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Particle Control for Low-Energy Boron Implantation

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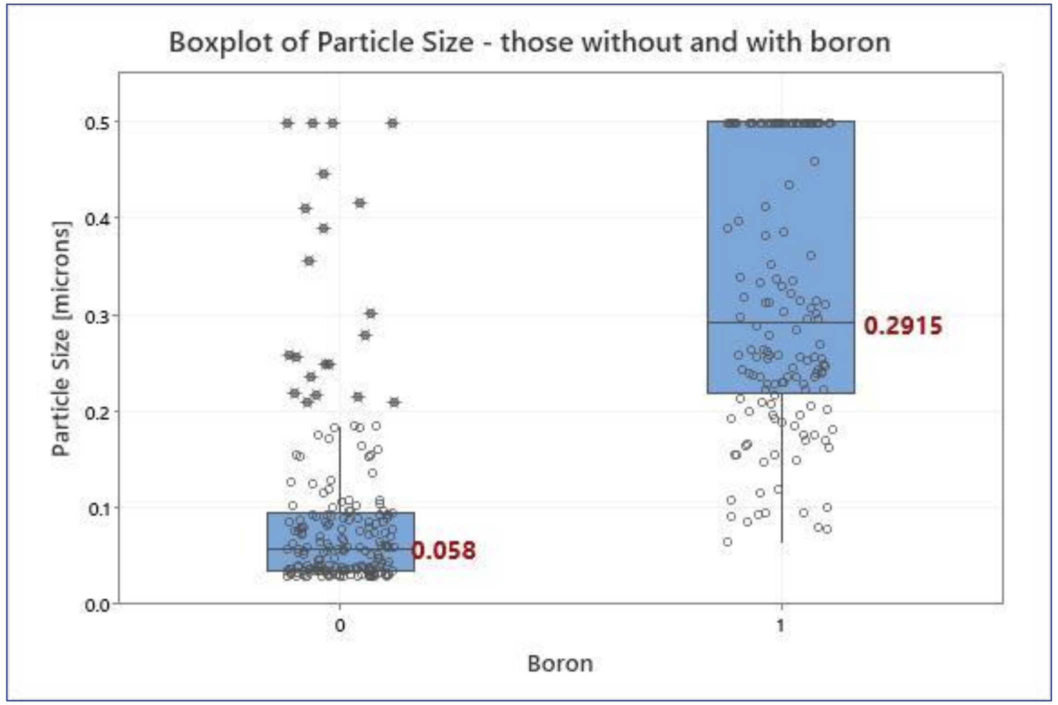
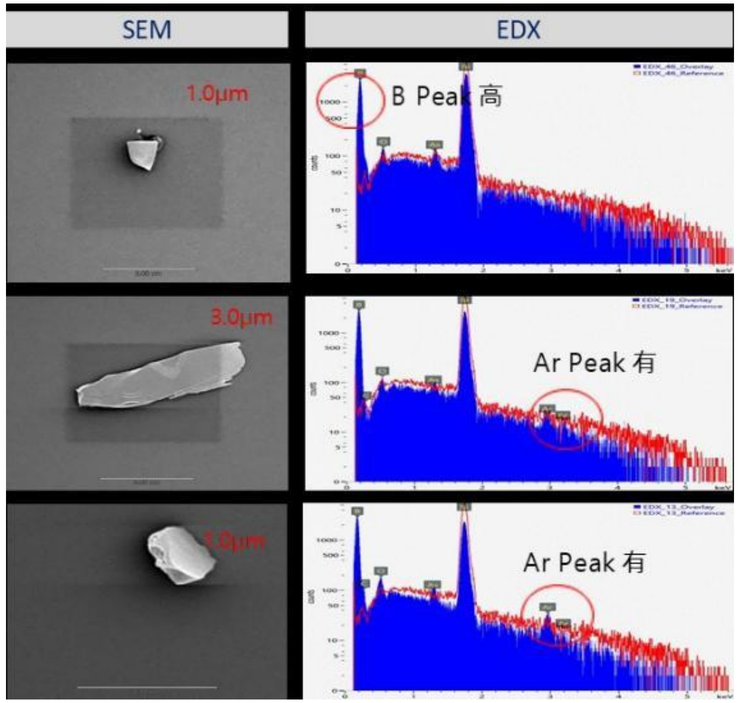
Outline

- Particles when running dedicated Low-Energy Boron (LEB) implants
- Graphite liners in the near-wafer environment of Axcelis’ Purion High Current Implanter
- Boron films on graphite liners
- Metrology used to study the particles and films
- Sputtering of films
- Serrated graphite liners
    - Sputtering model
    - Optimizing serration angle to minimize film growth
- Field data

Particles when running dedicated Low-Energy Boron (LEB) implants

- Dedicated LEB implants are a special use-case:
  - Generate large particles in a short period of time (2 to 5 days) after Preventive Maintenance (PM)
  - Particles primarily contain boron
  - Have a distinctive shape – flakes from delaminating films





