Elemental and topographical imaging of microscopic variations in deposition on NSTX-U and DIII-D samples

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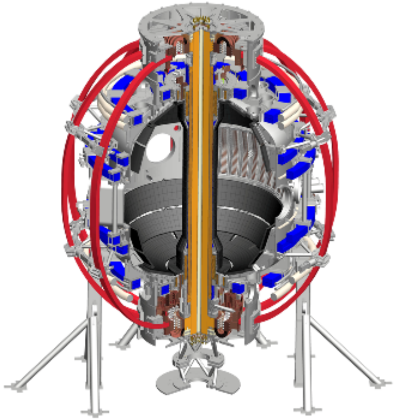


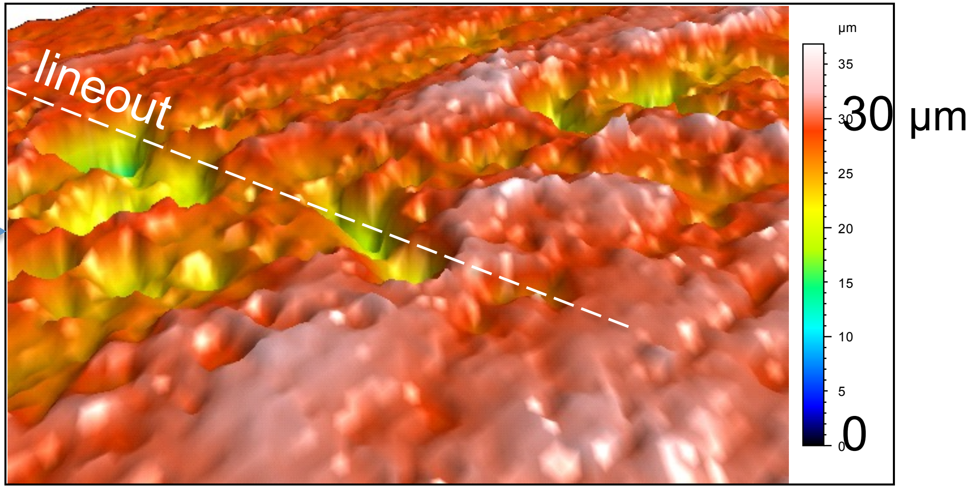
PFC surfaces can be rough.

- Erosion / deposition important for PFC lifetime, T retention, dust and plasma contamination
- Surface roughness can be a key factor in erosion and redeposition patterns.

NSTX-U upper divertor graphite tile with arc tracks

3D images of NSTX-U upper divertor tile from Leica confocal microscope

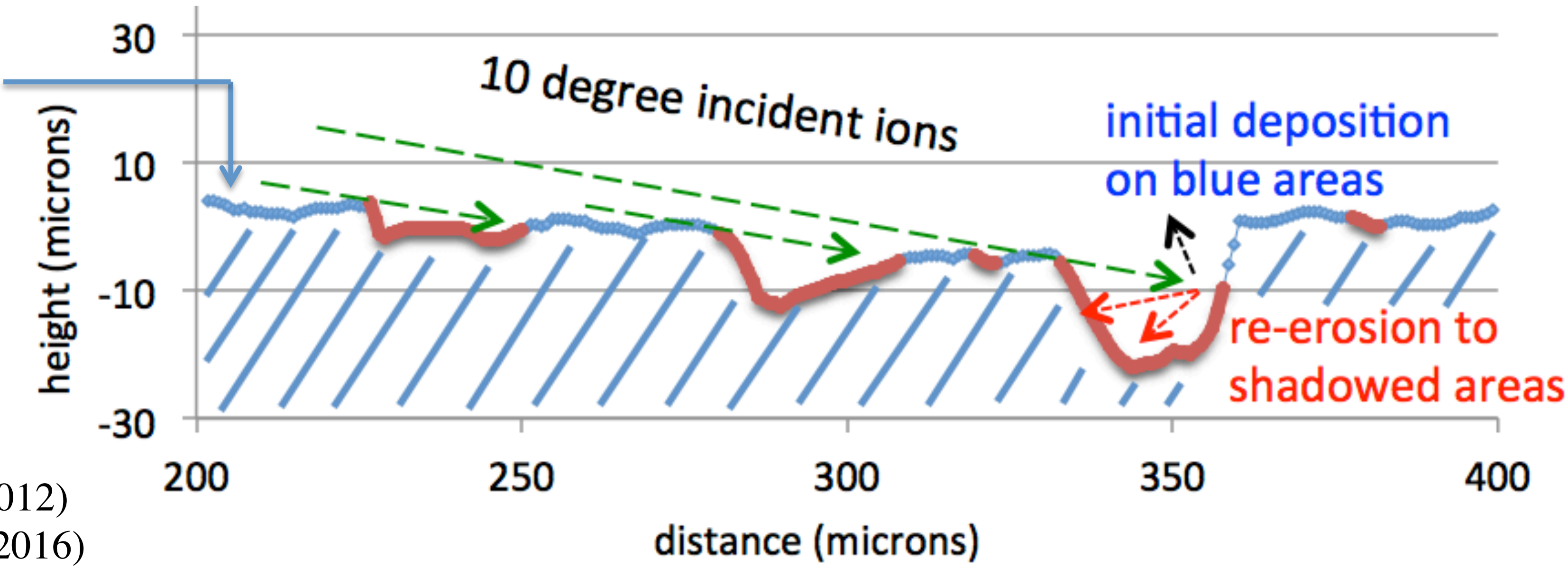
Depth scale



Surface roughness can shadow incident ions.

- Ion incidence angle can be close to surface due to magnetic pre-sheath*
- Re-eroded ions can deposit in red areas and be shadowed from further erosion
- So far no high resolution elemental measurements of this

Lineout from topographical image of NSTX-U upper divertor tile

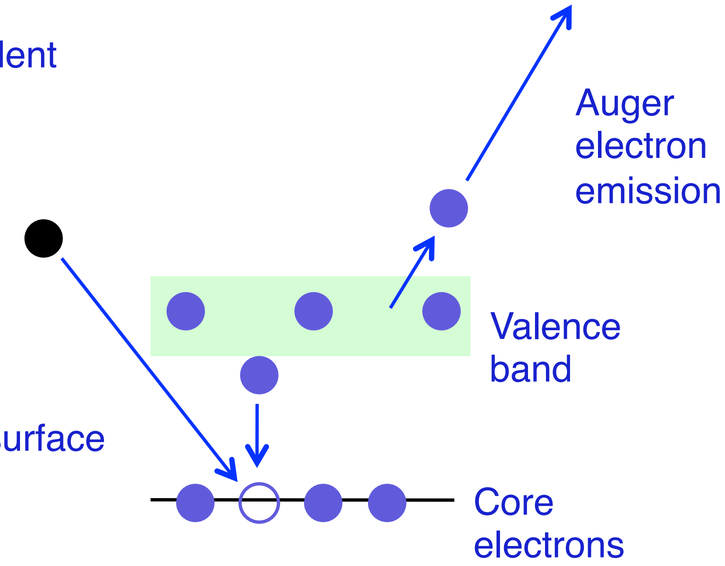


*Stangeby NF (2012)
Chrobak NME (2016)

Elemental imaging by Auger microprobe

Auger process

10 keV incident electron in Scanning Electron Microscope (SEM)



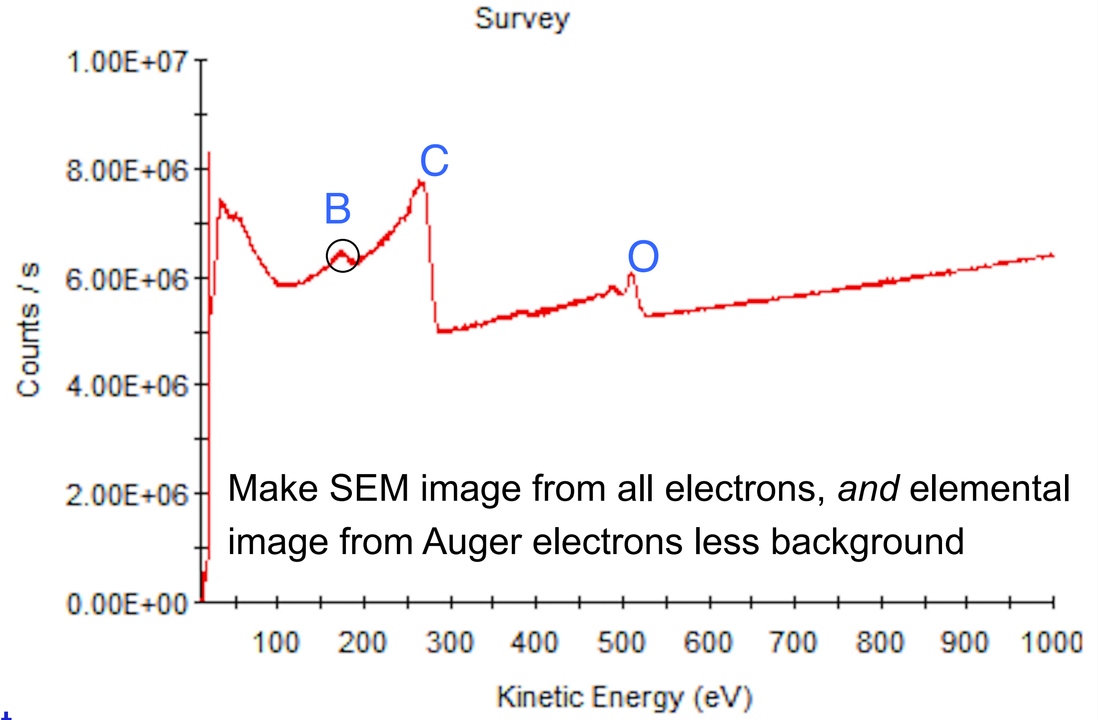
Atom on surface

10 keV electron beam excites core electron
- atom relaxes via 2-electron transition

