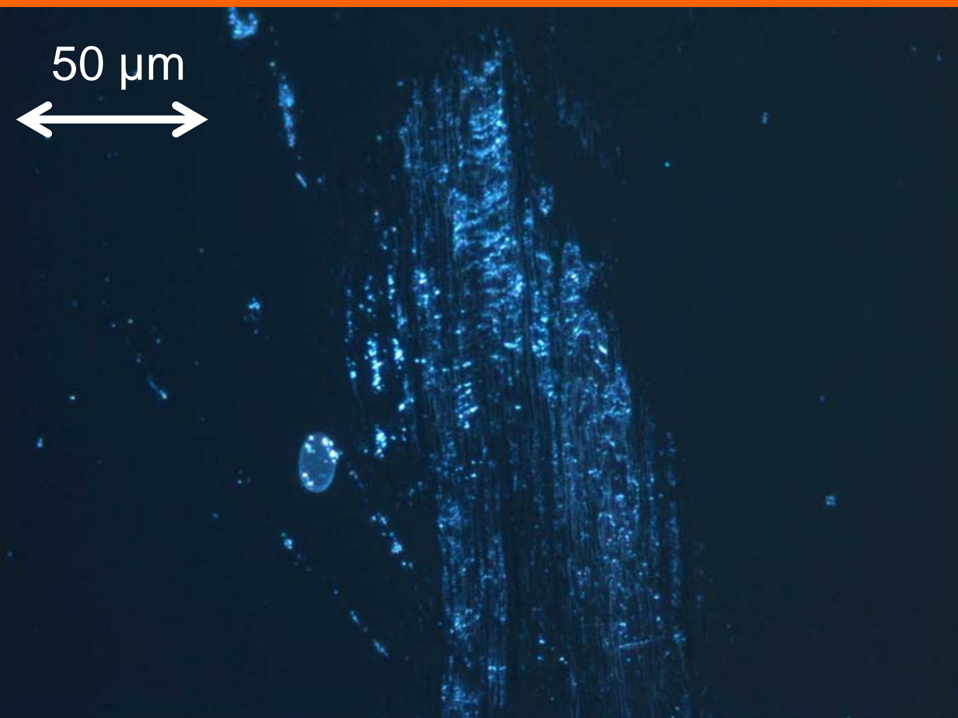
60107 SAP B/C array




50 µm


50 µm


50 µm


50 µm

STEM Study Objectives

- Characterize the Brown Stain and any other thin film contamination.
- Characterize (if possible) surface particle contamination and the interaction with the wafer surface.
- Characterize the native oxide layer and verify ellipsometry thickness results.
- Verify ellipsometry EMA layer model for Silicon and substrate alteration thickness.
- Did the Silicon substrate experience lattice alteration during flight?

FIB Pull Locations for Stratigraphic Profiles

5/1/2006, 2:49 PM

6

3 - Surface Particle &
Substrate Pull
(if possible)

4 - Surface Scratch Pull with Substrate
(if possible half on and half off)

7

1 - Clean Pull
(no surface particles)

5

2 - Clean Pull
(no surface particles)

60208 Si B/C Array

Ellipsometry Results for 60208

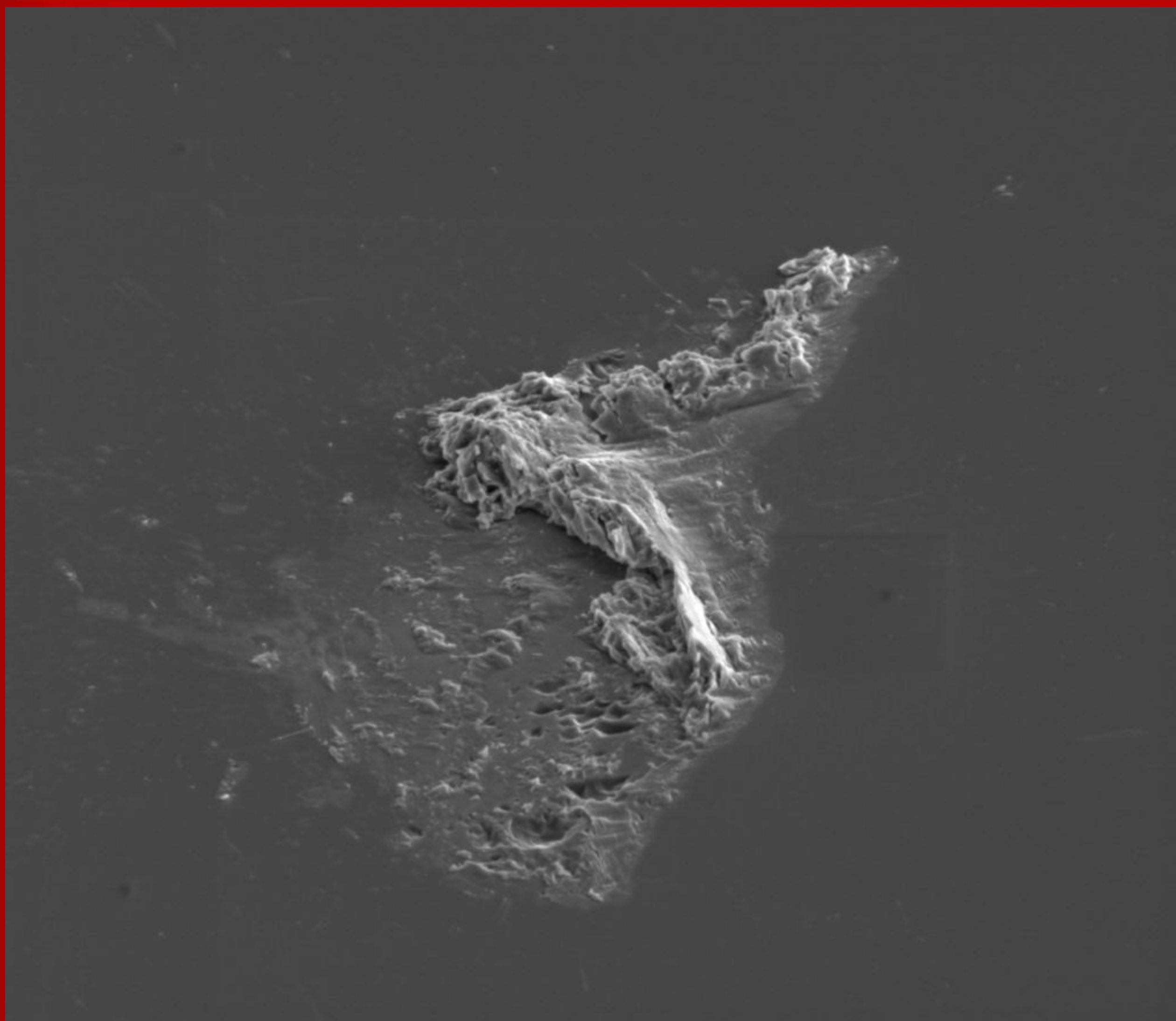
Measurement Location	Gain	Intensity	EMA (Å)	Cauchy (Å)	Native Oxide (Å)	Brown Stain (Å)	MSE
JAWstd Before	8	5.11	N/A	266.42	N/A	N/A	3.475
Before UPW	8	4.43	564.70 ±1.73	43.81 ±0.0702	18	25.81	7.979
Spot 1	8	3.60	604.19 ±1.17	32.06 ±0.037	18	14.06	4.38
Spot 2	8	3.56	602.65 ±1.42	32.64 ±0.0397	18	14.64	4.234
Spot 3	8	4.90	604.86 ±1.25	31.59 ±0.0397	18	13.59	4.828
Spot 4	8	2.50	622.64 ±4.86	32.80 ±0.161	18	14.80	12.91
Spot 5	8	4.70	603.43 ±1.22	32.04 ±0.0382	18	14.04	4.541
JAWstd After	8	5.20	N/A	265.74	N/A	N/A	3.863

Flown Si B/C Array Sample 60208; 5.78 X 7.69 mm; 35.03 mm^2

Cleaning: UPW/Megasonic at 40° C for 5 min. at 1 MHz oscillations

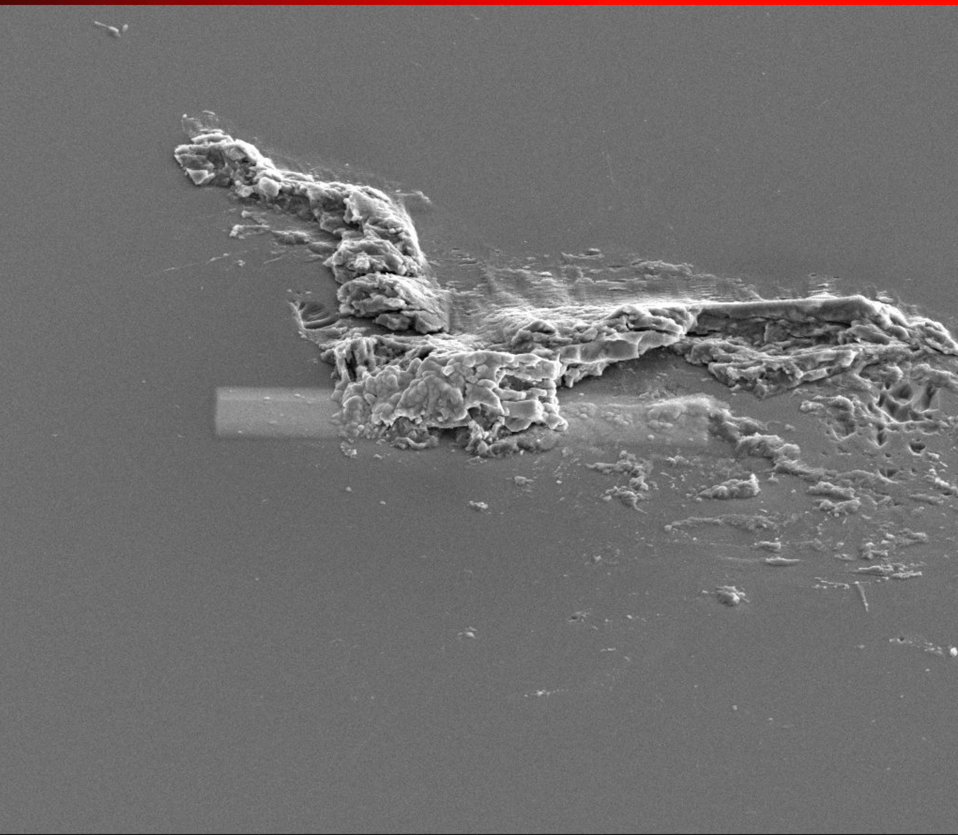
Spot 1 to 5 are after UPW cleaning and Spot 4 had edge effects during run

FIB Startigraphic Cross-section Pull
Sample 60208.4 (Surface particle Pull)