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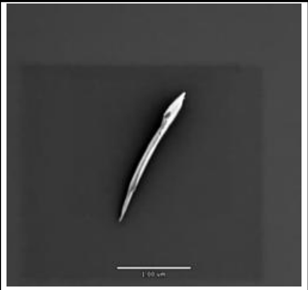
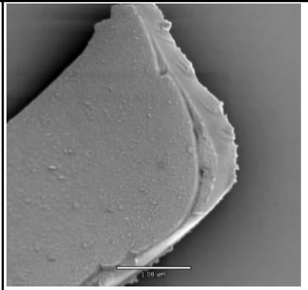
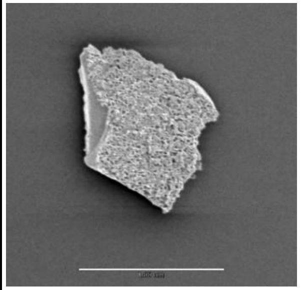
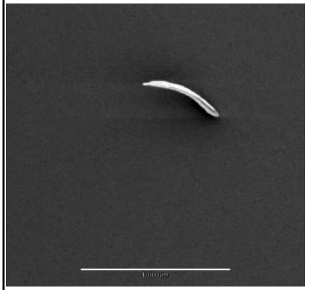
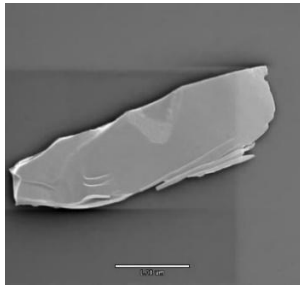
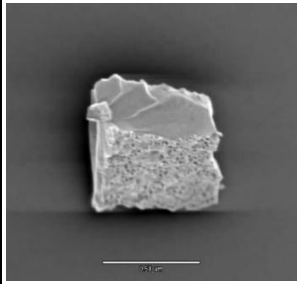
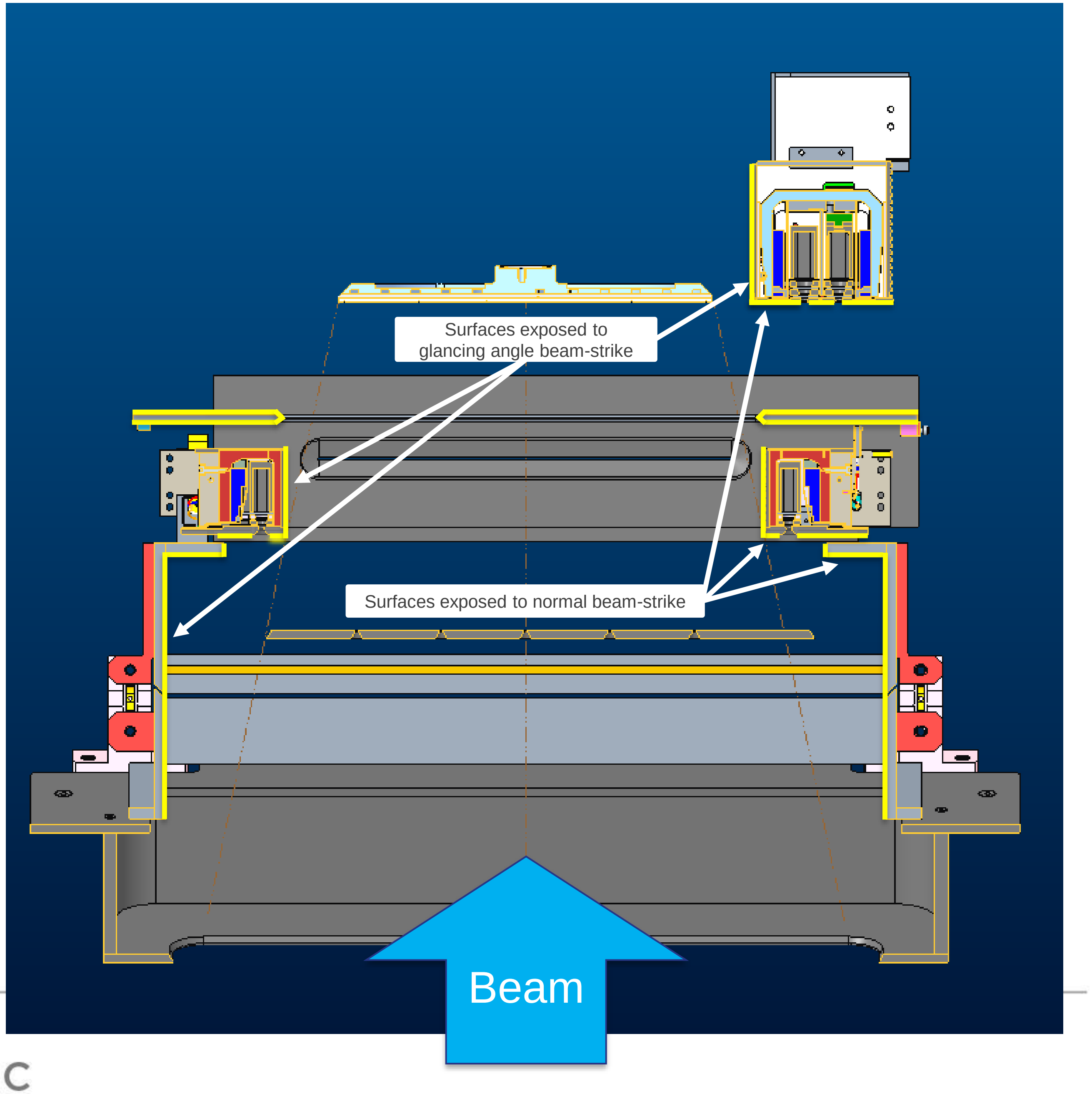
SEM			
SEM			
Proportion	3%	85%	12%

Graphite Liners in the Near-Wafer Environment

- Axcelis Purion High Dose implanter uses graphite liners (shown in yellow) to shield areas of the process chamber from beam strike.