Auger electron energy is characteristic of element

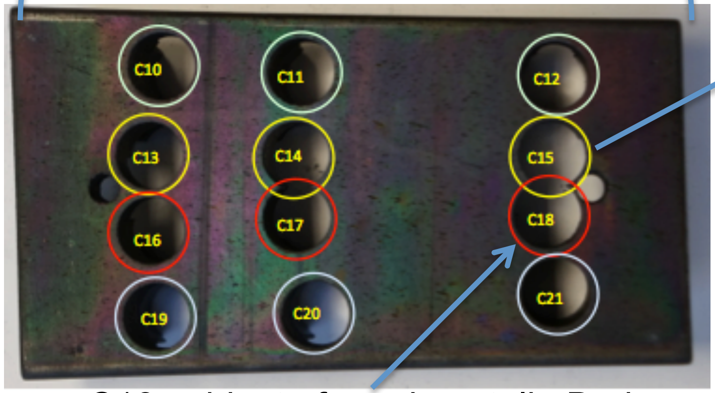
SEM has sub-micron resolution, cf ≥30 μm XPS, 100 μIBA.

Secondary, backscattered, and Auger electron spectrum from NSTX-U core sample C-15:

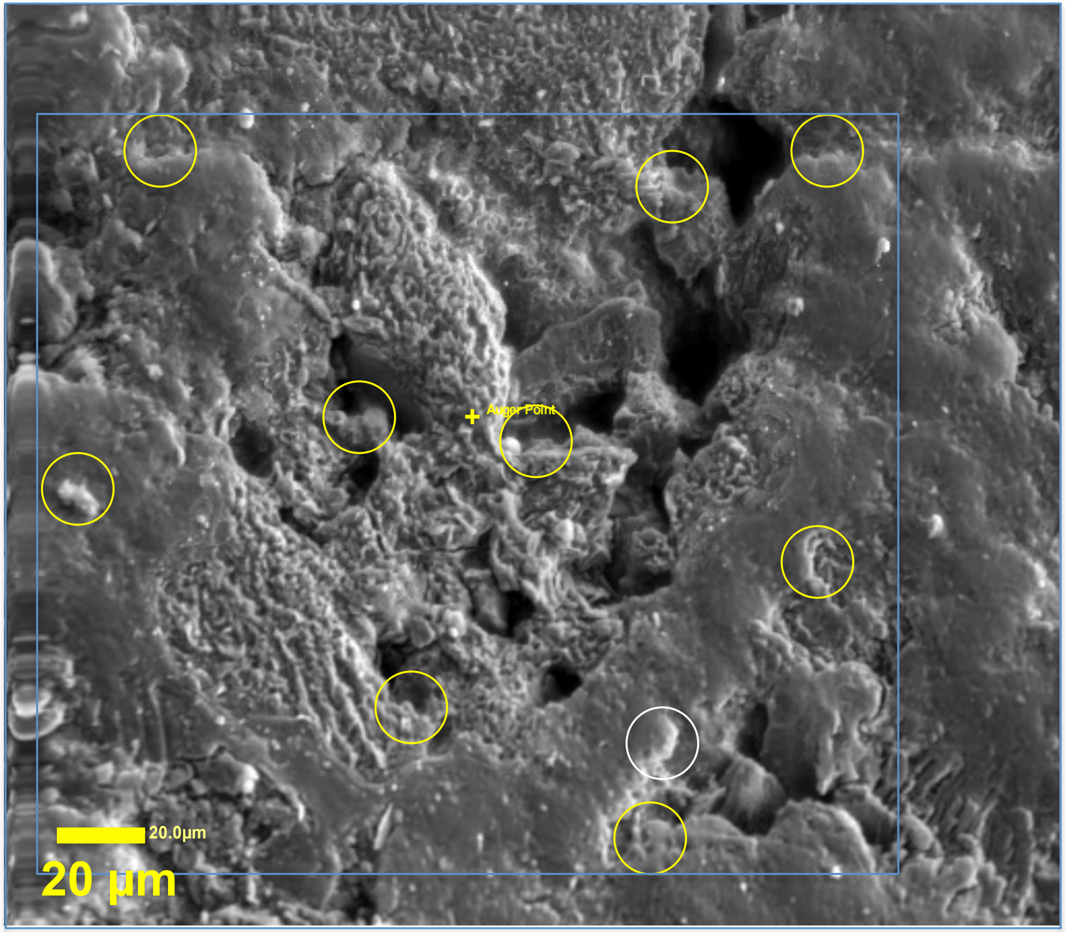


Sampling depth = 3 * inelastic mean free path
B:1nm C:1.5nm O:2.2nm Al:4.7 nm

NSTX-U: SEM image of tile core

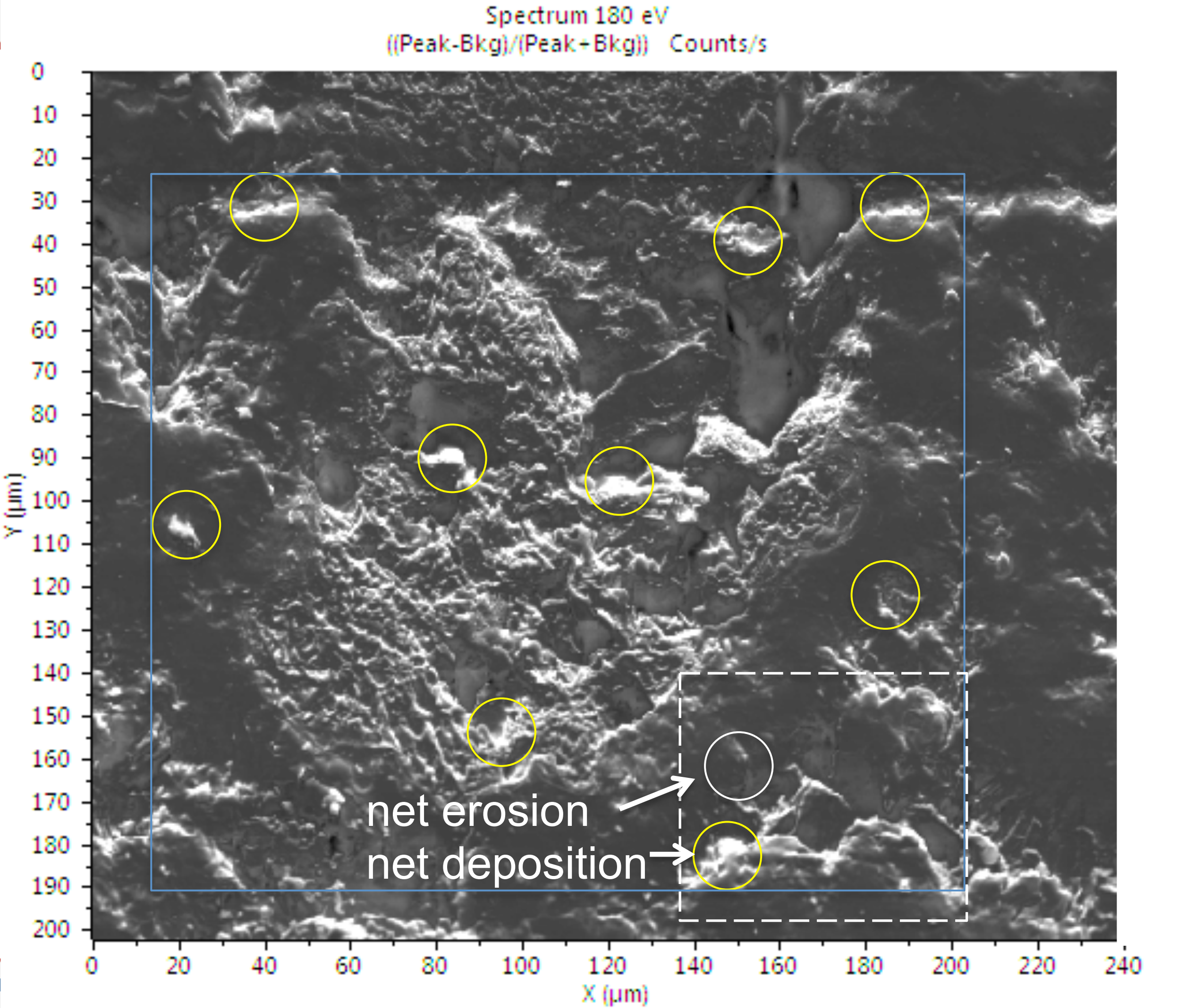