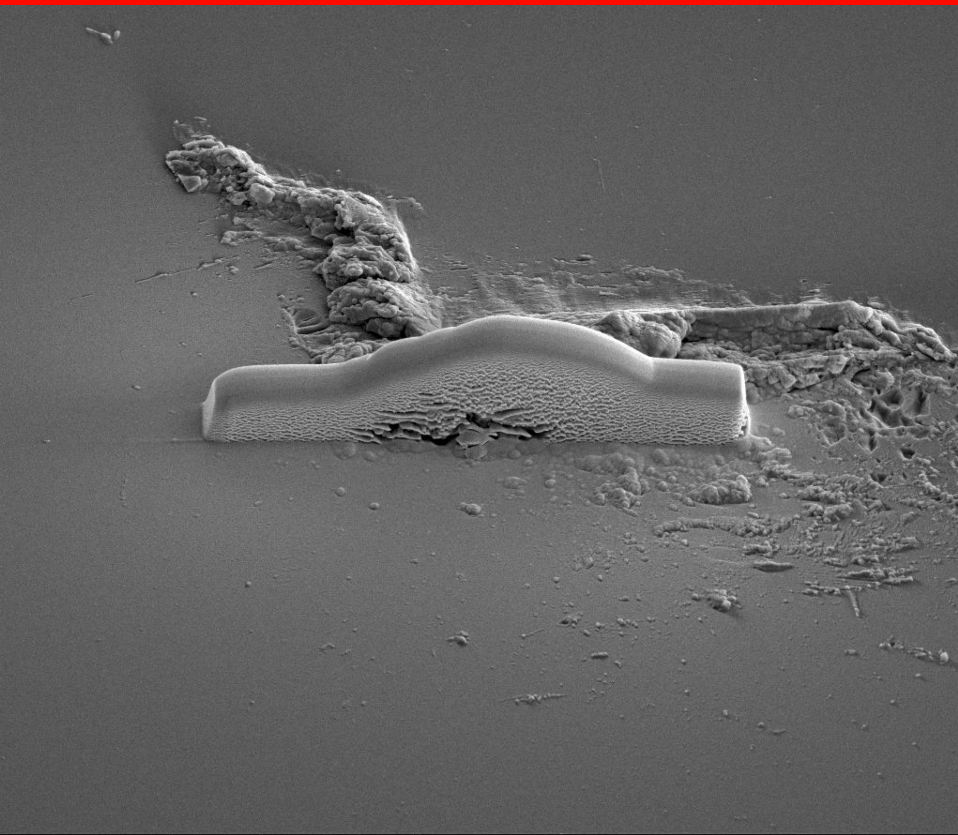


Platinum Coating FIB Pull Section

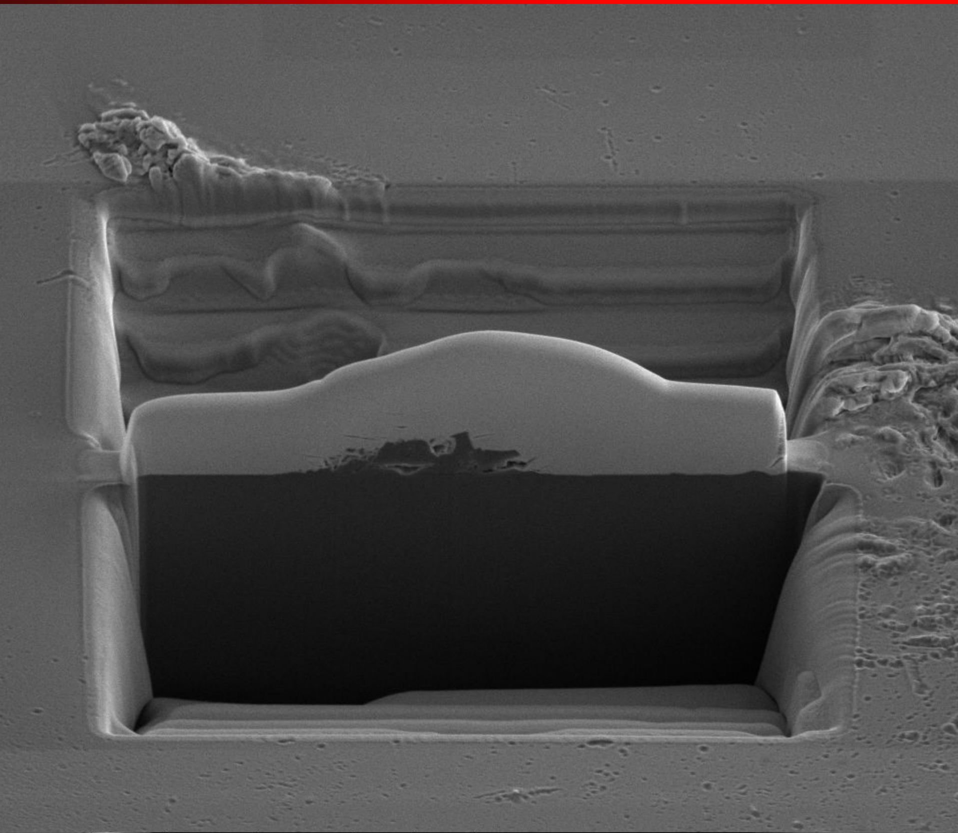
1st Coat

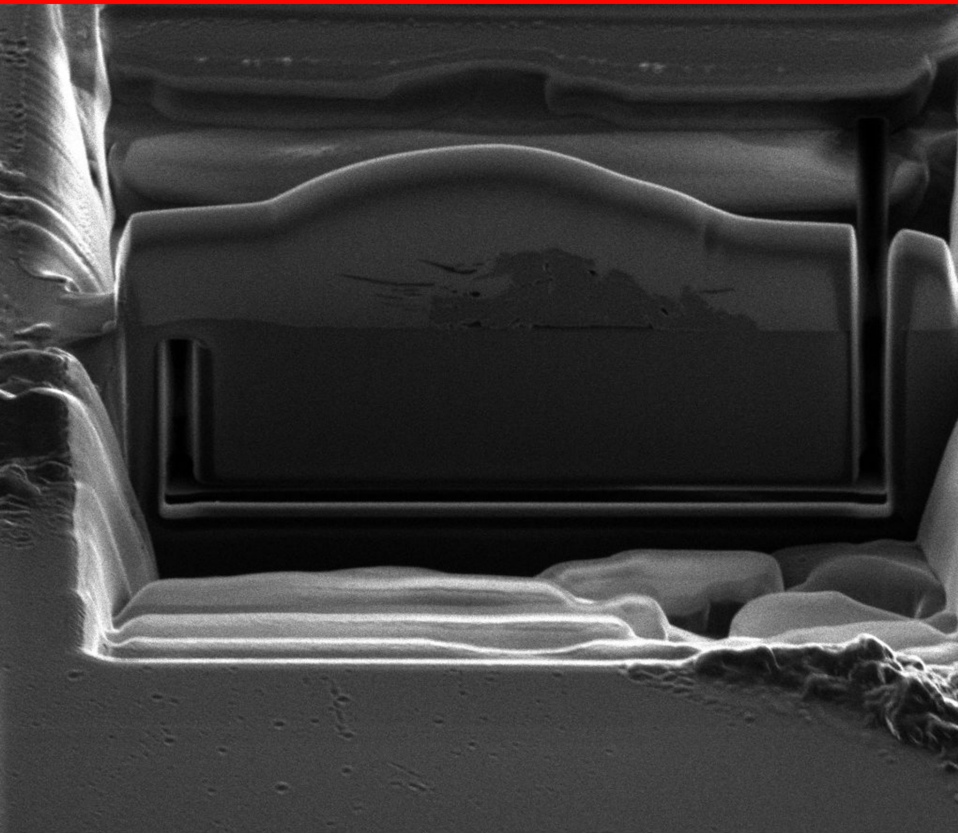


2nd Coat

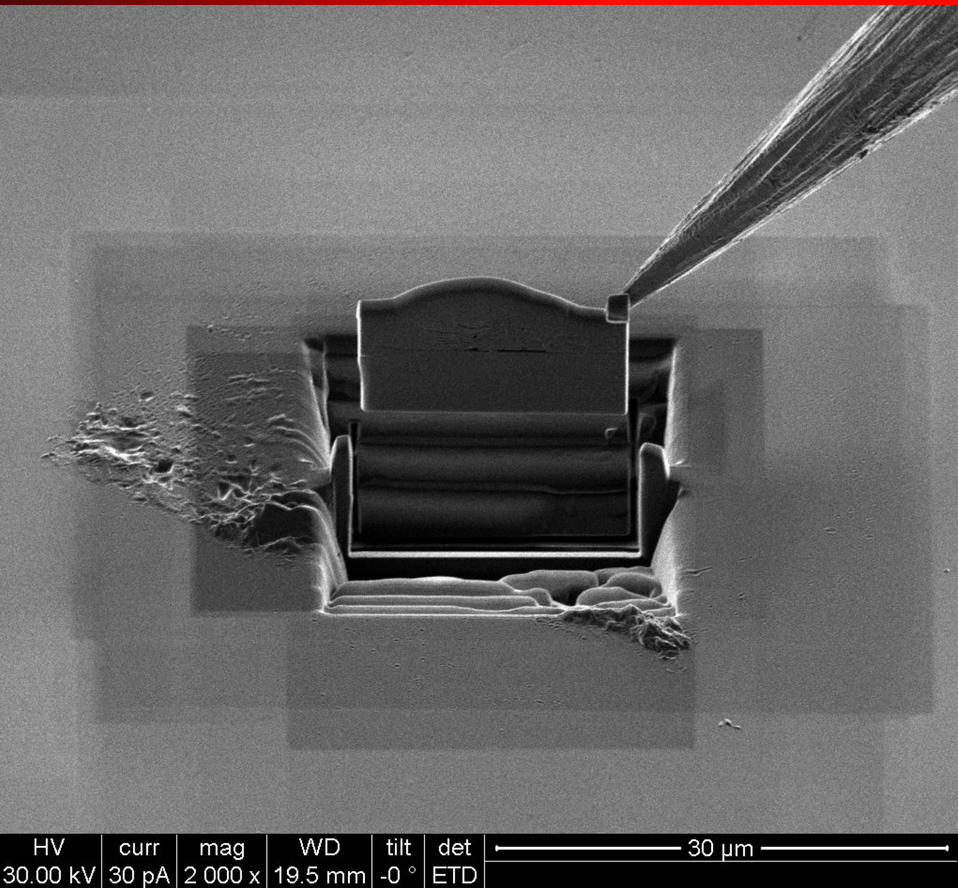


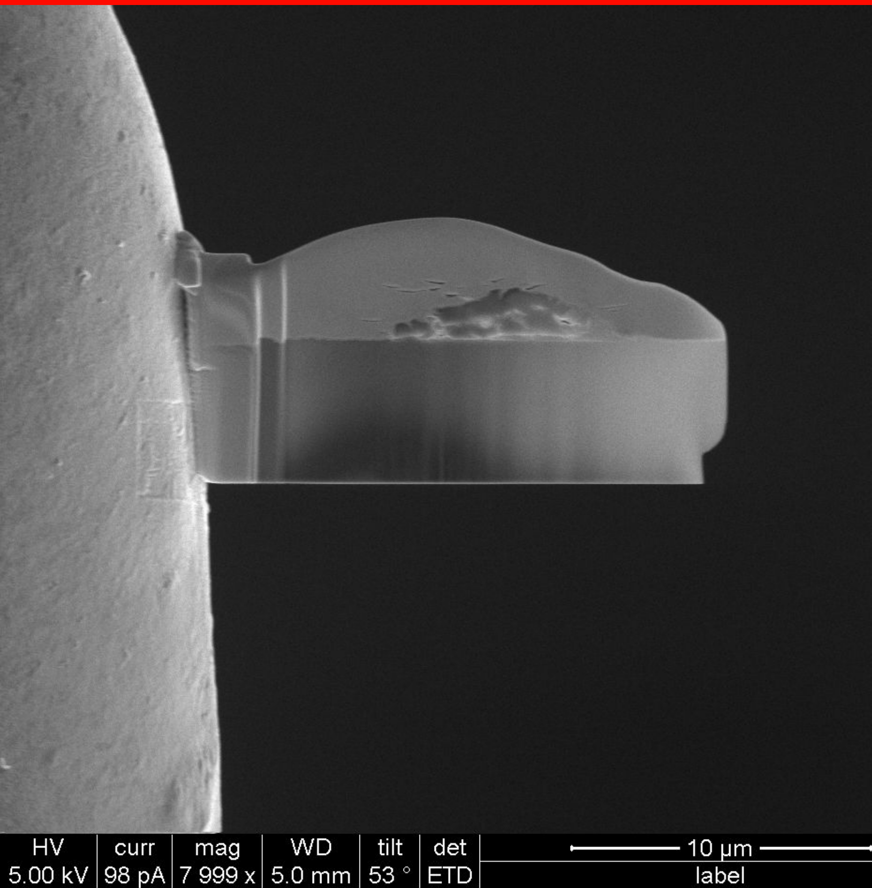