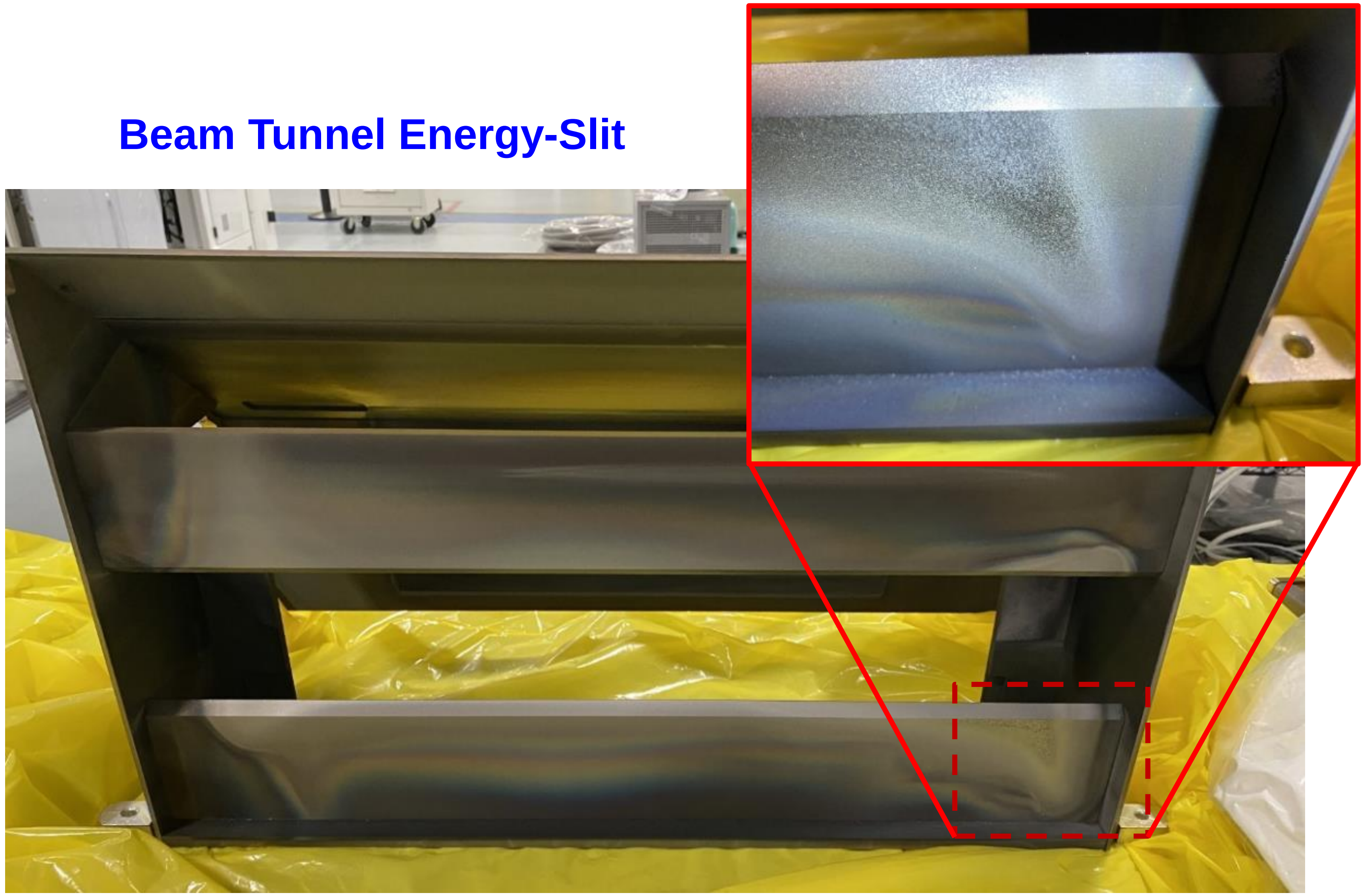
- This includes a beam tunnel and liners surrounding dosimetry components in the near-wafer environment.

- Surfaces exposed to normal and glancing-angle beam strike need to be treated differently due to differences in their sputtering yields



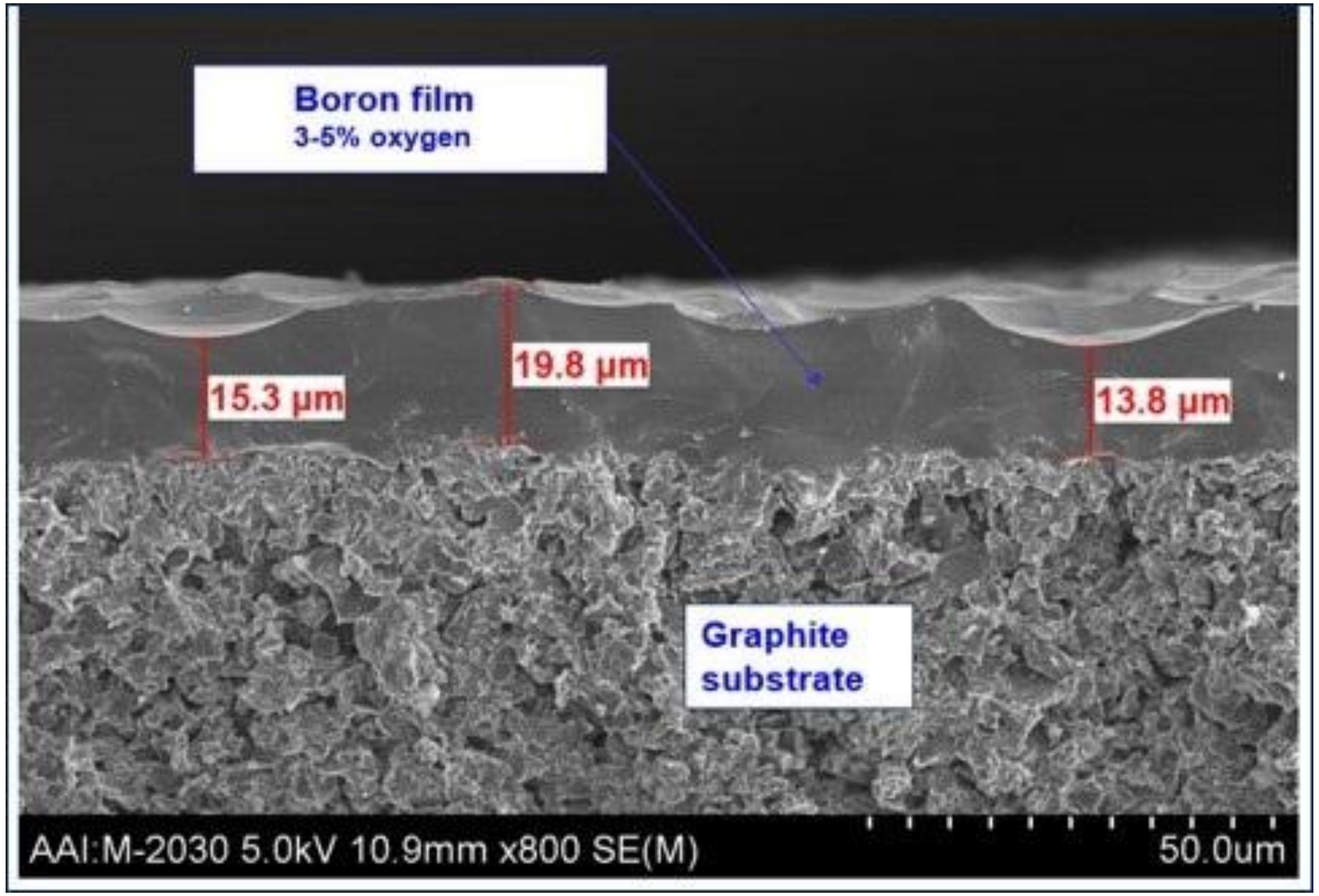
Boron Films on Beam Tunnel and Dose Faraday Aperture Graphite