C18 subject of previous talk, Bedoya et al.,



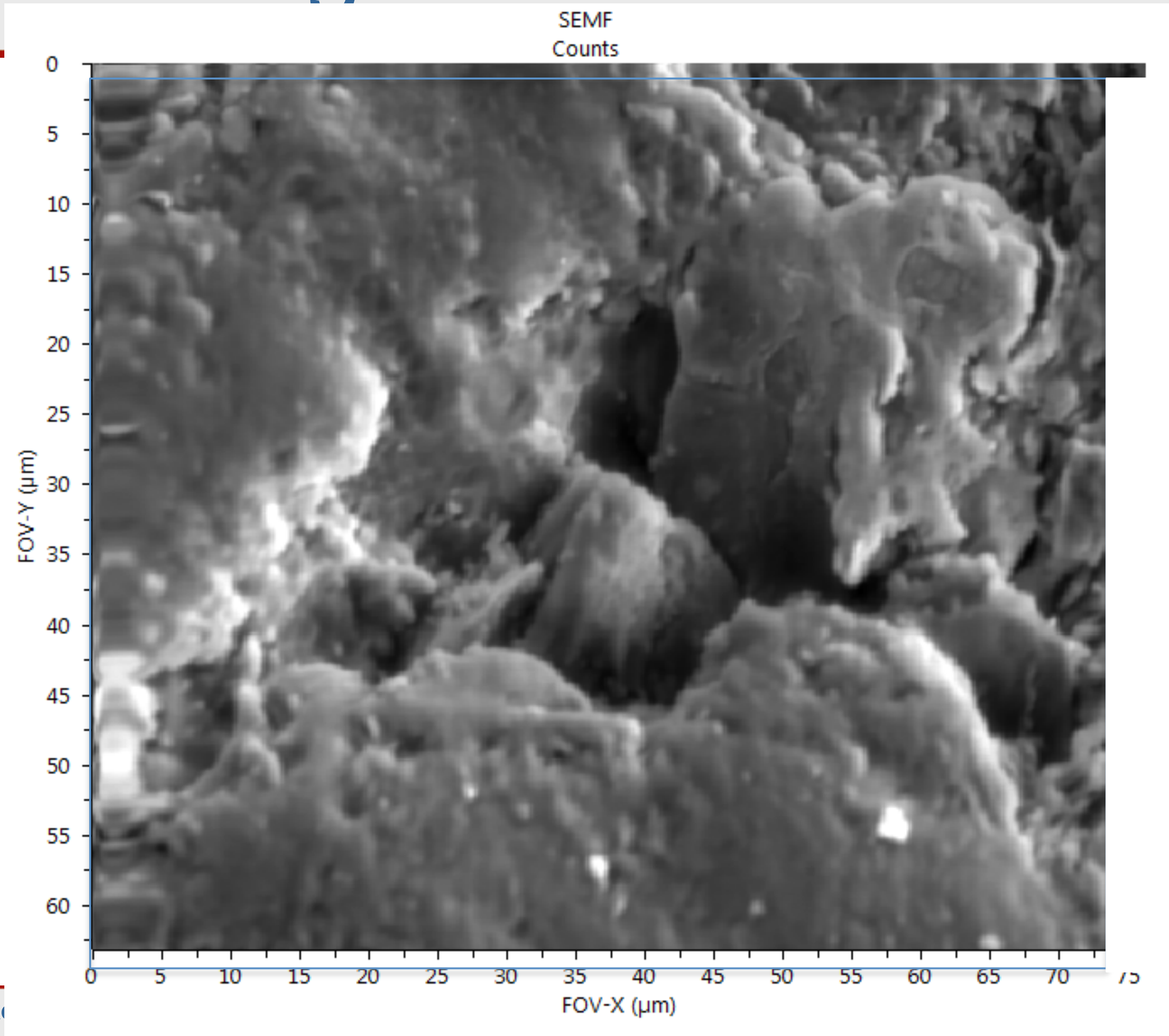
Auger image of boron 1

- Auger line scans show atomic concentration of boron ~ 4% – 16%.
- Appears to be higher B concentrations on North facing cliffs and little boron on South facing cliffs (toroidal field direction uncertain)
- Area in white square in next slides.



SEM higher magnification

- Zoom in to white square in previous slide.