Ion Milling Startigraphic Cross-section



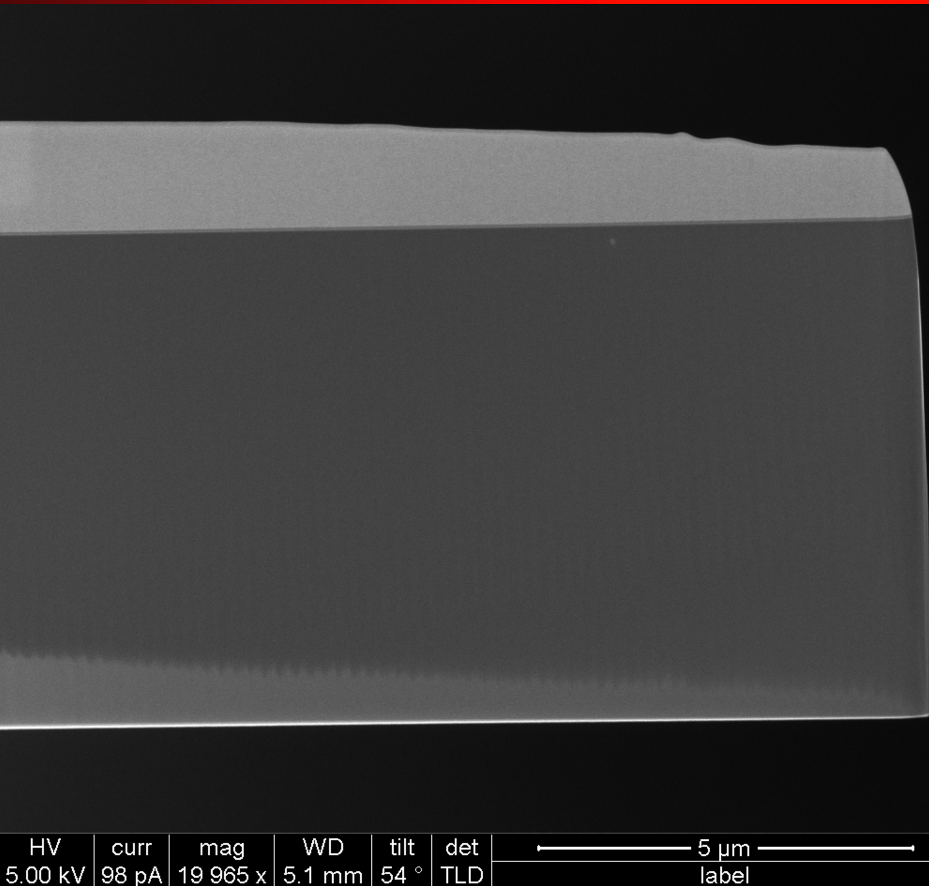


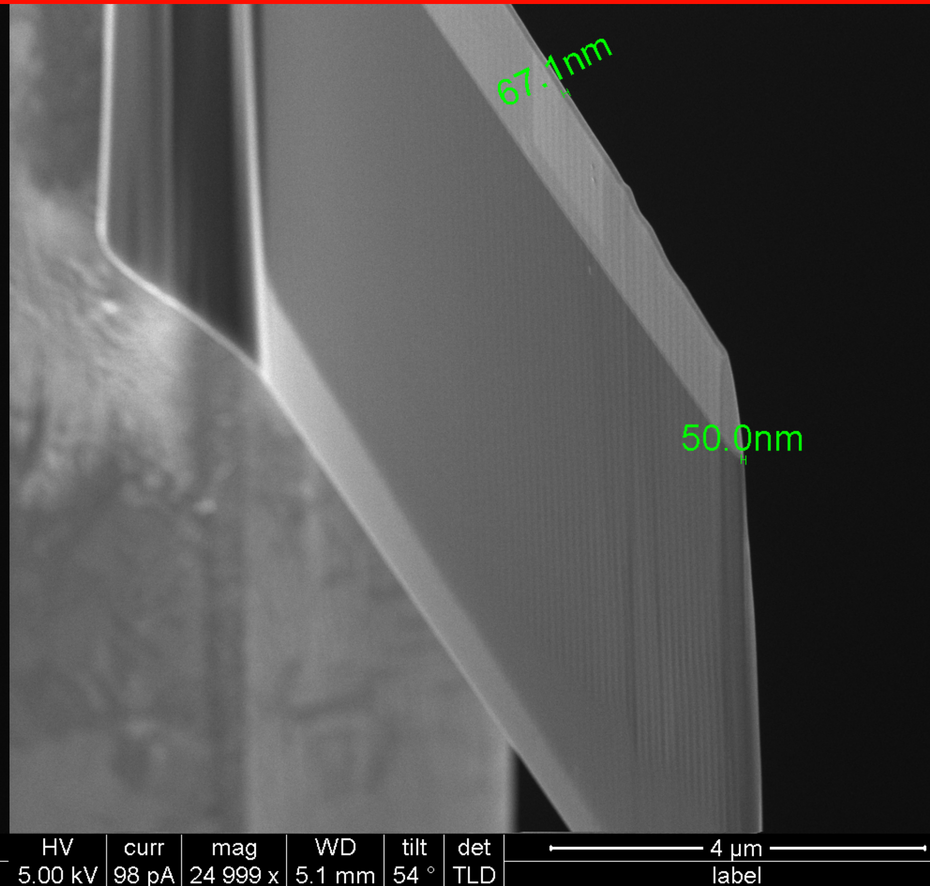
FIB Pull and Mounting Section on TEM Grid



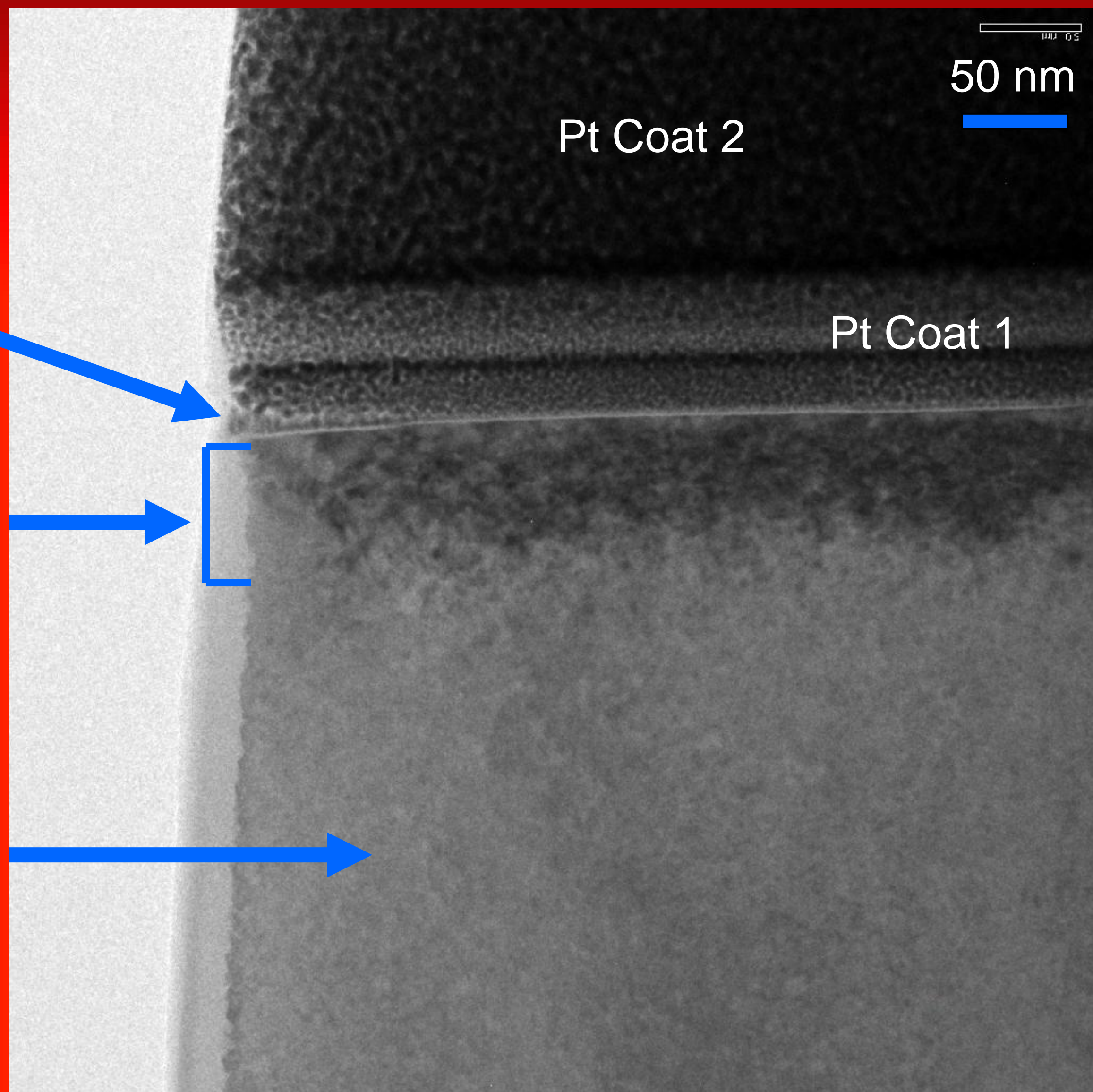


Final Configuration After Polishing
Sample 60208.1
(~ 10 x 6 μm and ~ 60 nm thick)