Beam Tunnel Energy-Slit



Dose Faraday Aperture

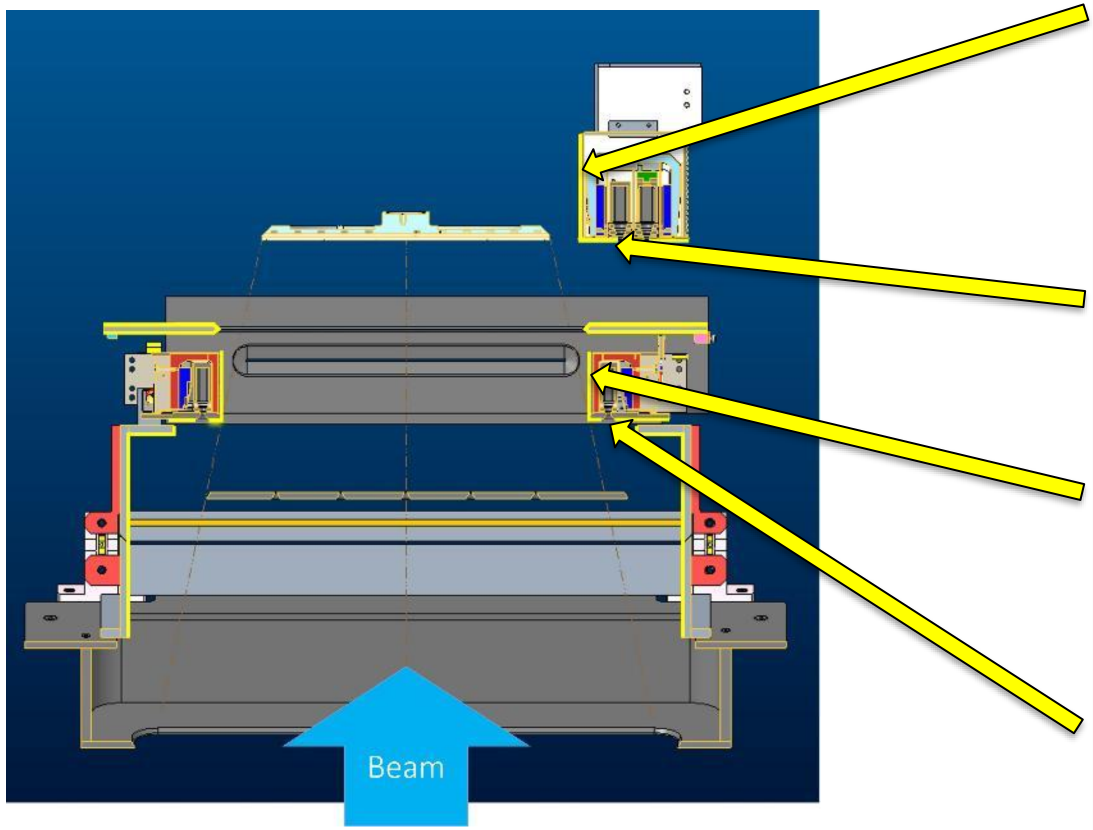
Boron Films on Dose Faraday Aperture Graphite – SEM

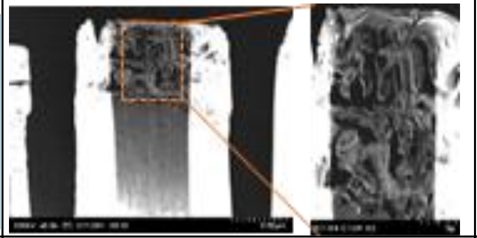
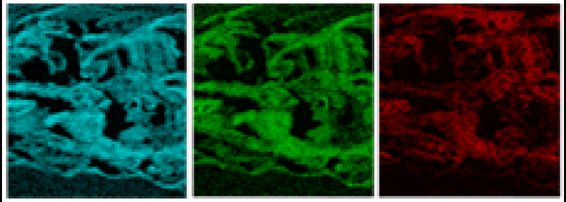
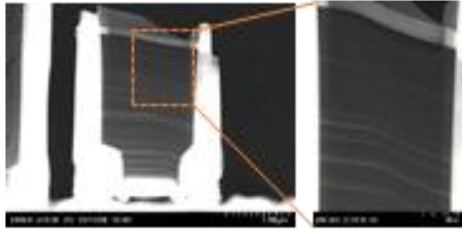
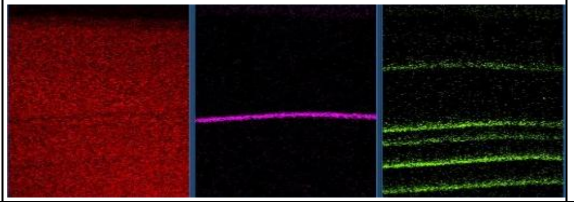
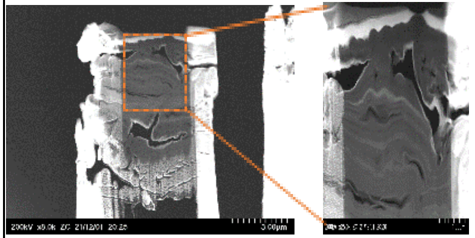
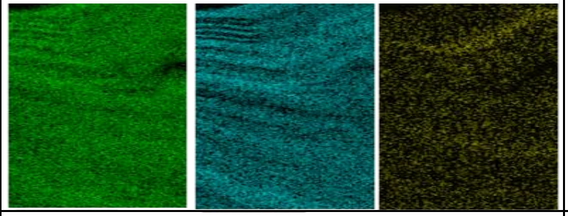
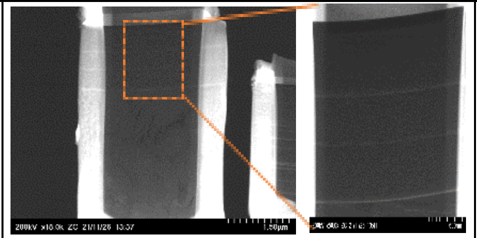
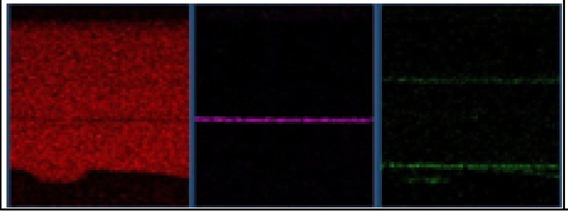


- SEM cross-section of a Purion HC dose Faraday aperture after implanting dedicated Low-Energy Boron (LEB) for 10 days.
- The film is 10 to 20µm thick and almost pure boron (not a boron-carbide compound)

Metrology of Films on Faraday Graphite Liners – TEM, EELS

To identify the origin of these particles, we analyzed films on surfaces in the near-wafer environment.