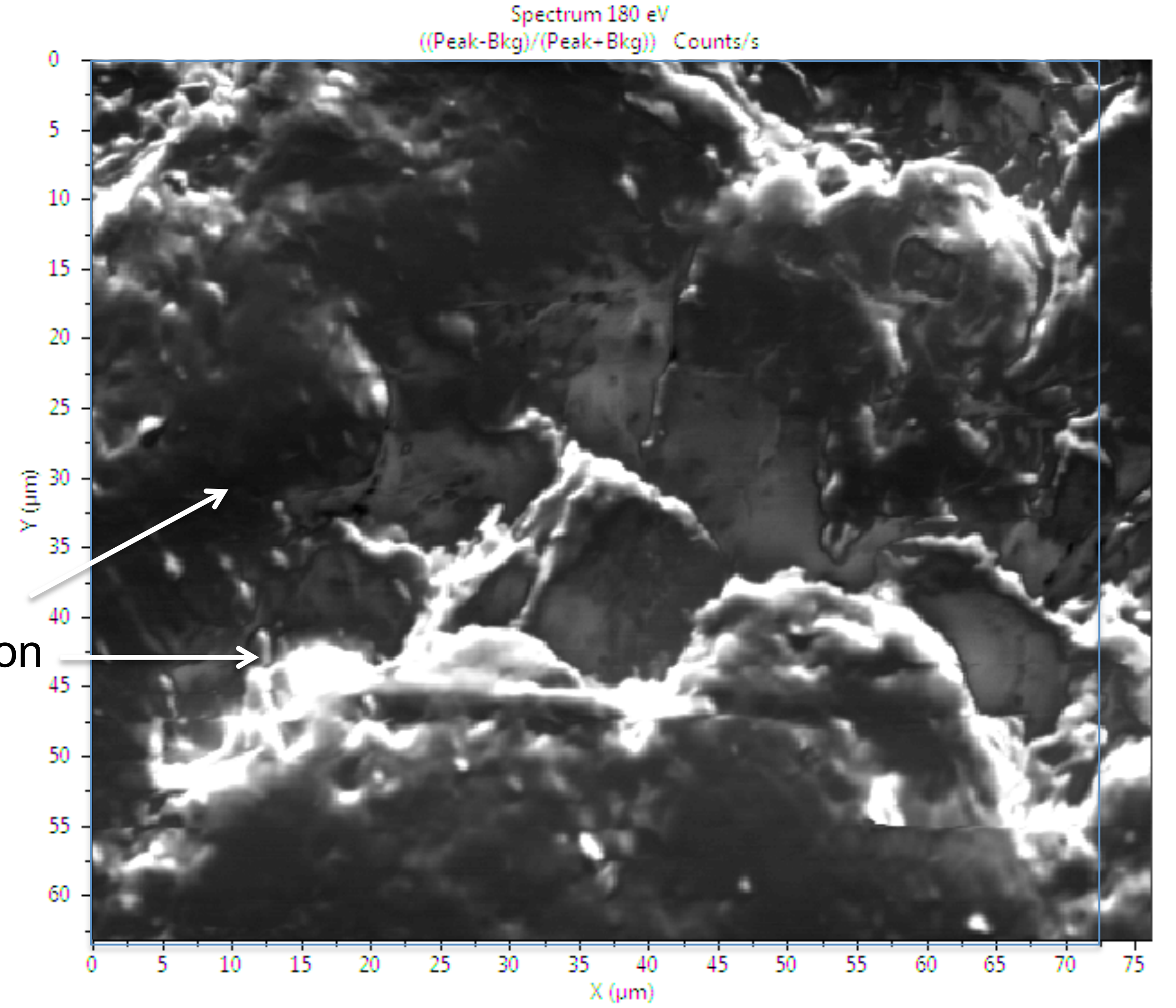


Auger image of boron at higher magnification

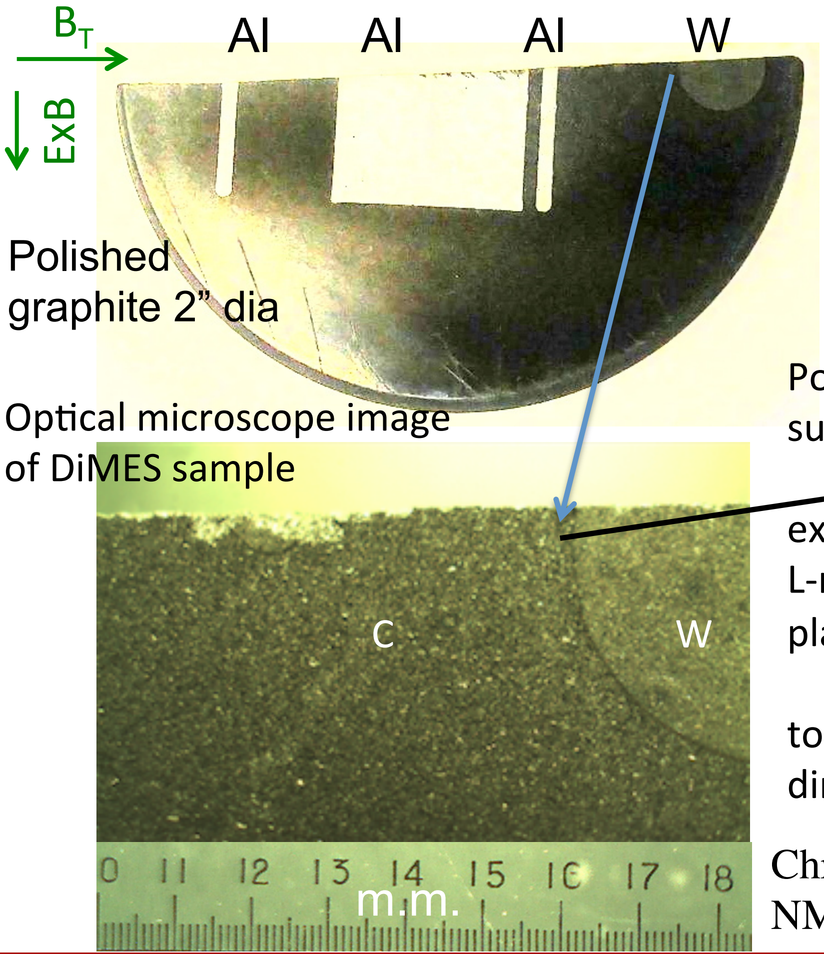
- Higher magnification image also shows higher B concentrations on ‘north’ facing cliffs and little boron on ‘south’ facing cliffs.

- More analysis planned.

- Topographical 3D mapping planned with Leica confocal microscope.



DiMES material migration study

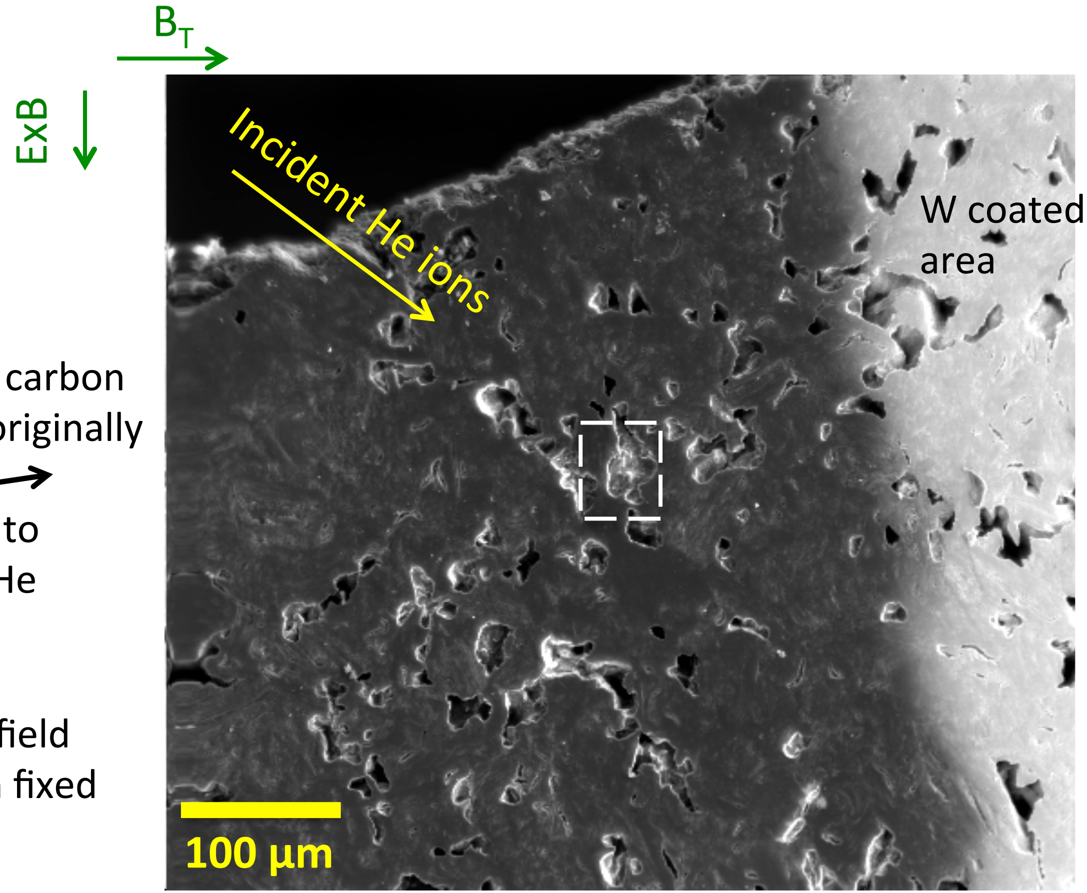


Polished carbon surface originally exposed to L-mode He plasmas

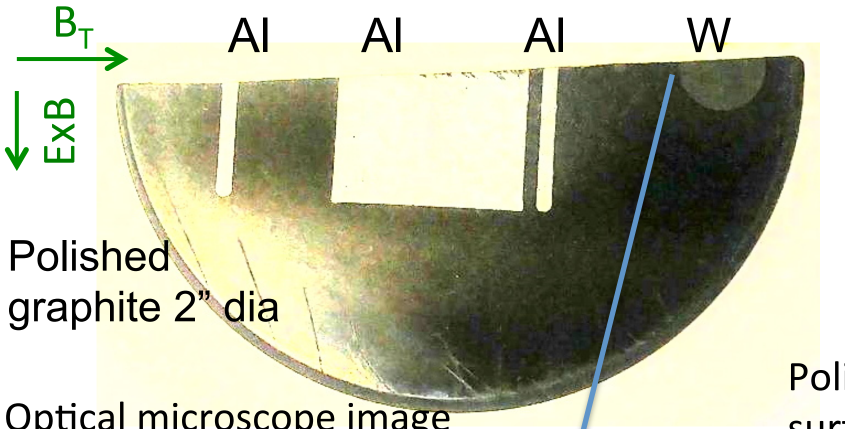
toroidal field direction fixed

Chrobak NME (2016)