JEOL JEM 2500SE STEM Image of 60208.1 Si B/C Array

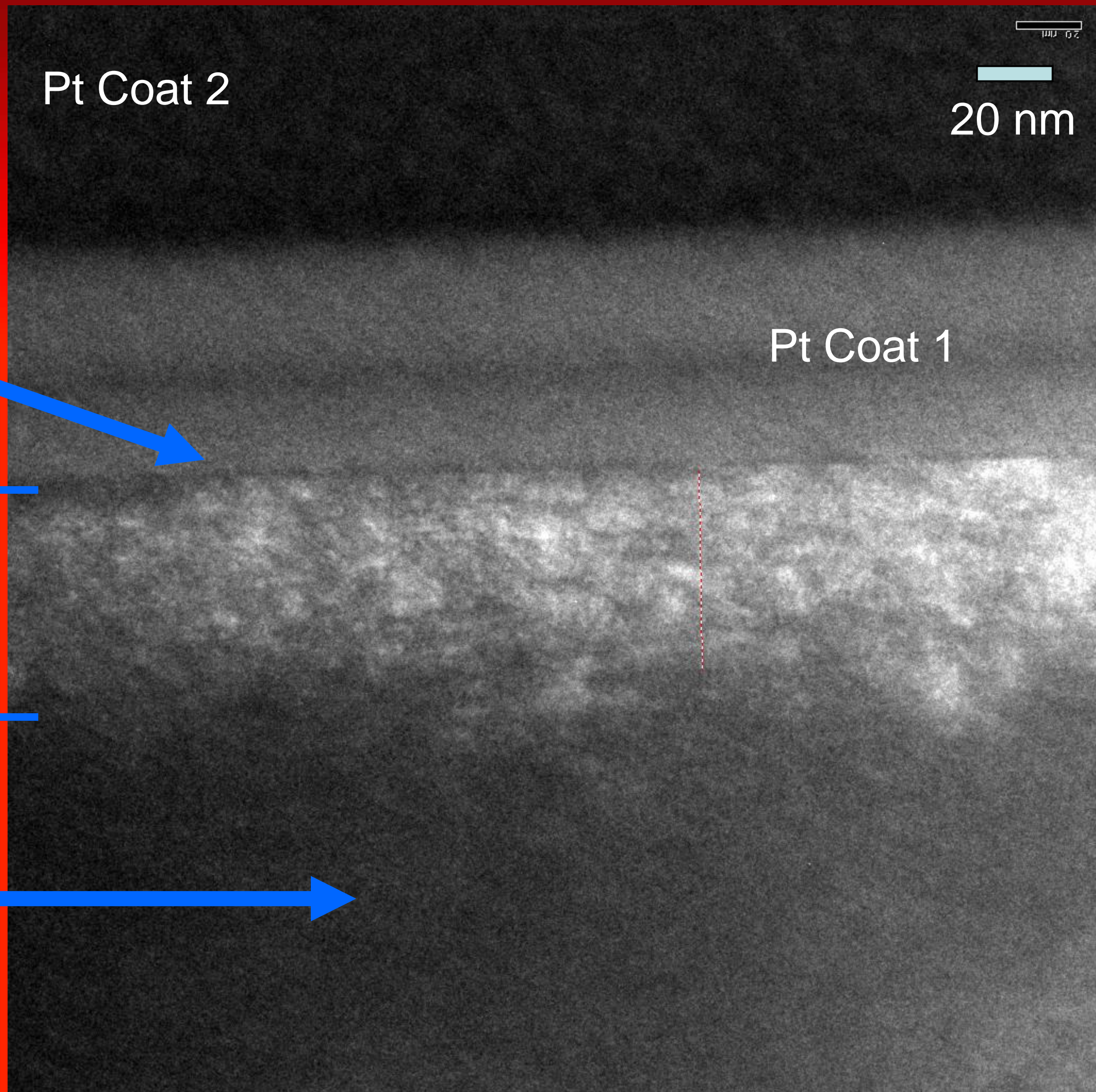


Wafer Surface
Native Oxide Layer
SiO_2 = ~ 38 Å

Radiation Damage Zone
Depth = ~ 610 Å

Crystalline Si Substrate

STEM Image of 60208.1 Si B/C Array



Wafer Surface
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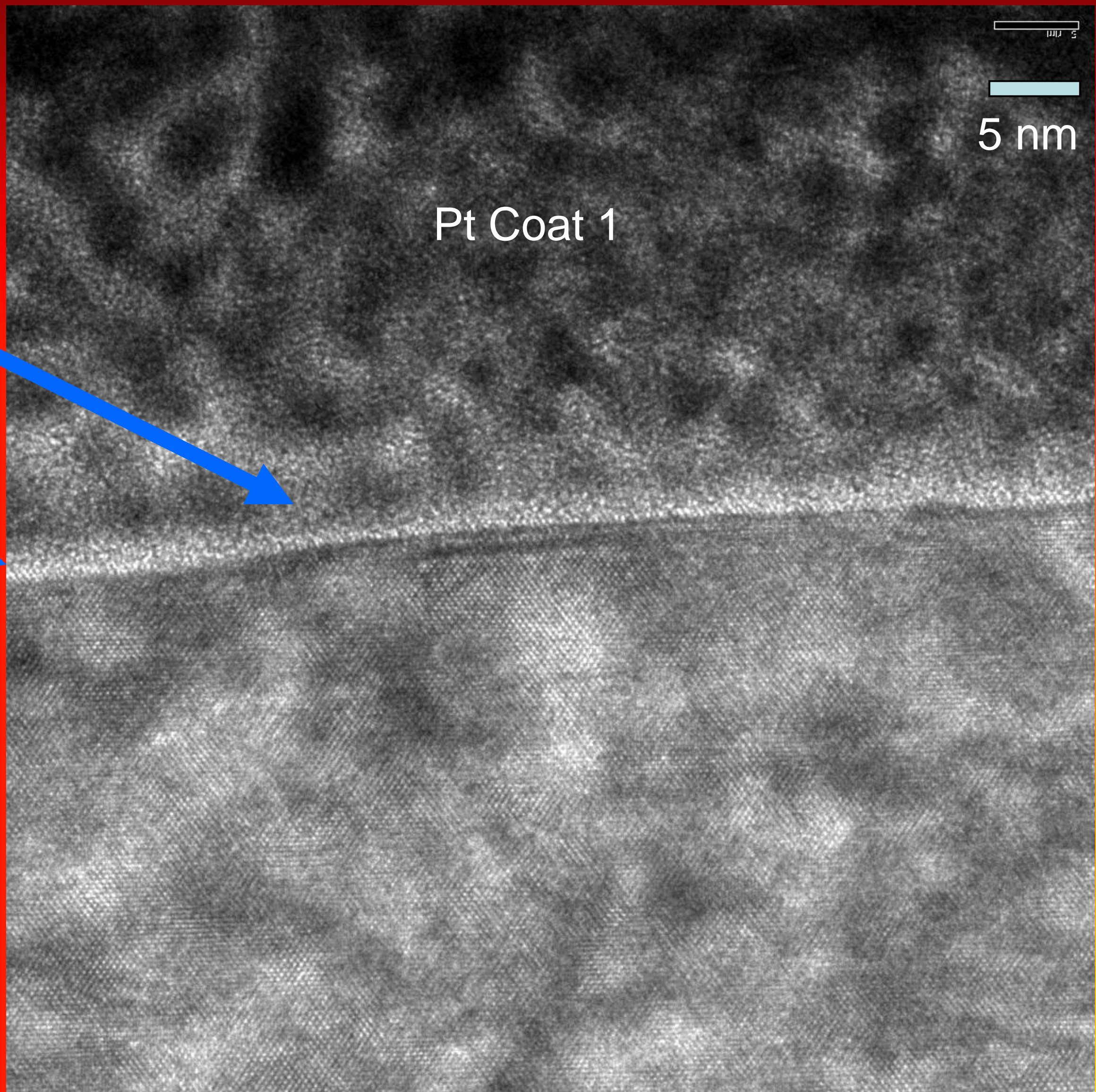
Crystalline Si Substrate

STEM Image of 60208.1 Si B/C Array

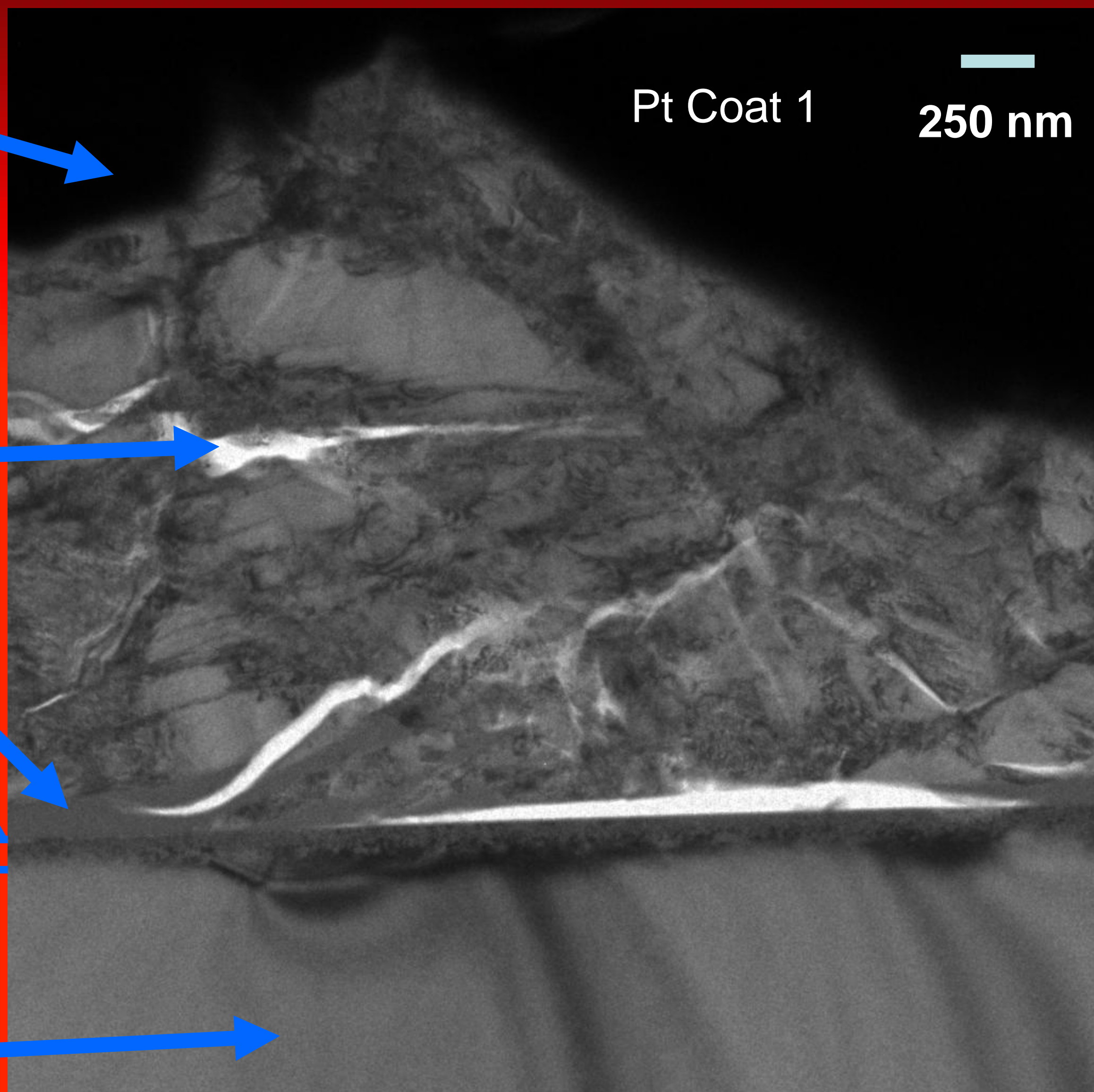


Wafer Surface

Native Oxide Layer
SiO_2 = ~ 38 Å

Radiation
Damage Zone

STEM Image of 60208.4 Si B/C Array



c-Si Particle
on wafer surface
(EELS spot verification)