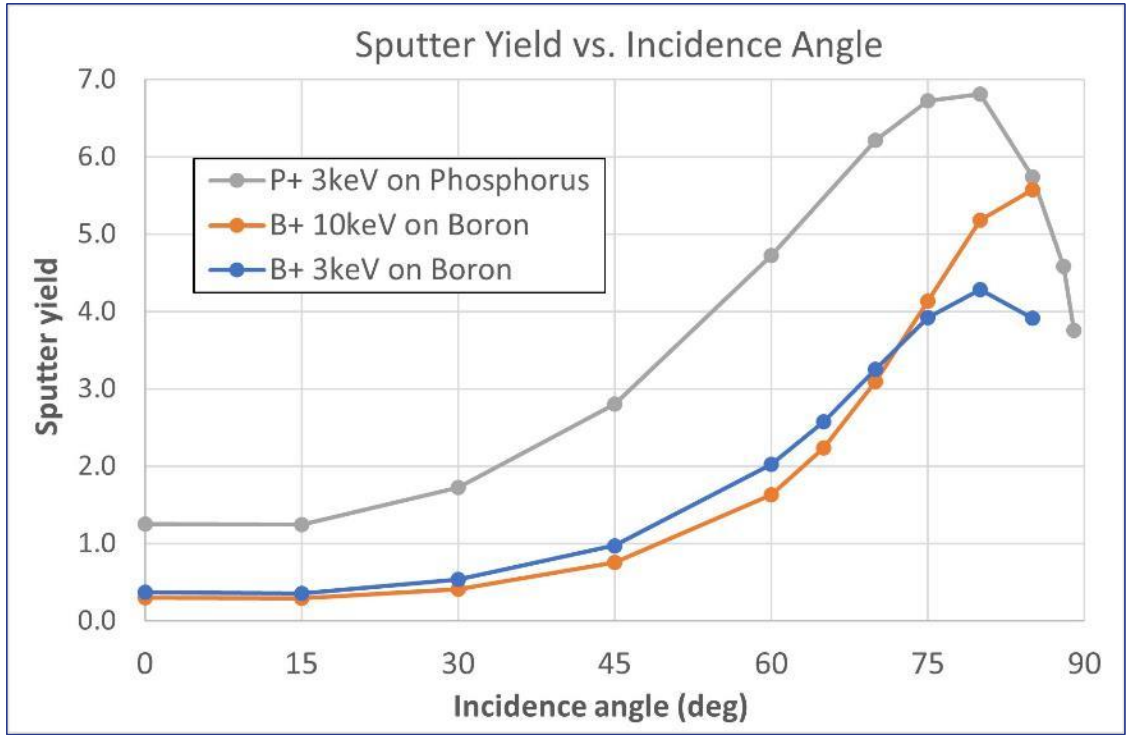


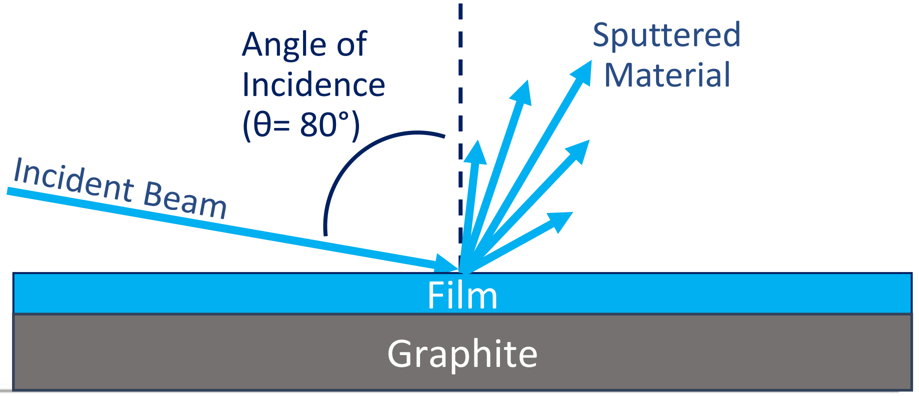
Part	Image	TEM	EELS Map	Species
Profiler Side			O K Series, Si K Series, As K Series 	Si, O, As
Profiler Front			B K Series, Ar K Series, As K Series 	B, As, Ar
Dose Side			O K Series, Si K Series, As K Series 	Si, O, As
Dose Front			B K Series, Ar K Series, As K Series 	B, As, Ar

Species and relative concentrations of films normal to the beam match those of large particles on the wafer

Sputtering of Films

- Sputtering depends on incoming atomic species, target material, energy, and incident angle
- Sputter yield S = number of atoms removed from surface per incident ion
  - An incoming beam with S > 1 can remove more material than it adds
- Sputter yield Monte Carlo simulations conducted using SRIM software
  - B+ 3keV on boron, sputter yield < 1 @ normal incidence (0°)
  - P+ 3keV on phosphorus, S > 1 for all angles