SEM image

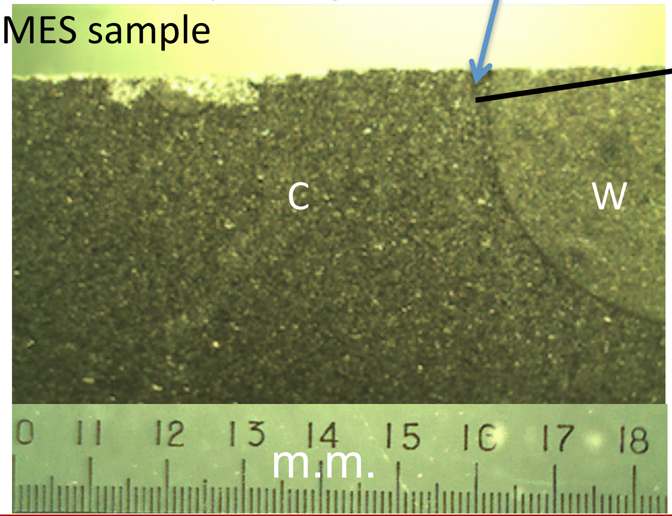


DiMES sample, Auger image of Al deposits



Polished graphite 2" dia

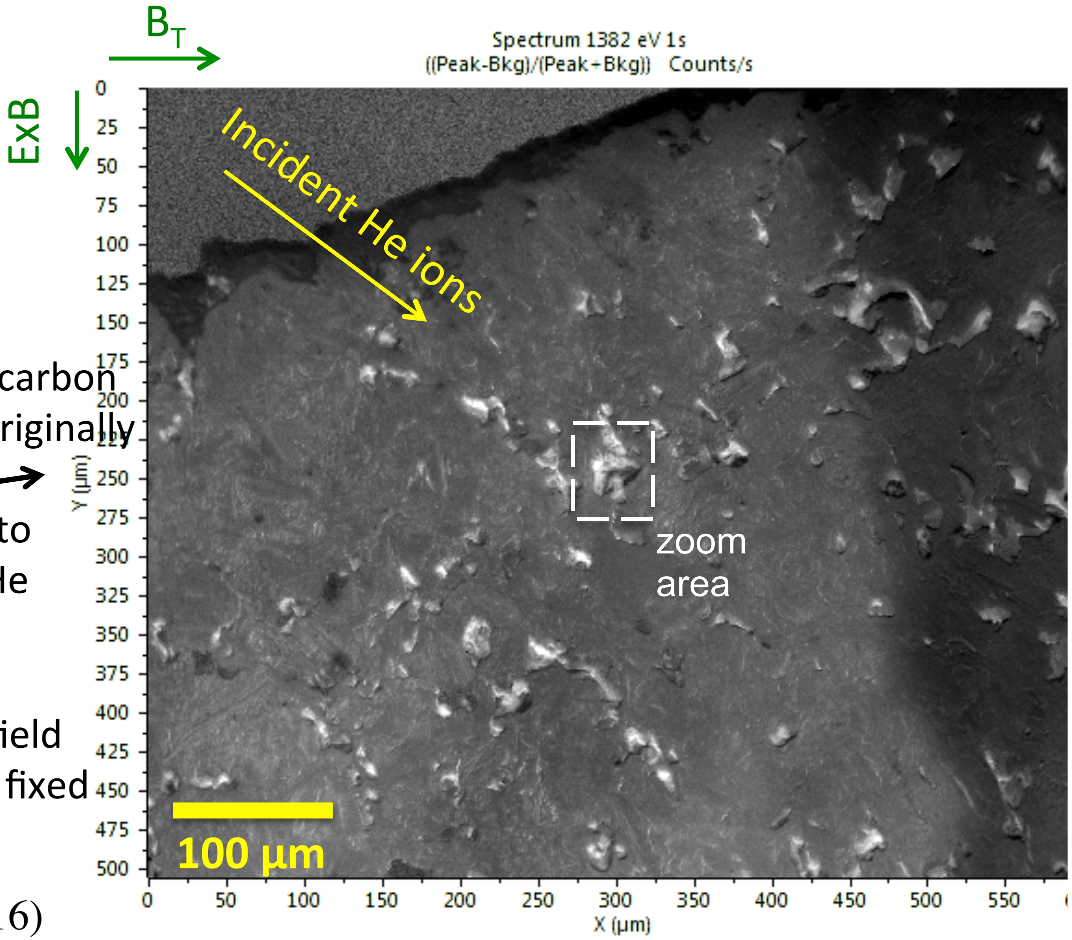
Optical microscope image of DiMES sample



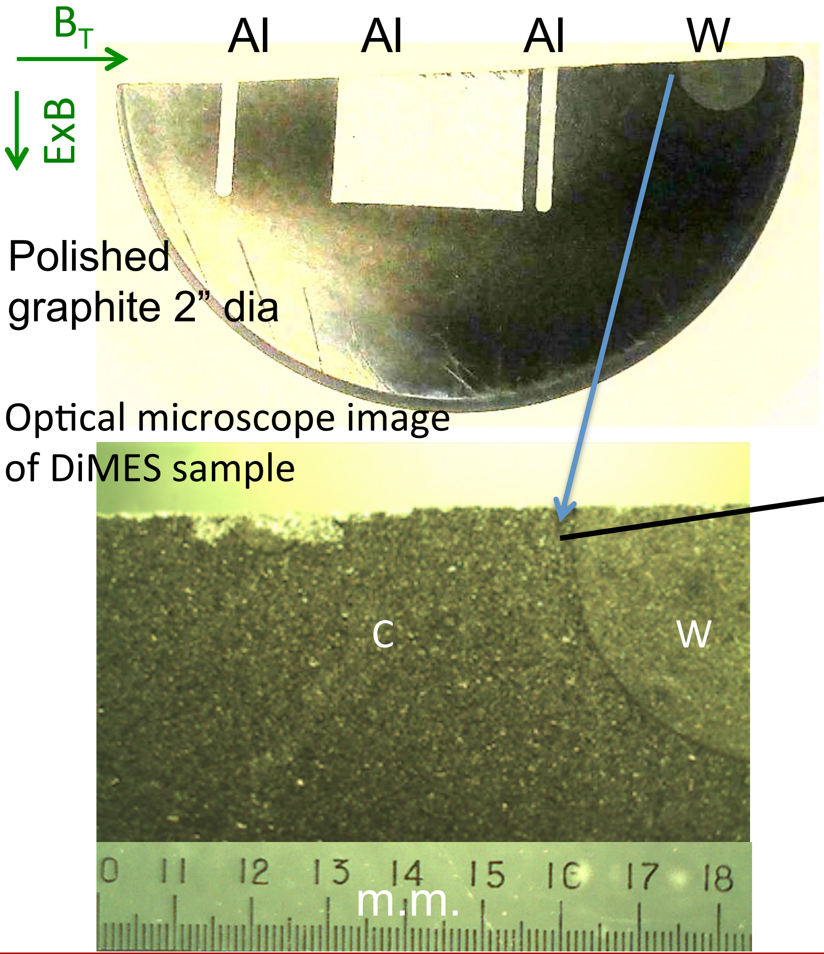
Polished carbon surface originally exposed to L-mode He plasmas

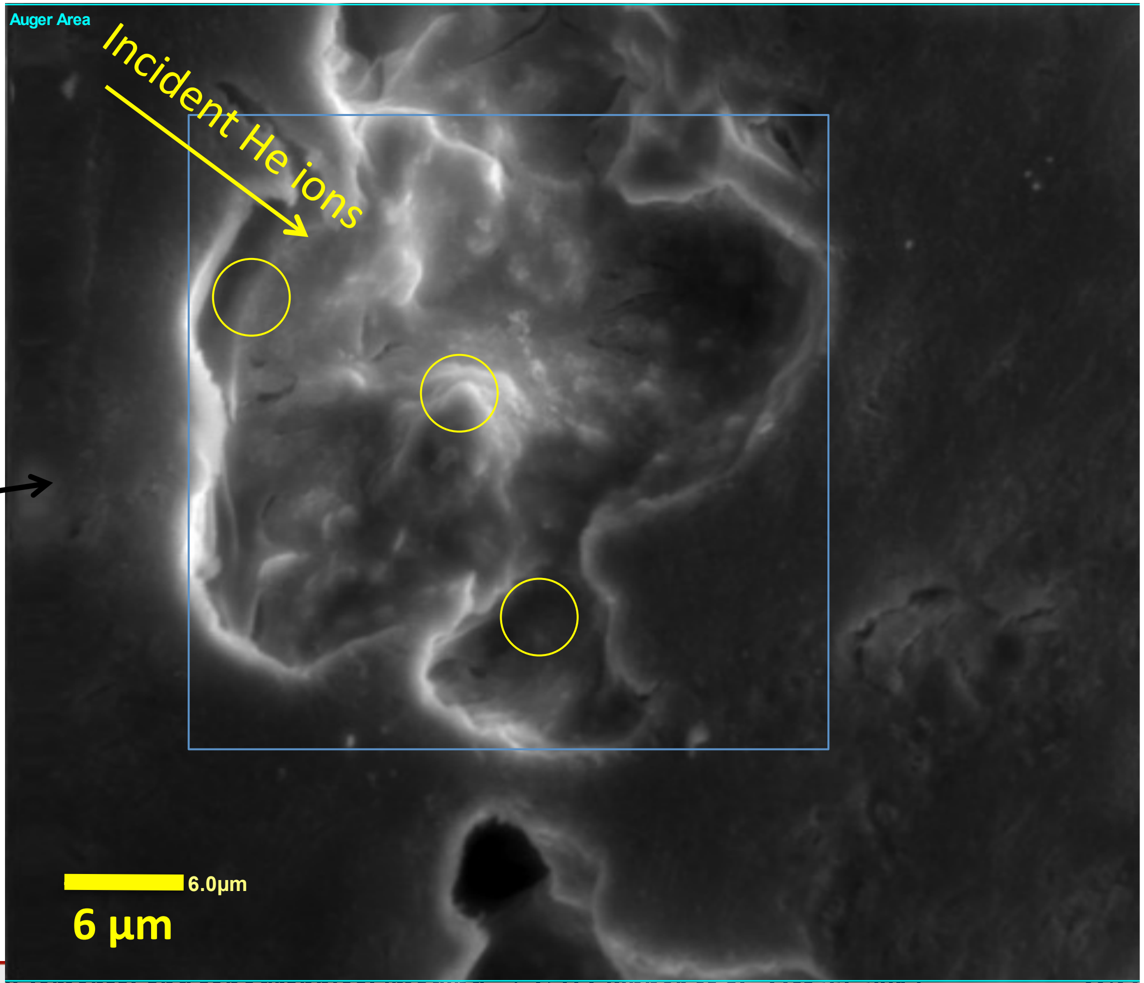
toroidal field direction fixed

Chrobak NME (2016)