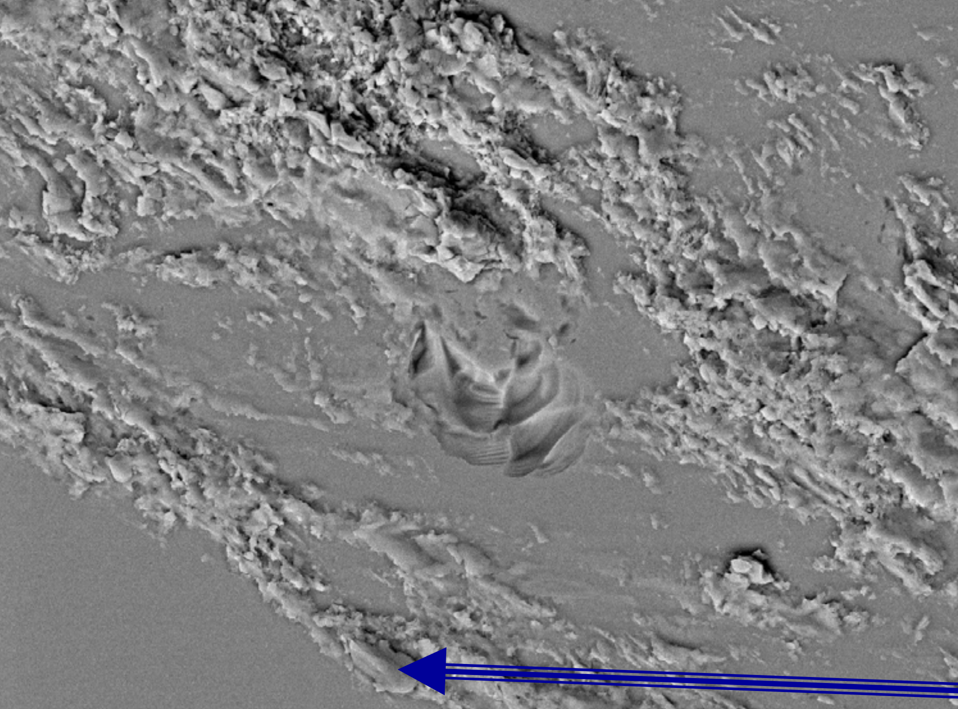
Void Space

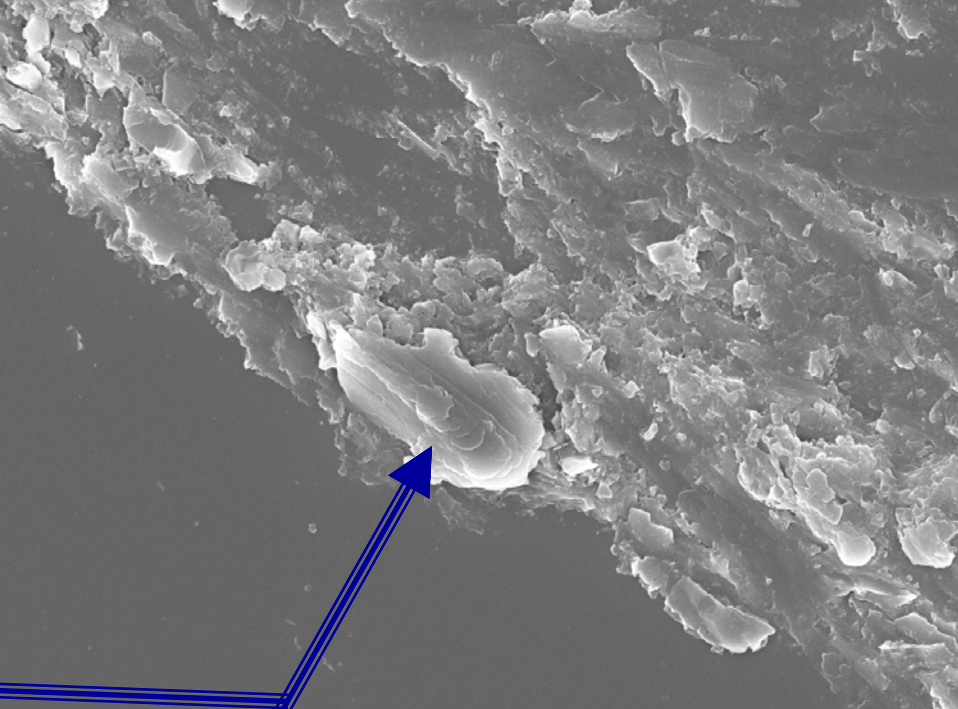
a-Si

Wafer Surface

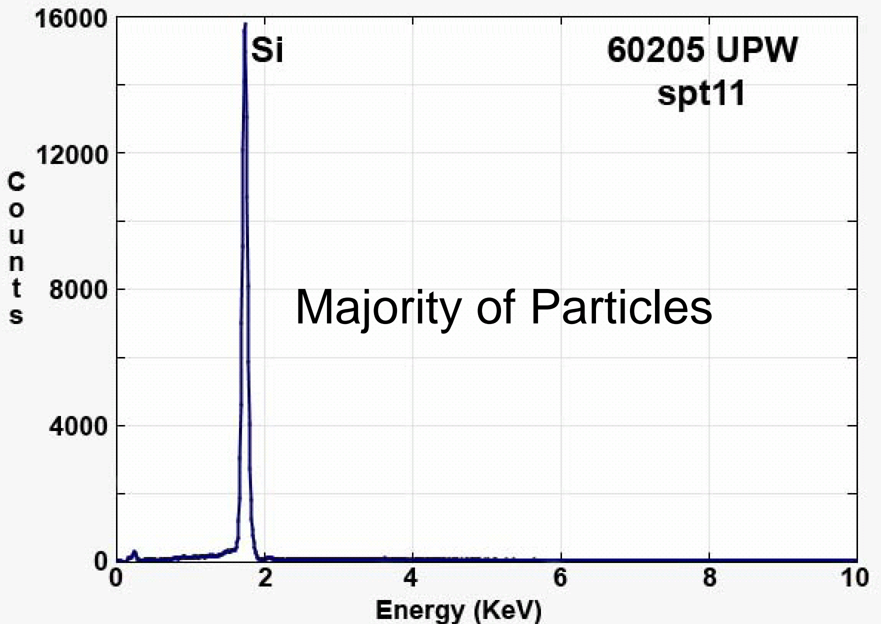
Radiation
Damage Zone

c-Si wafer substrate

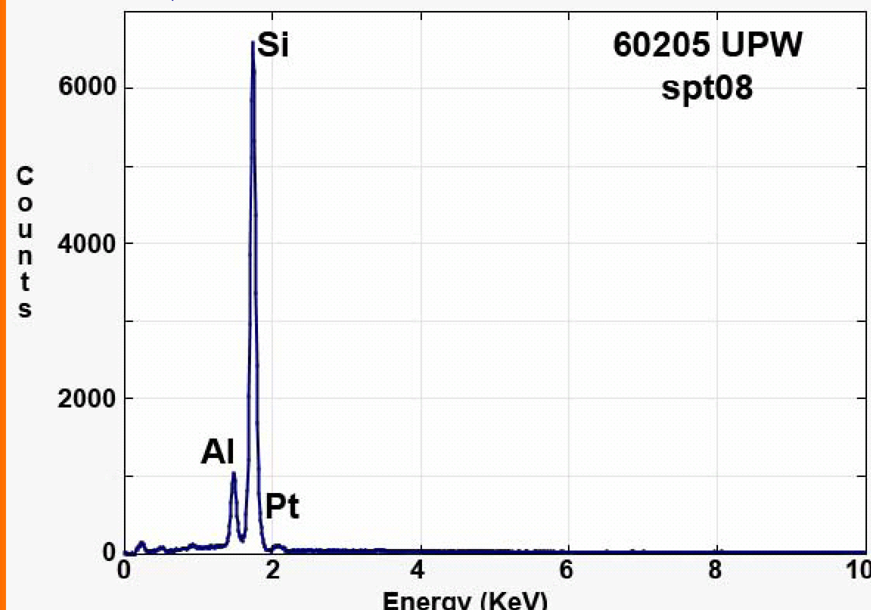




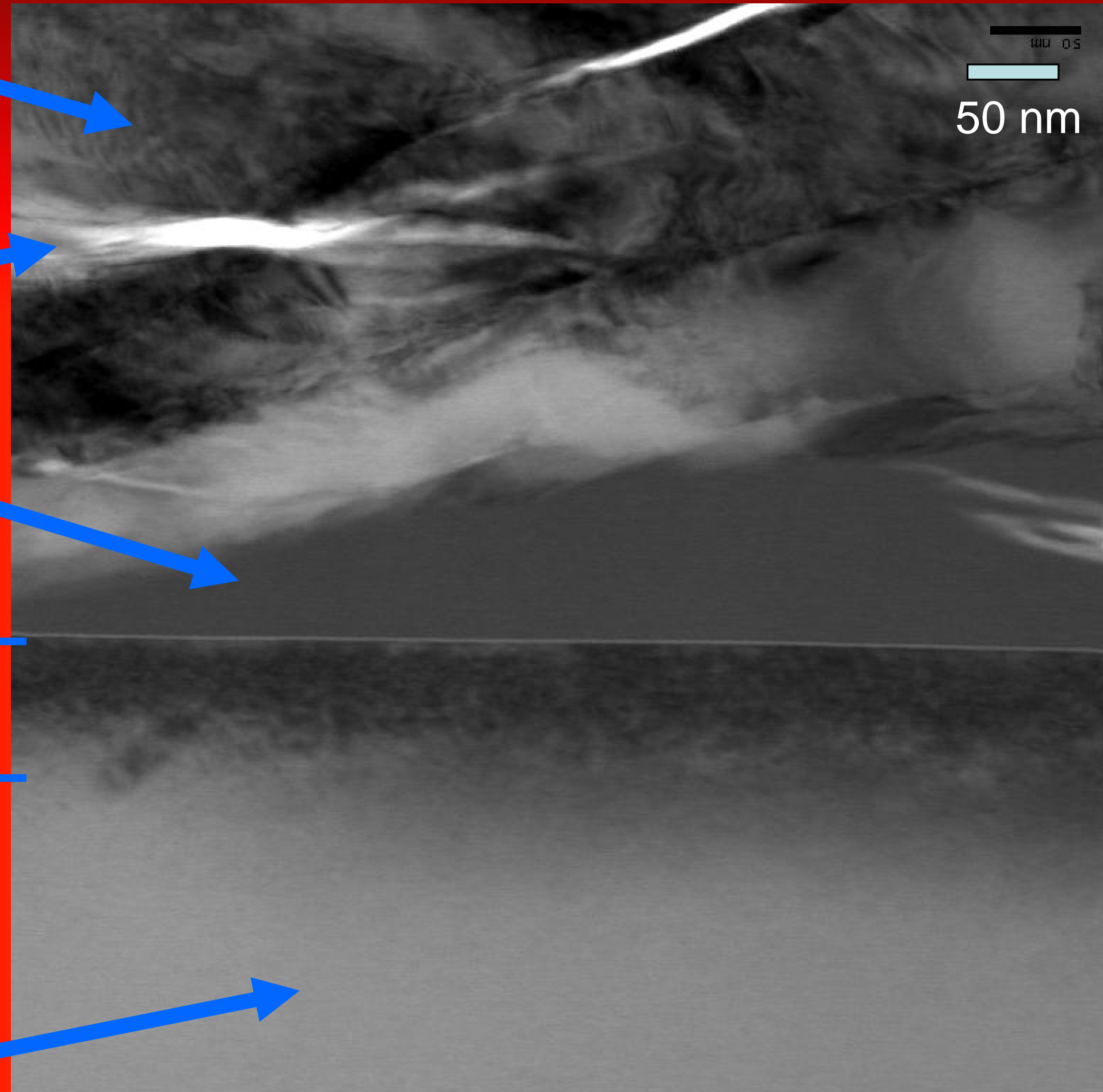
Si wafer



Al oxide grain (Im 60205-30)