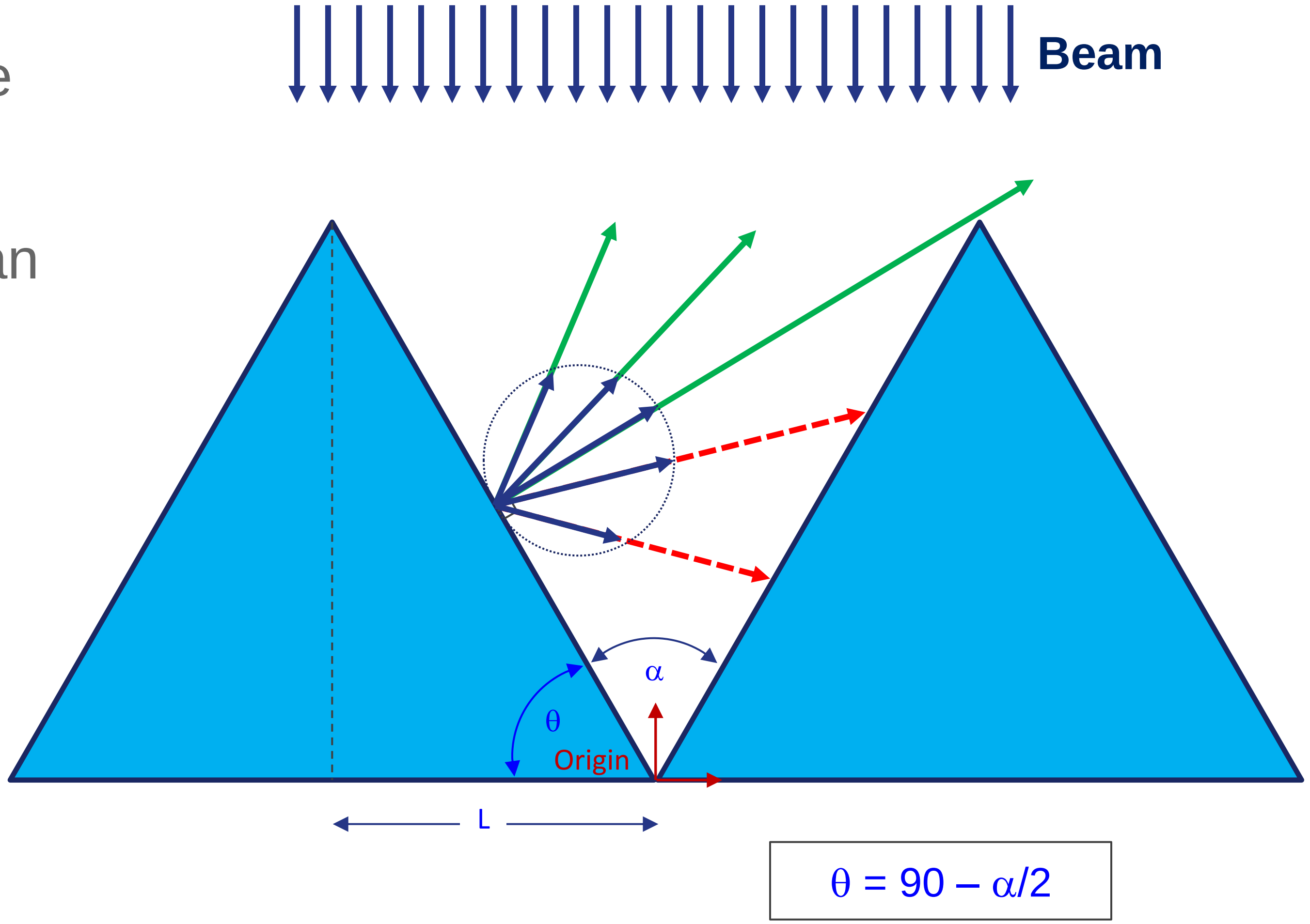




Sputtering can keep surfaces clean by keeping films from growing

High Angle Serration Graphite – Sputtering and Redeposition Model

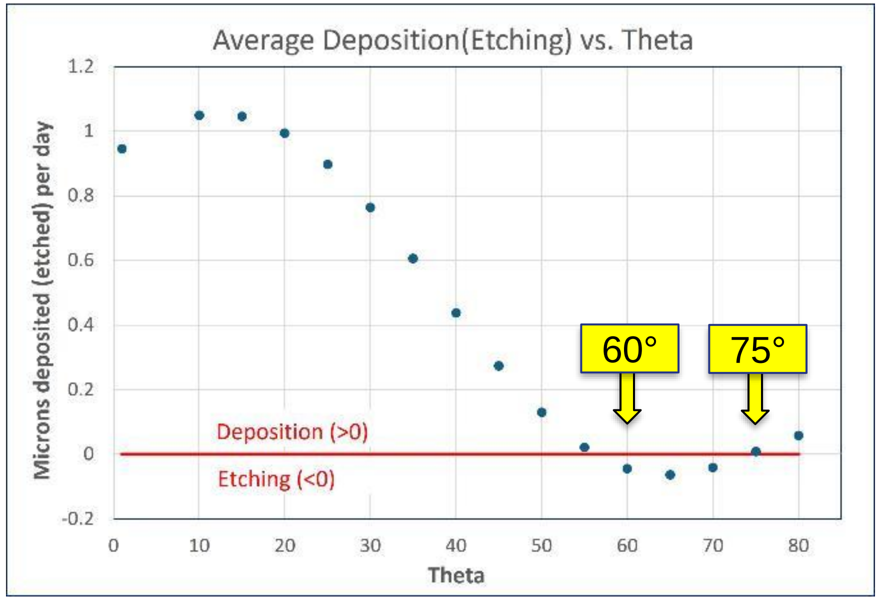
- Some sputtered material will be completely removed, but some will be redeposited onto the other side of the structure
- Steep features sputter more effectively, but steep walls mean more redeposition
- The sputter plume can be modelled in a few different ways
  1. Equally distributed through a range of angles
  2. A cosine function (traditional)
  3. More complicated differential angular yield from the literature