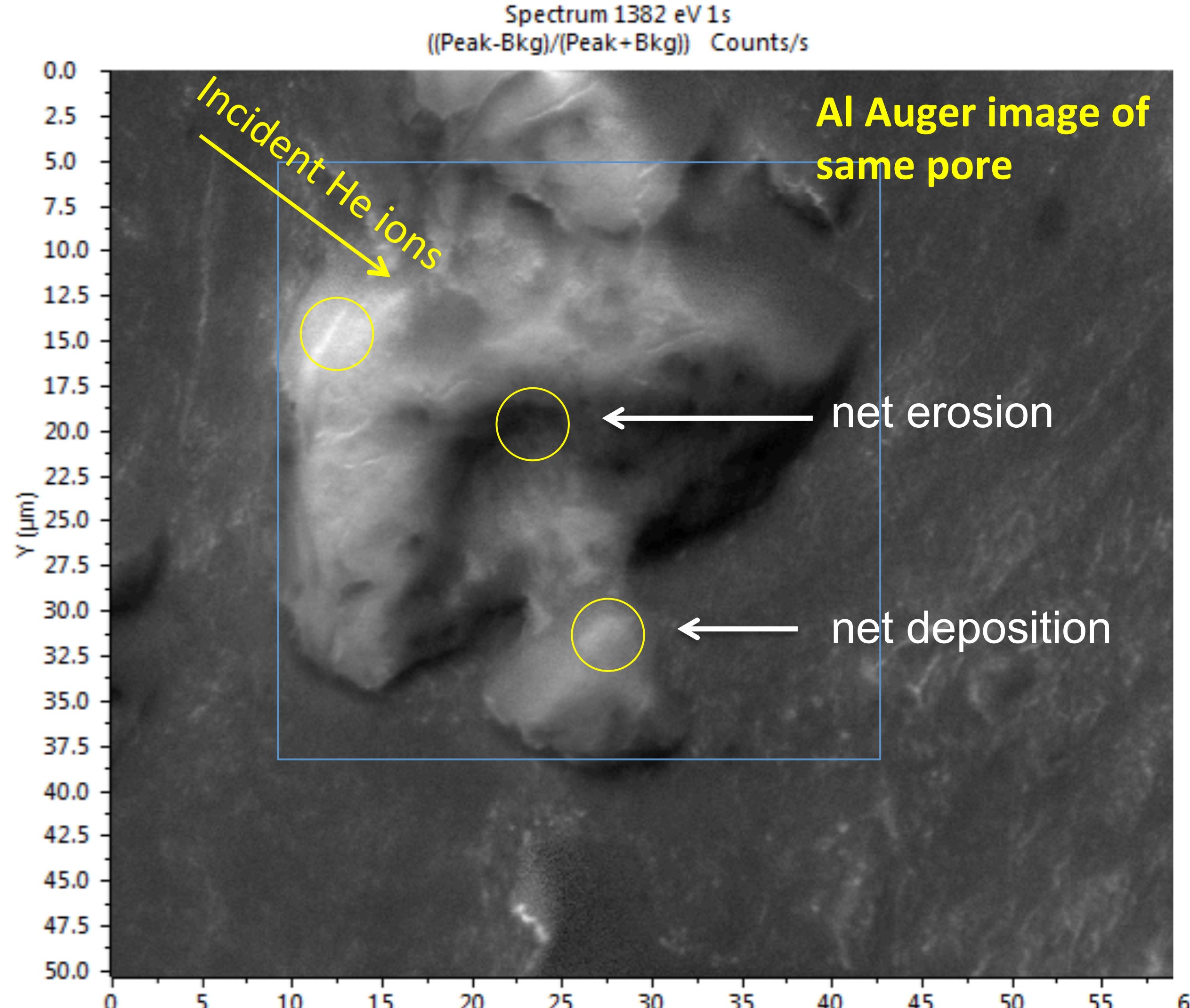
DiMES sample, SEM image of pore:





Al Auger image of same pore

Microscopic features of surface affect erosion and redeposition.



W Auger image of same pore

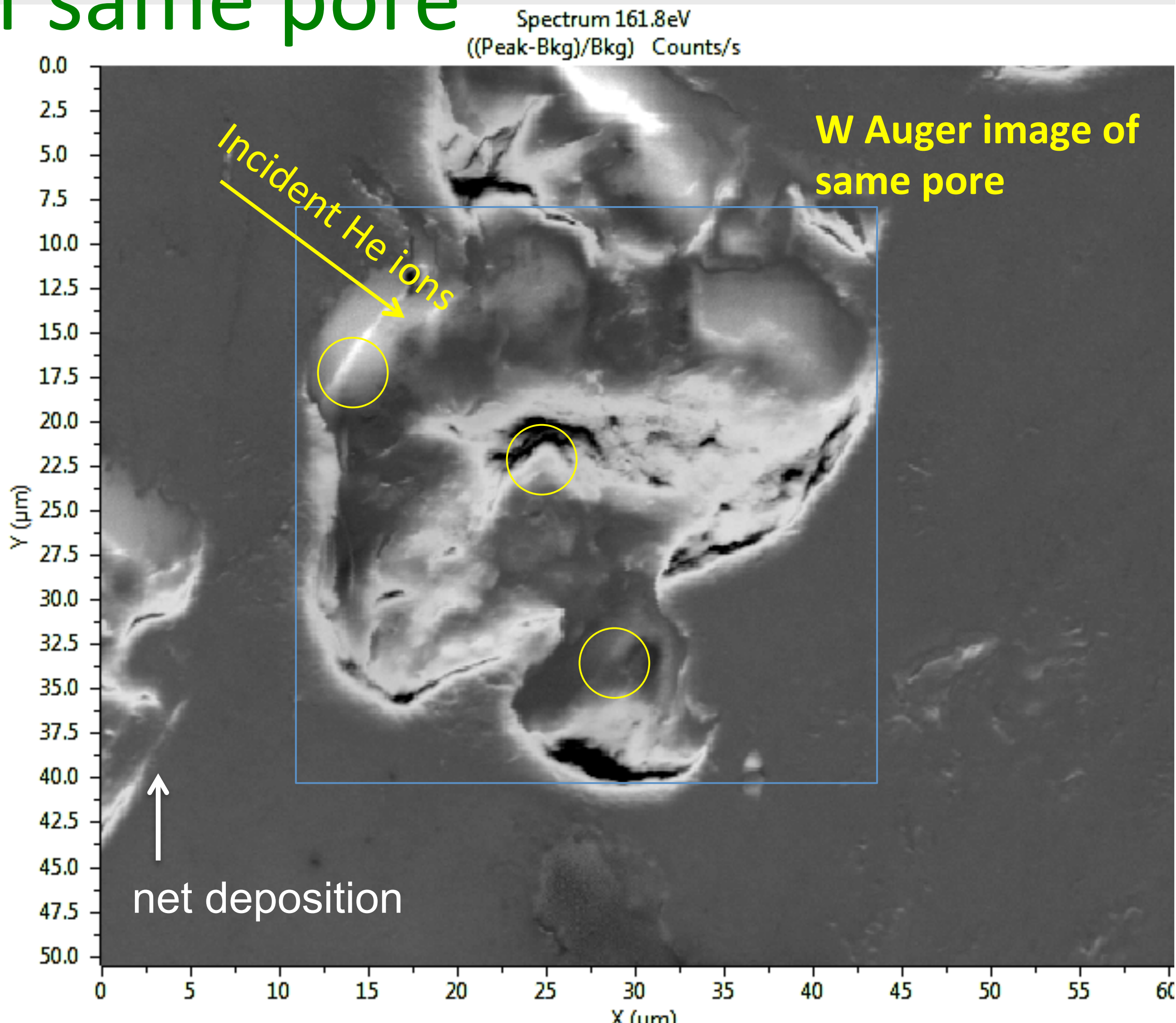
Most W eroded by incident C (not D) and promptly redeposited.

W is migrating upstream

<u>Conclude:</u>

Auger elemental images show how surface affect erosion and redeposition.

Surface topography needs to be taken into account in modeling erosion and redeposition on rough surfaces.



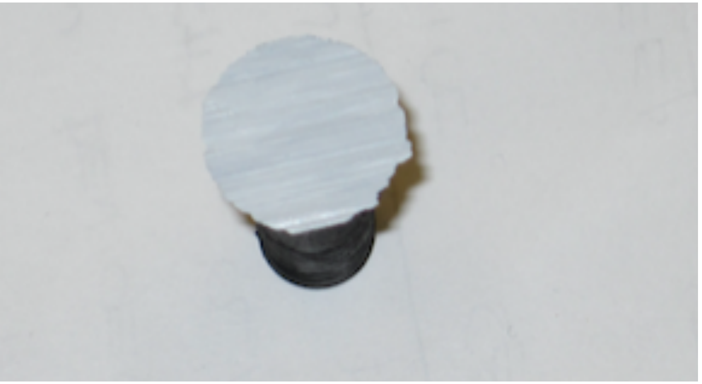
Conclusions:

- Direct elemental mapping at sub-micron resolution shows net deposition is inhomogeneous in NSTX-U and DiMES samples
- Surface morphology on micron scale influences net deposition patterns
- Net deposition pattern is consistent with magnetic pre-sheath causing shallow angle incident ions and less erosion on shadowed areas.
- 3D topographical mapping planned to correlate deposition patterns with detailed topography
- Illustrates how surface science can illuminate fundamental sheath physics and fusion energy issues.