STEM Image of 60208.4 Si B/C Array



c-Si Particle
on wafer surface

Void Space

a-Si

Wafer Surface
Native Oxide Layer
SiO_2 = ~ 18 Å

Radiation
Damage Zone

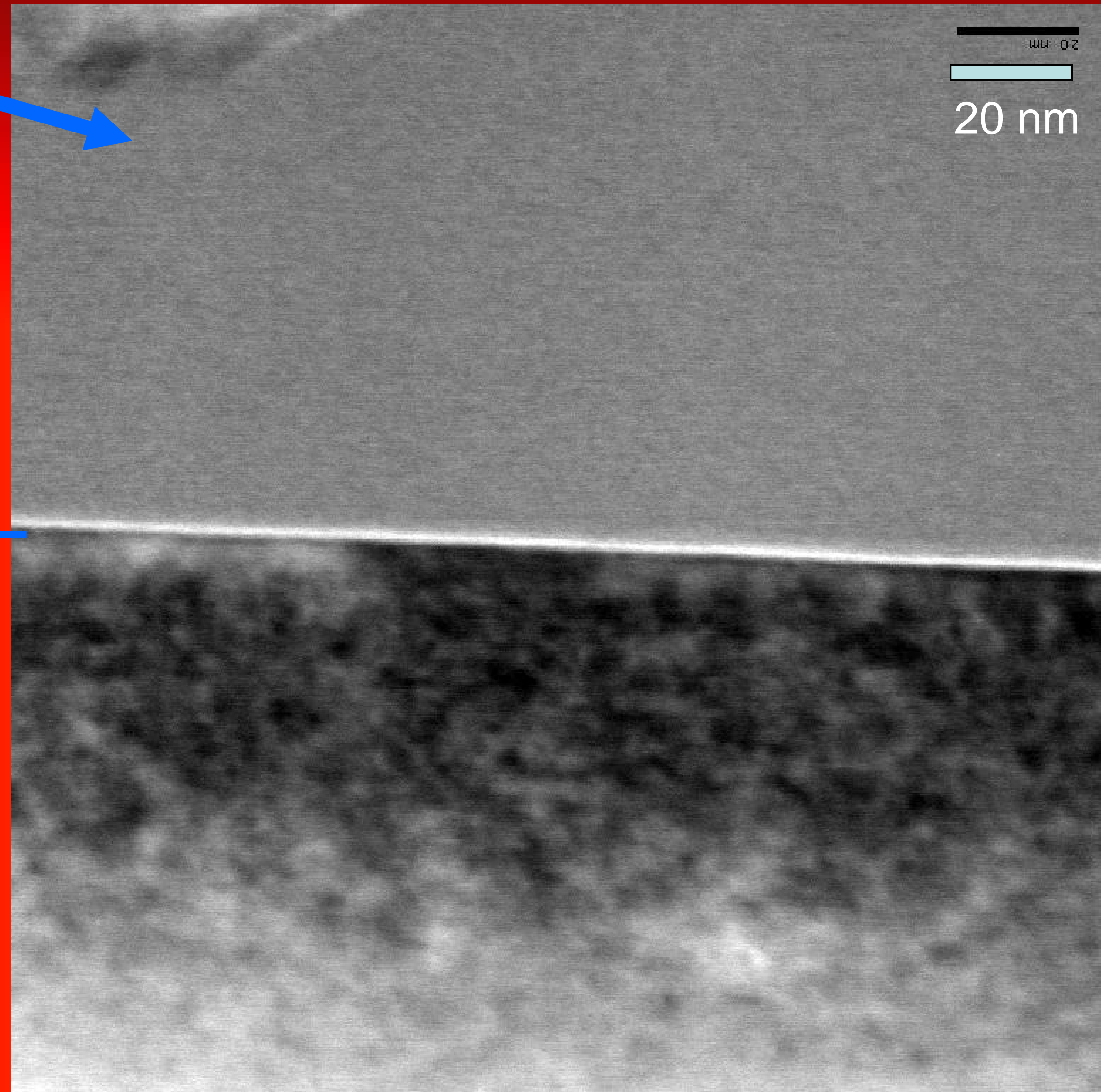
c-Si wafer substrate

STEM Image of 60208.4 Si B/C Array

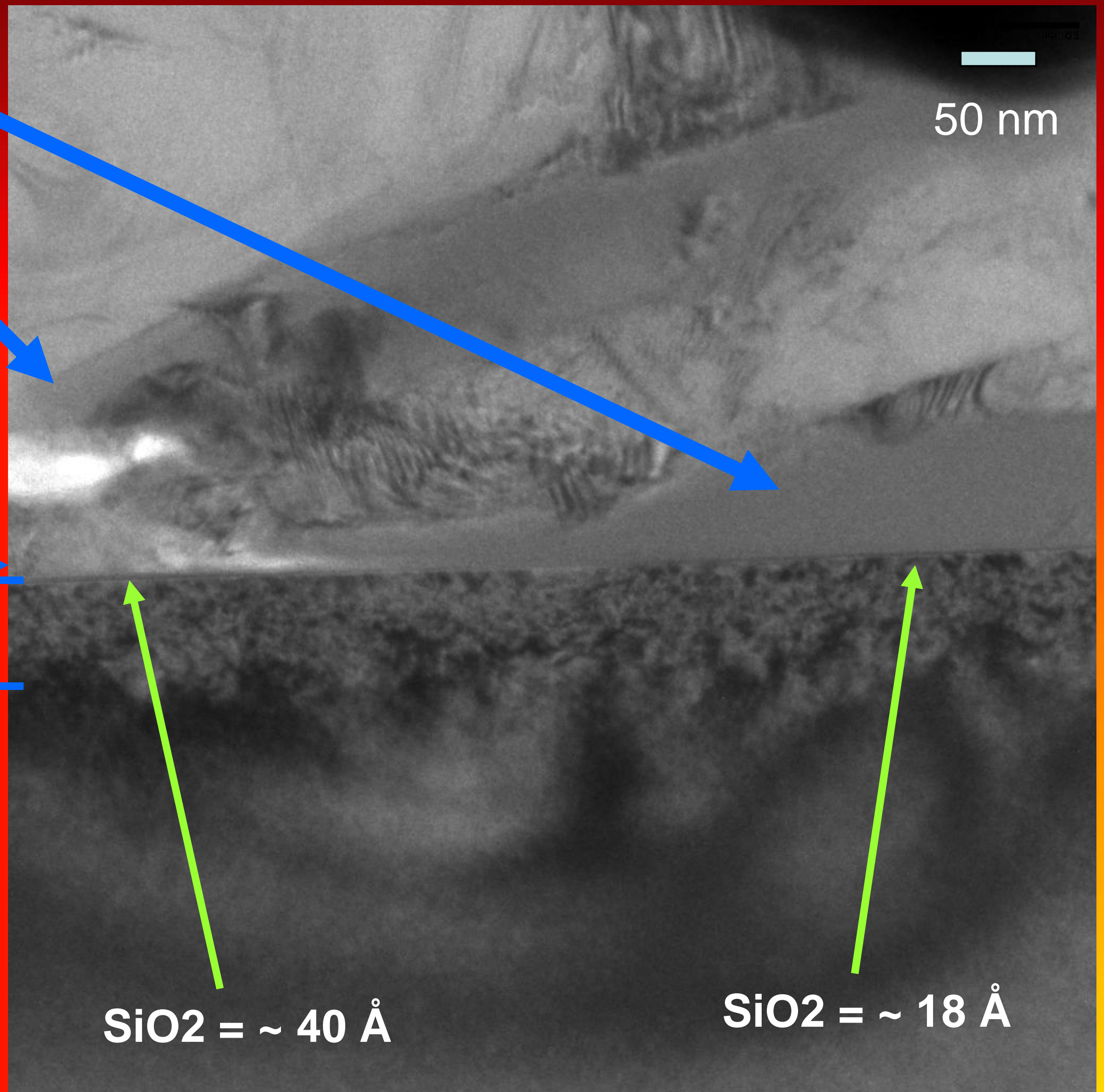
a-Si Particle
on wafer surface

Wafer Surface
Native Oxide Layer
SiO_2 = ~ 18 Å

Radiation
Damage Zone



STEM Image of 60208.4 Si B/C Array



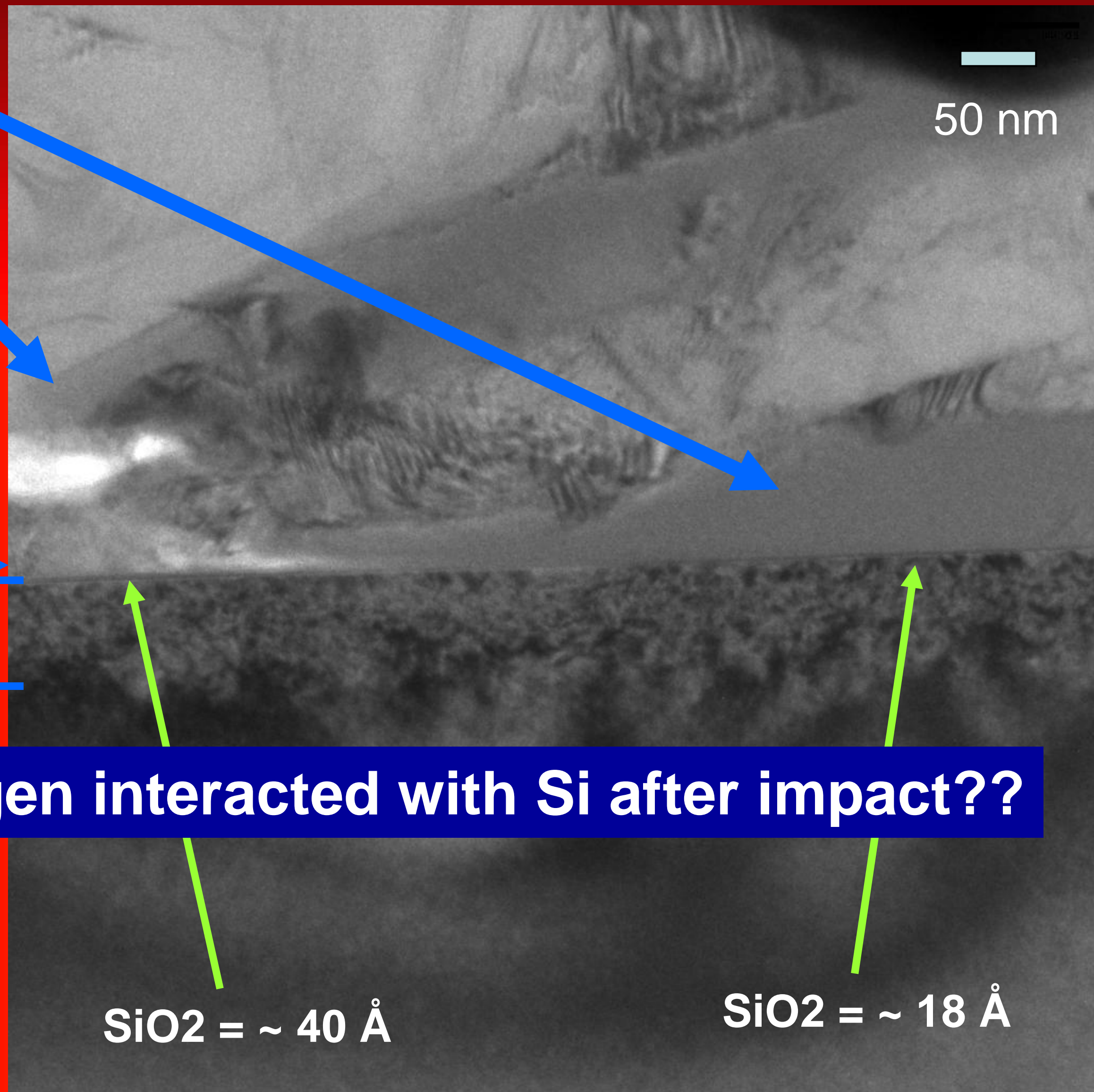