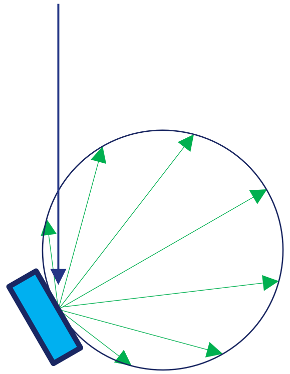


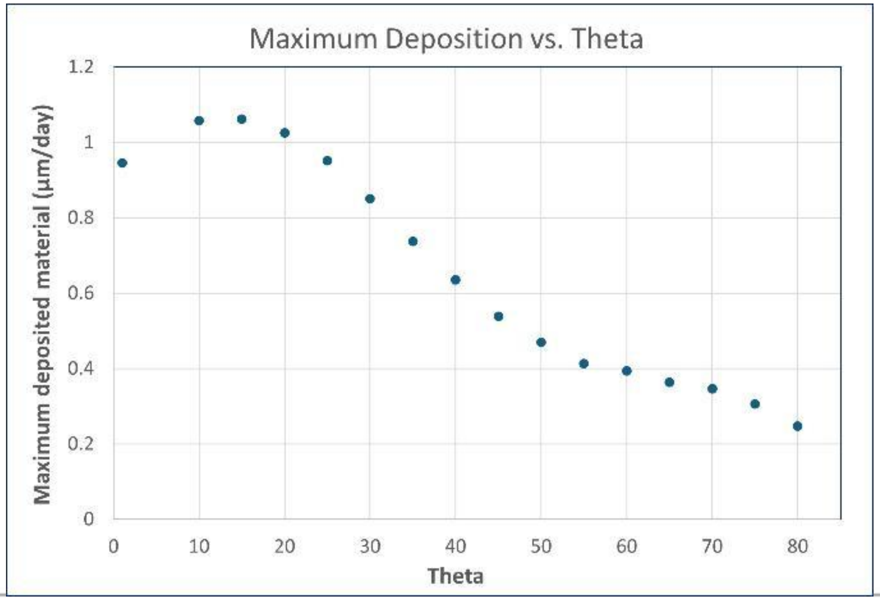
$\theta = 90 - \alpha/2$

Average and Maximum Deposition vs. Serration Angle

- Modelling the sputter plume to be a cosine distribution predicts average deposition is minimized @ θ = 65°
- However, the model predicts that some material will still deposit at the bottom of the serration valleys.
- The maximum deposition decreases with higher serration angle
    - This suggests testing parts with serrations > 65°
- We tested parts with θ = 60° and 75° serrations to increase etching of boron films while limiting the etching of graphite