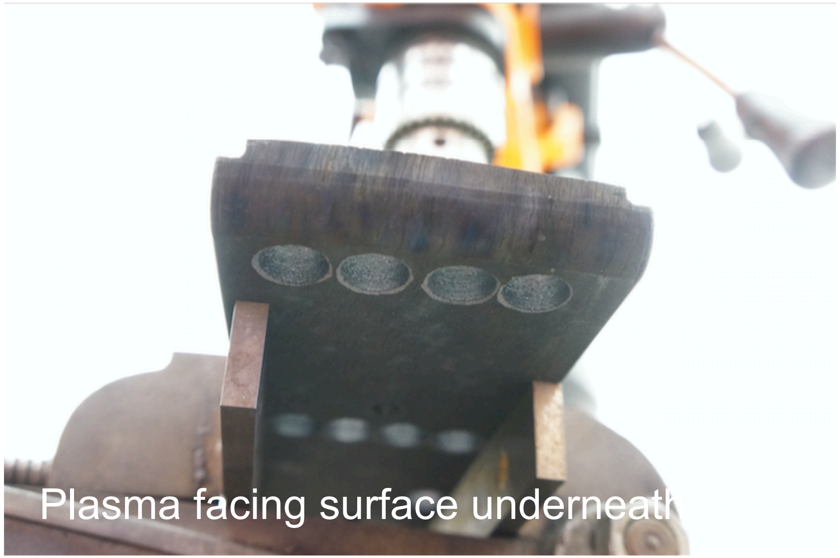
Backups

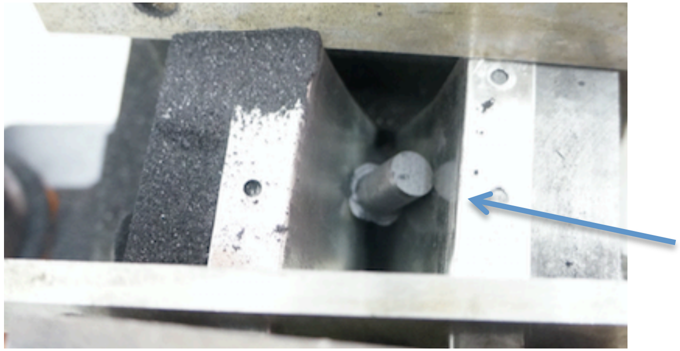
Backups

Precision, custom-made 3/8” i.d. core drill’



No dust evident on trial sample after coring



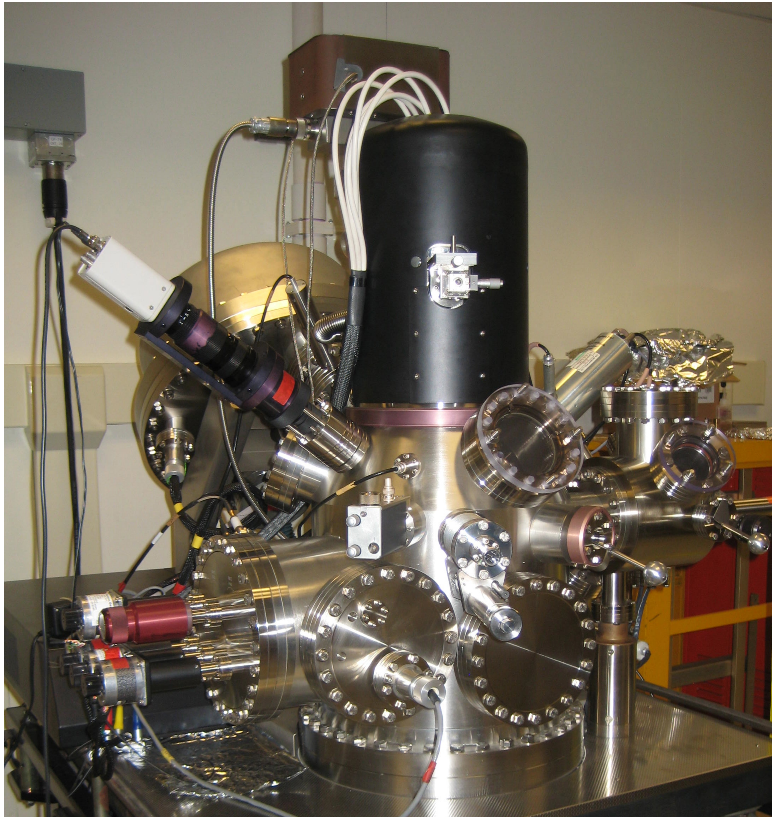


Core in 'catcher’

Backups

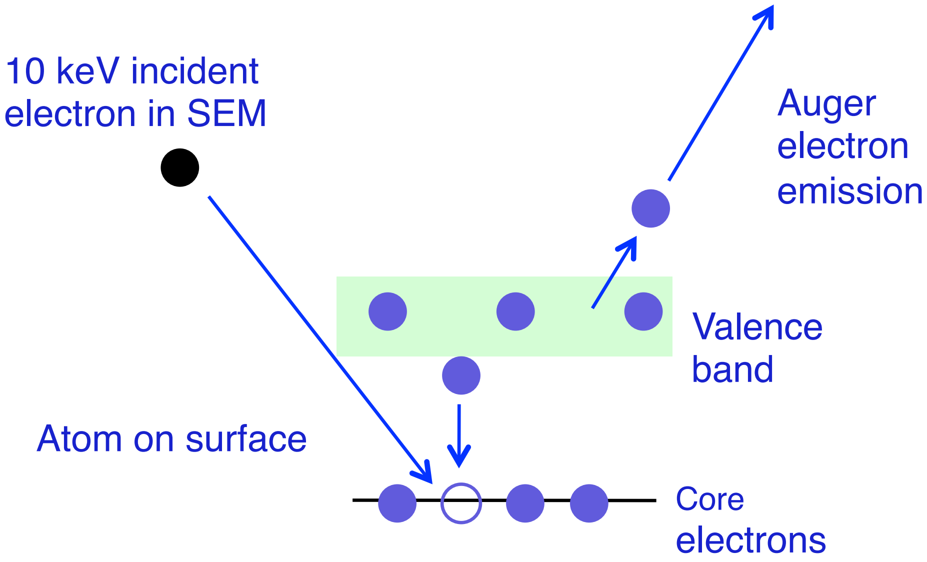
Scanning Auger Microprobe (SAM) combines:

- Secondary electron microscopy (SEM)
- Auger electron spectroscopy (AES) for 2D elemental mapping (SAM)
- Ion sputtering for surface cleaning and depth profiling