a-Si Particle

c-Si Particle

Wafer Surface
Native Oxide Layer

Radiation
Damage Zone

STEM Image of 60208.4 Si B/C Array



a-Si Particle

c-Si Particle

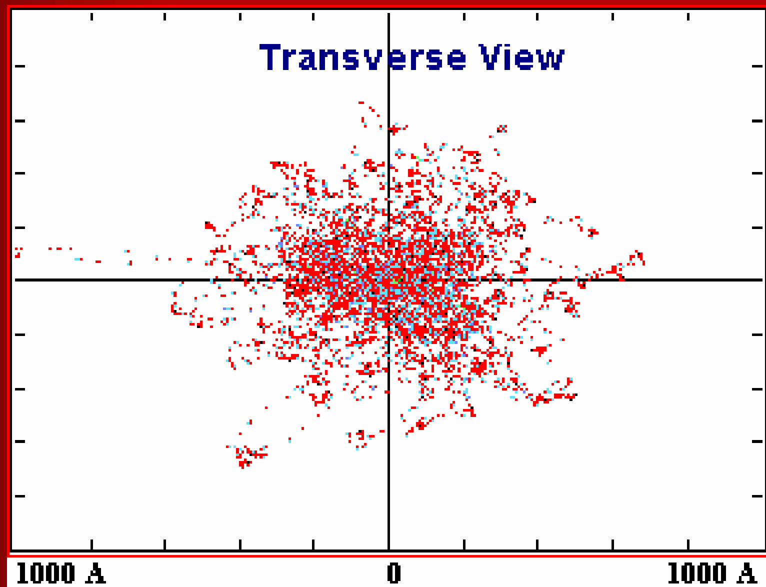
Wafer Surface
Native Oxide Layer

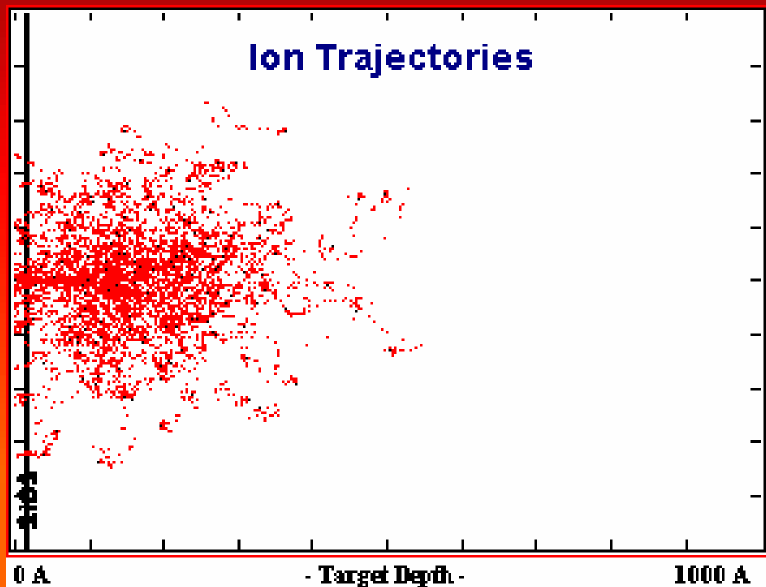
Radiation
Damage Zone

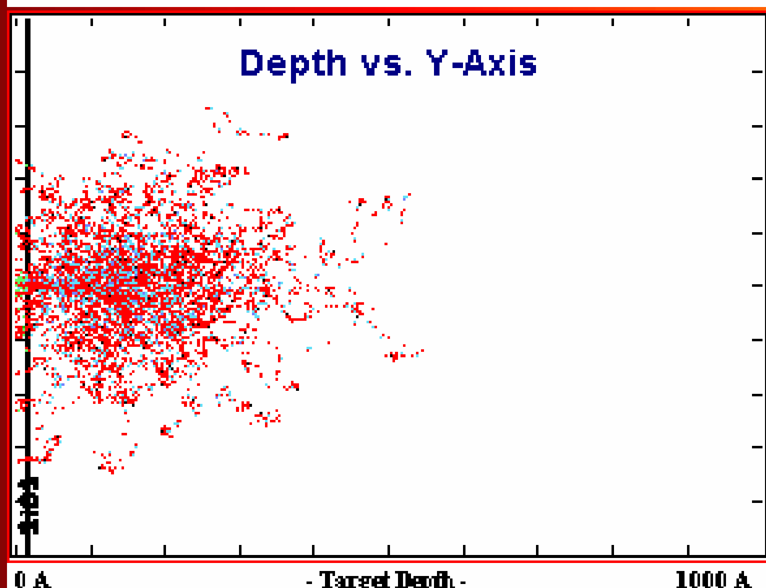
Atmospheric Oxygen interacted with Si after impact??

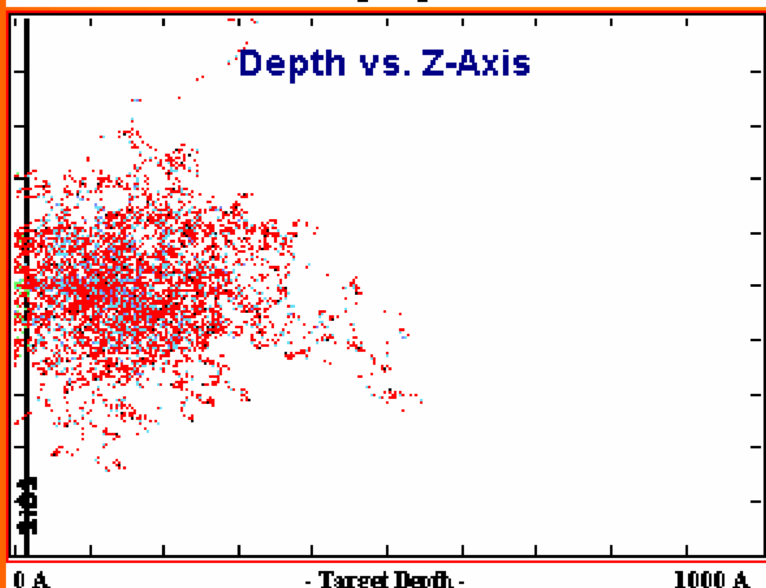
TRIM Monte Carlo Simulation from SRIM-2006