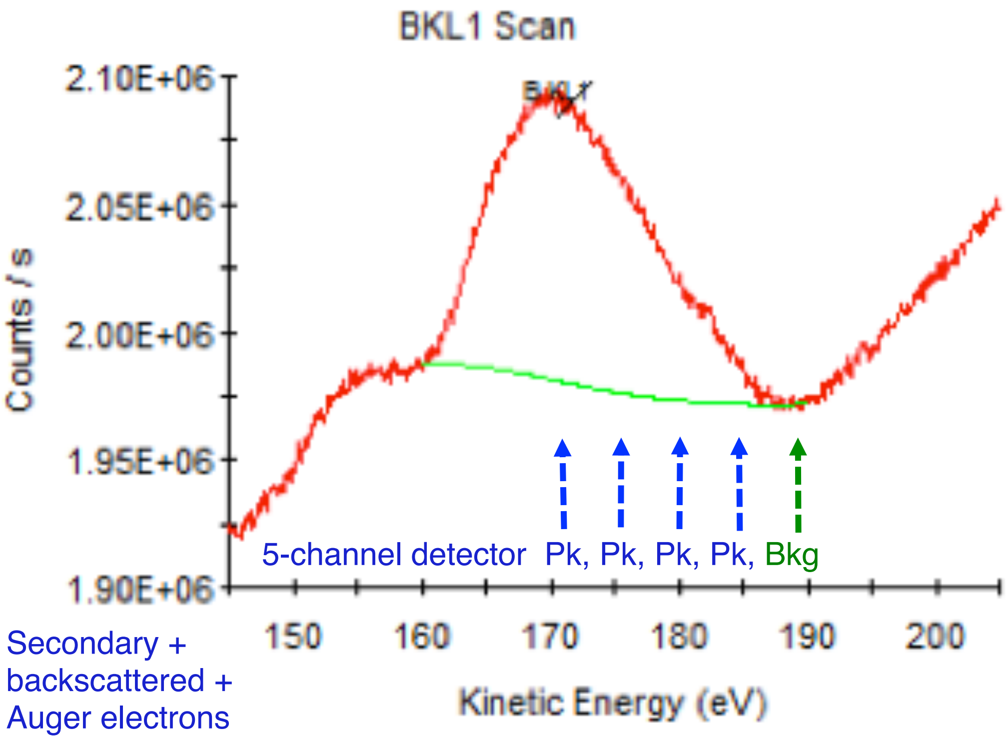


Elemental imaging by Auger microprobe

Auger process



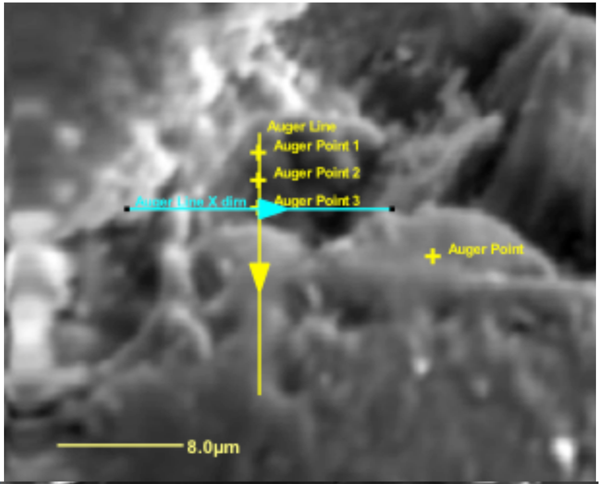
Boron Auger Line:

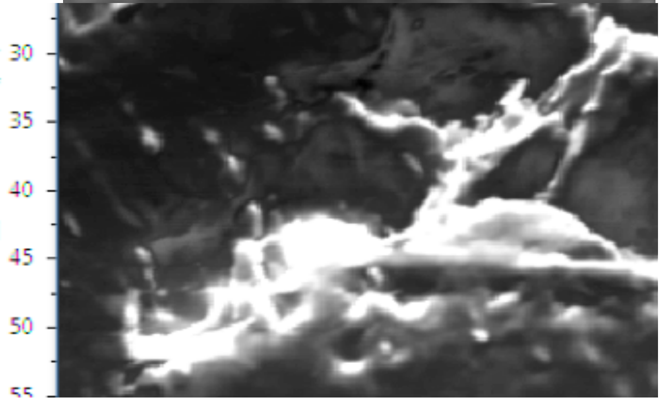


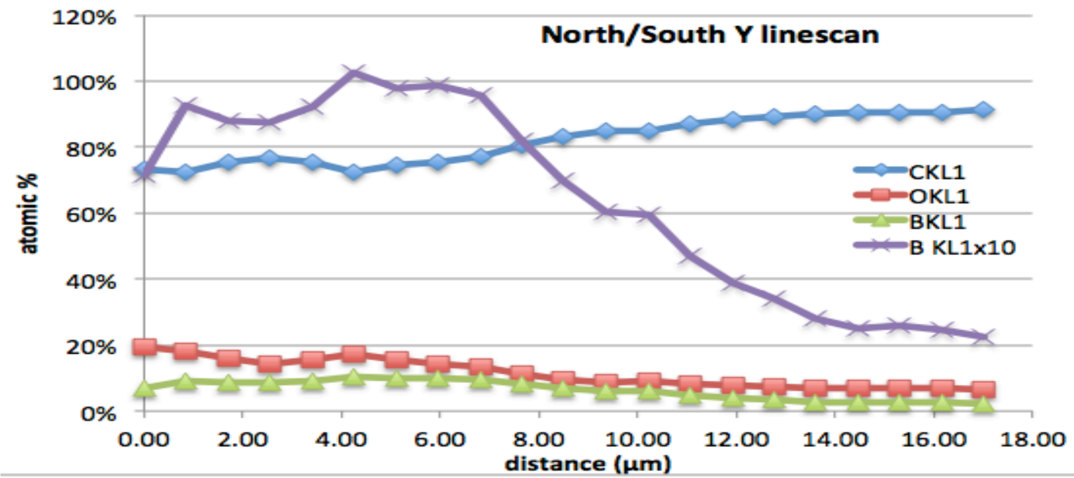
10 keV electron beam excites core electron
- atom relaxes via 2-electron transition
Auger electron energy is characteristic of element

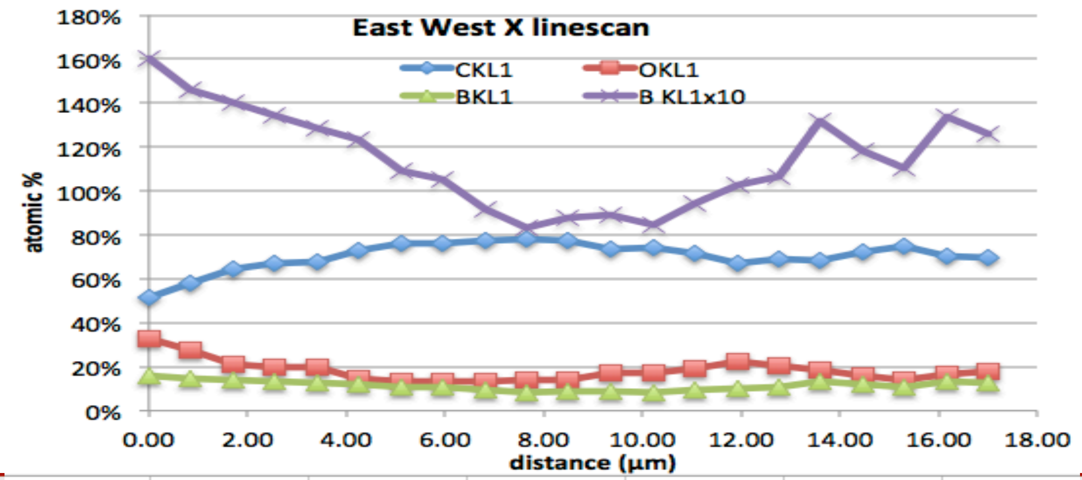
Images calculated from (Pk-Bkg) / (Pk + Bkg)

Auger linescans of NSTX-U sample



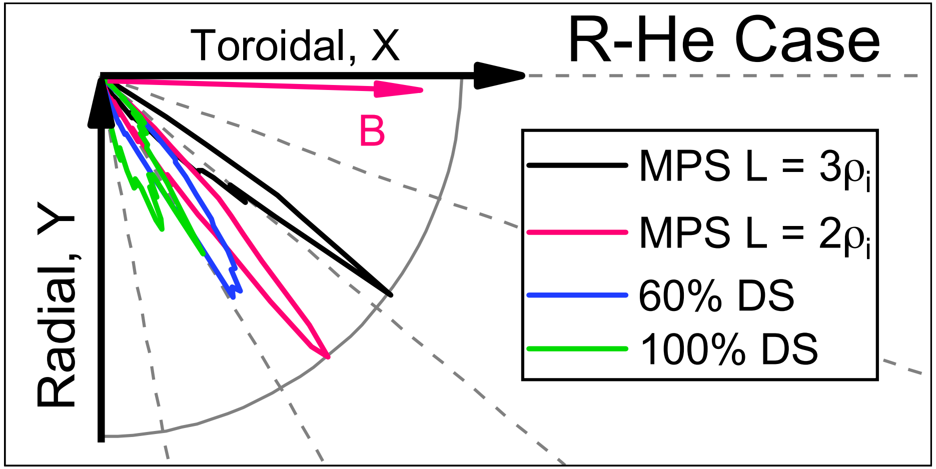


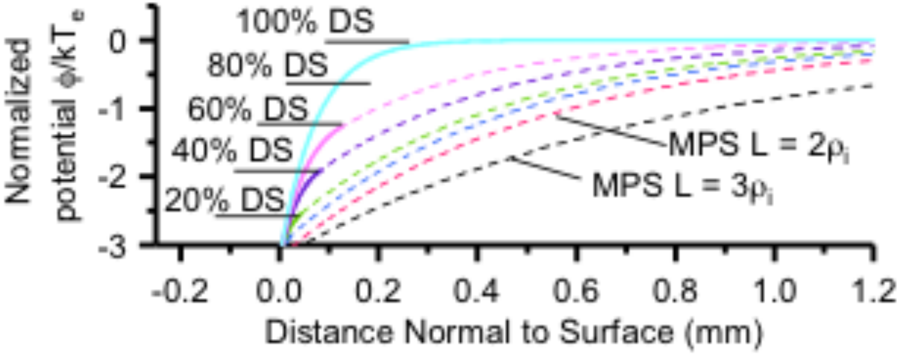




Incident Ion Angle Distribution

Chrobak





IAD For Case R-He with Varied Sheath