Slow Solar Wind H^+ implantation at 400 km/s

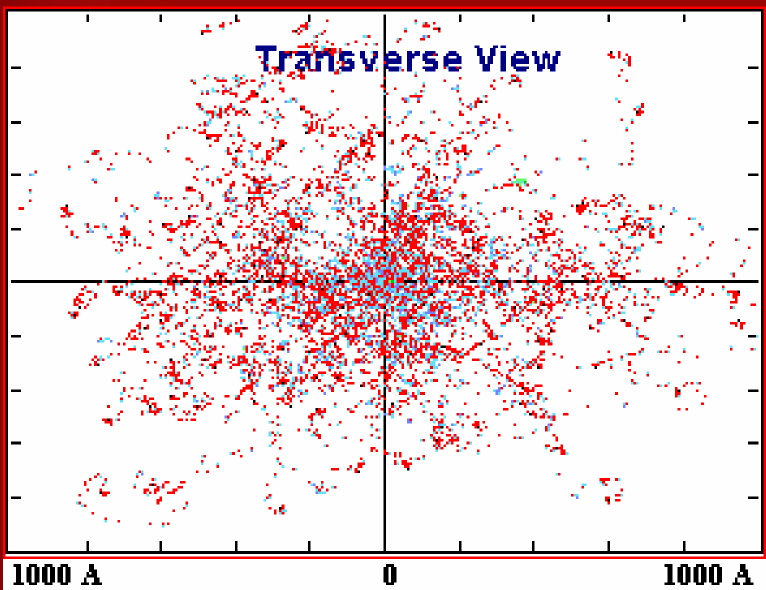


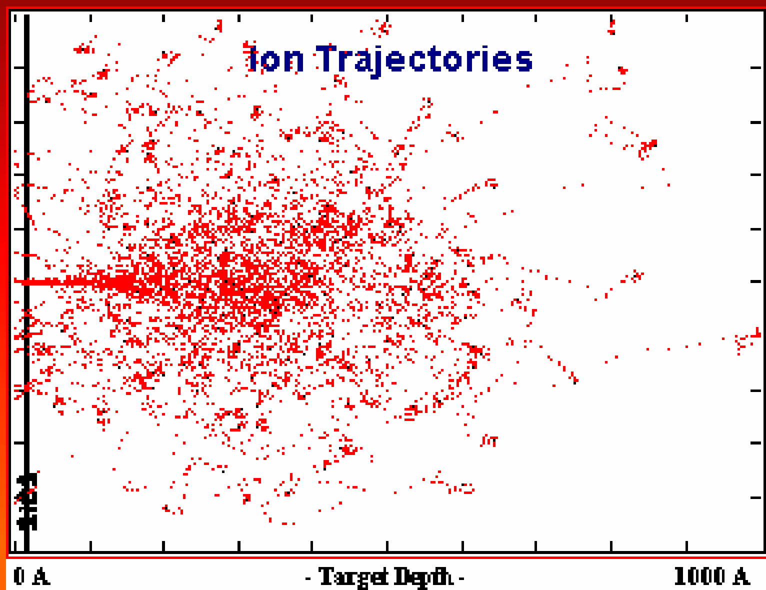


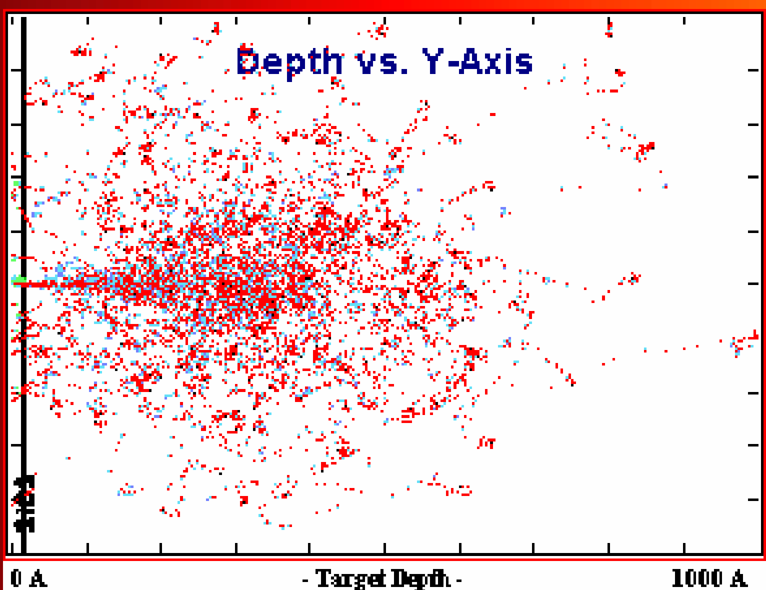


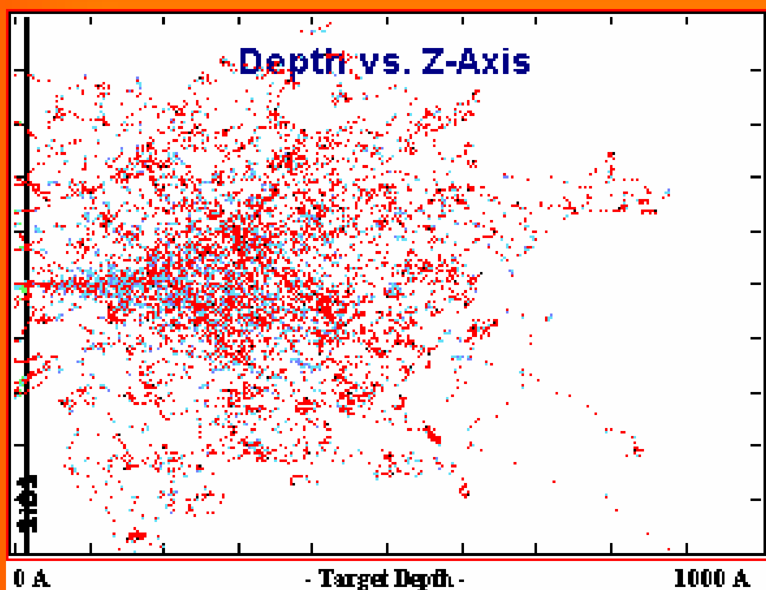


Fast Solar Wind H^+ implantation at 600 km/s

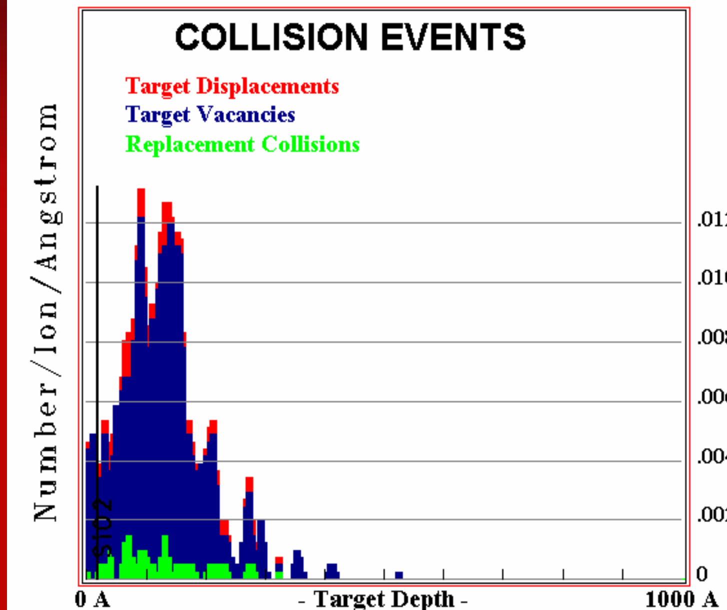


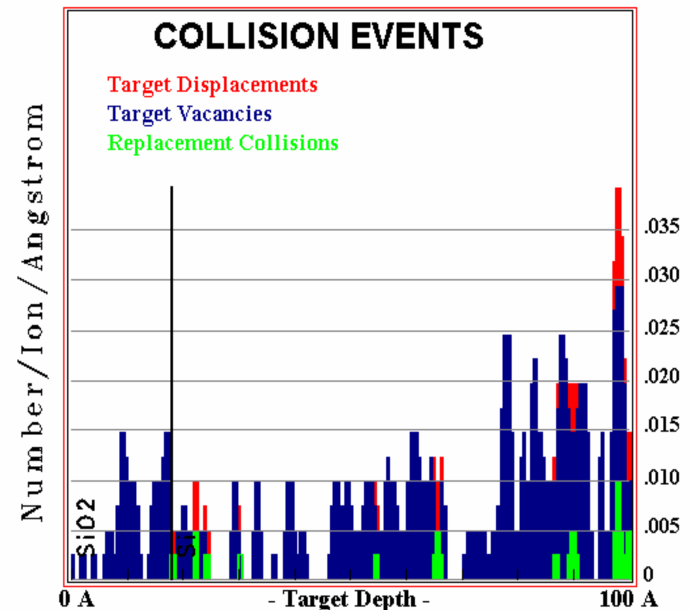




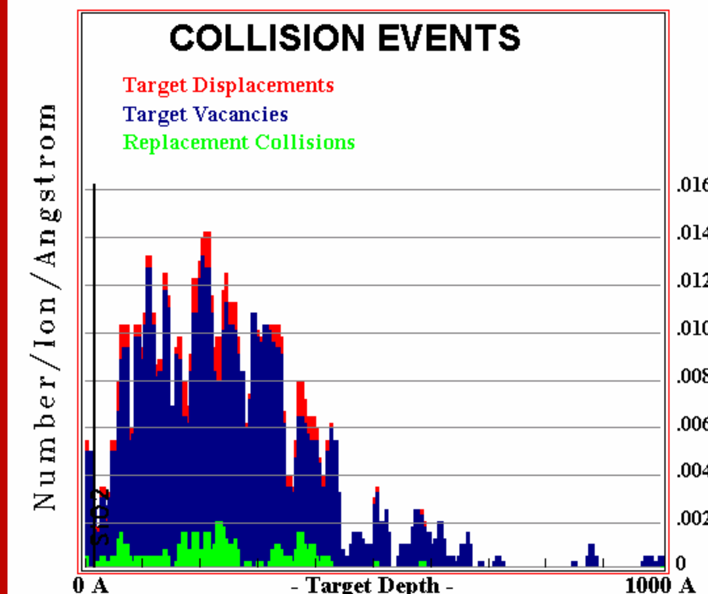


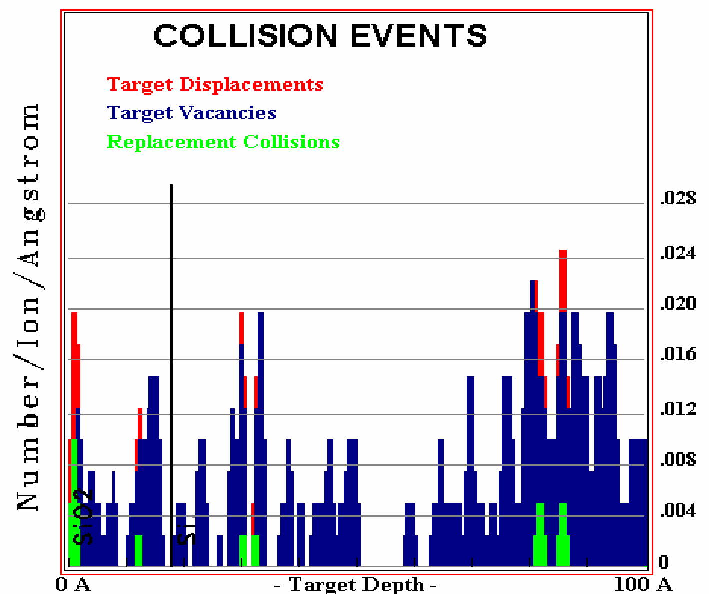
H^+ implant
Slow Wind
400 km/s





H^+ implant
Fast Wind
600 km/s





Study Results

- No Brown Stain is present and no sign of any other elemental contamination on this sample.
- SiO_2 native oxide layer has grown from ~ 18Å to ~32 to 40Å on this sample.
- Substrate alteration has occurred in the first 604 Å in this sample. Substrate alteration in Si B/C array materials has occurred below the Si/SiO_2 interface to a depth of 592 to 626Å.
- Ellipsometry results are accurate for SiO_2 native oxide layer and for substrate alteration zone (± 10Å conservatively).

Possible Conclusions

- Analysis of elemental abundances must take into account changes in the substrate lattice structure due to solar wind radiation damage that may have occurred throughout the implantation time.
- A radiation damaged native oxide layer may have allowed a reaction between atmospheric oxygen and Si substrate after impact. This caused new growth of the native oxide layer that came to a new equilibrium at 30 to 60Å.
- Should we rethink thin-film contamination on array materials (brown stain hypothesis).