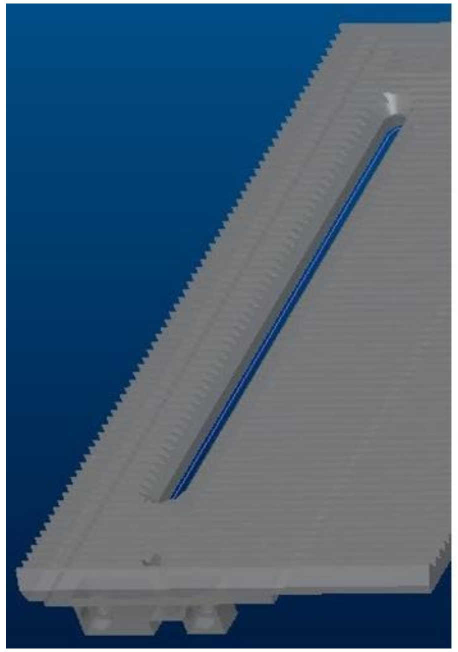


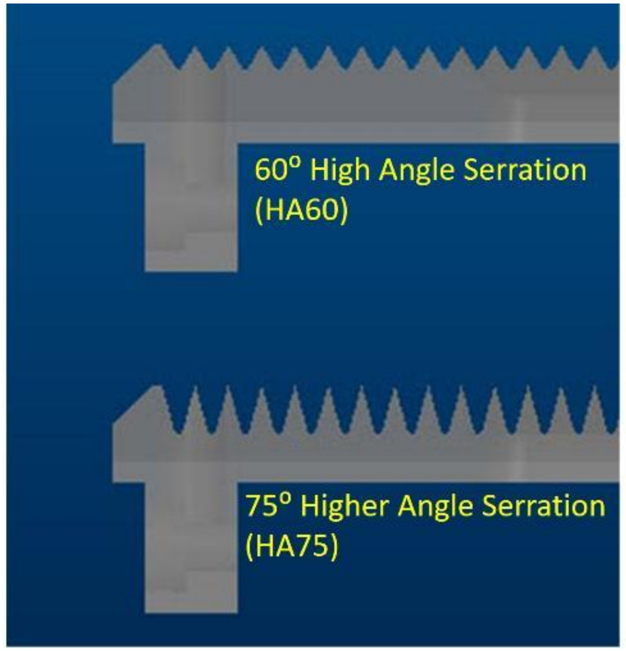


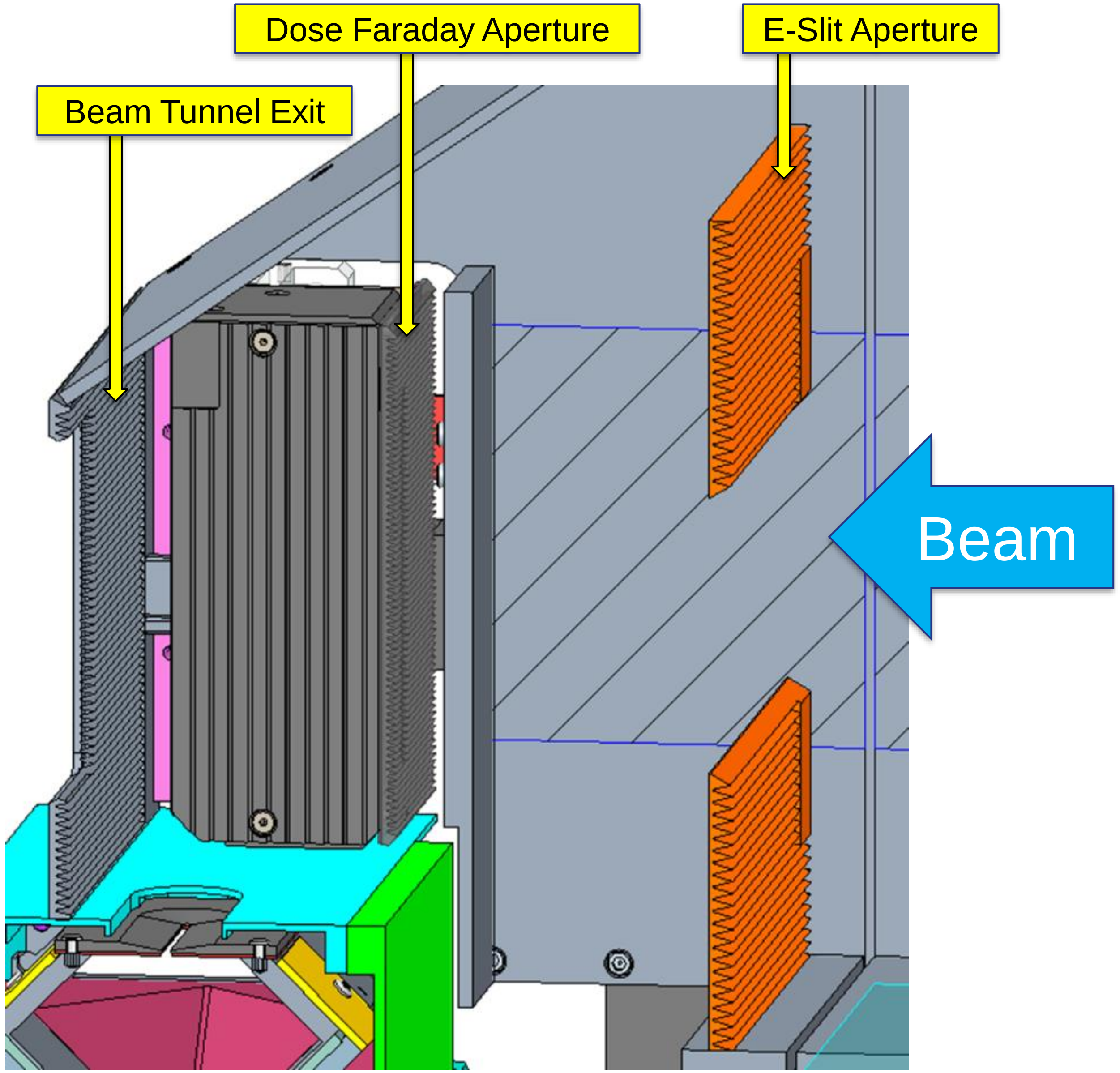


High Angle Serrated Graphite Liners

- Components were tested with both high angle (θ=60°) and higher angle (θ=75°) serrations:
  - Beam Tunnel E-Slit Aperture
  - Dose Faraday Apertures
  - Beam Tunnel Exit Aperture

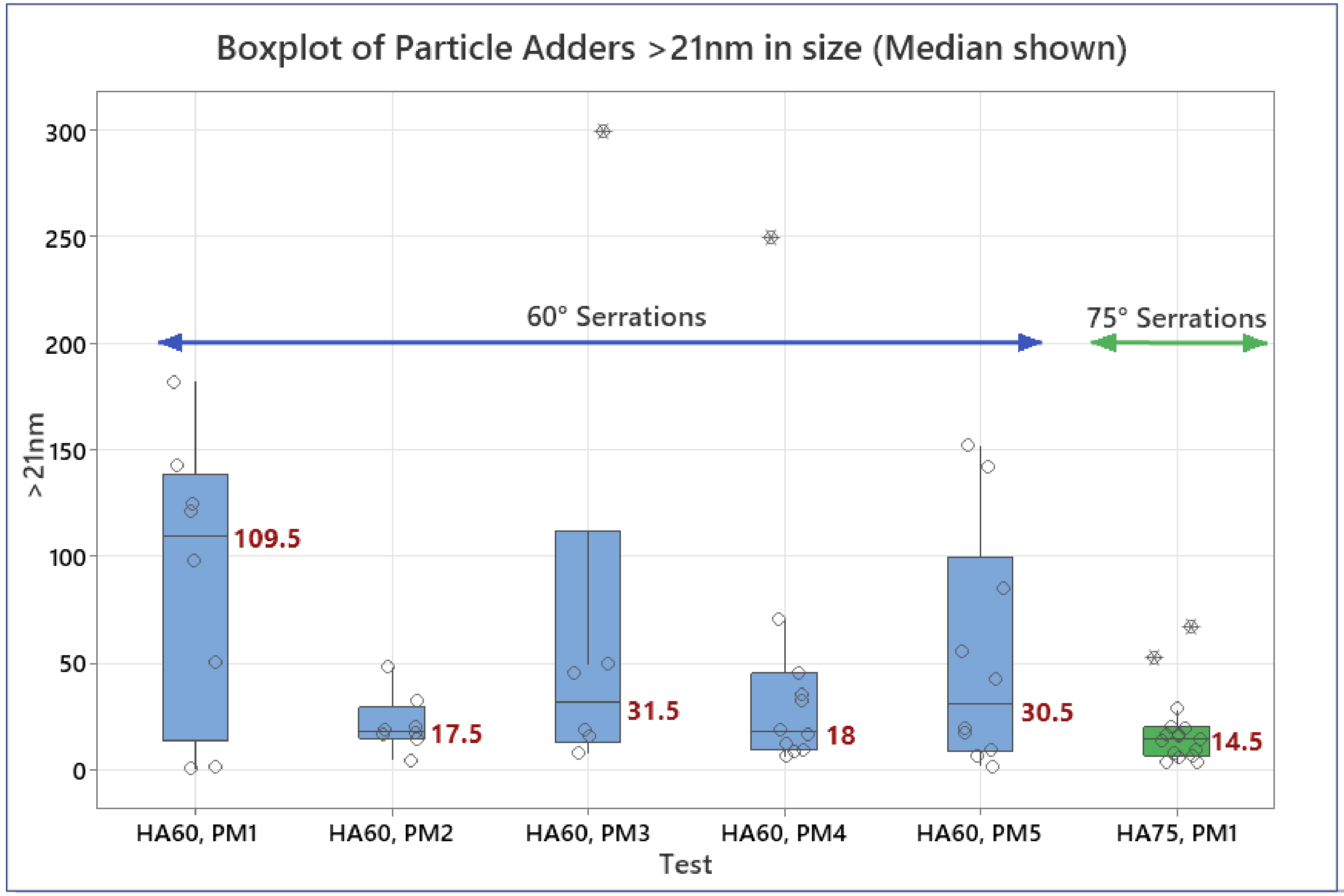


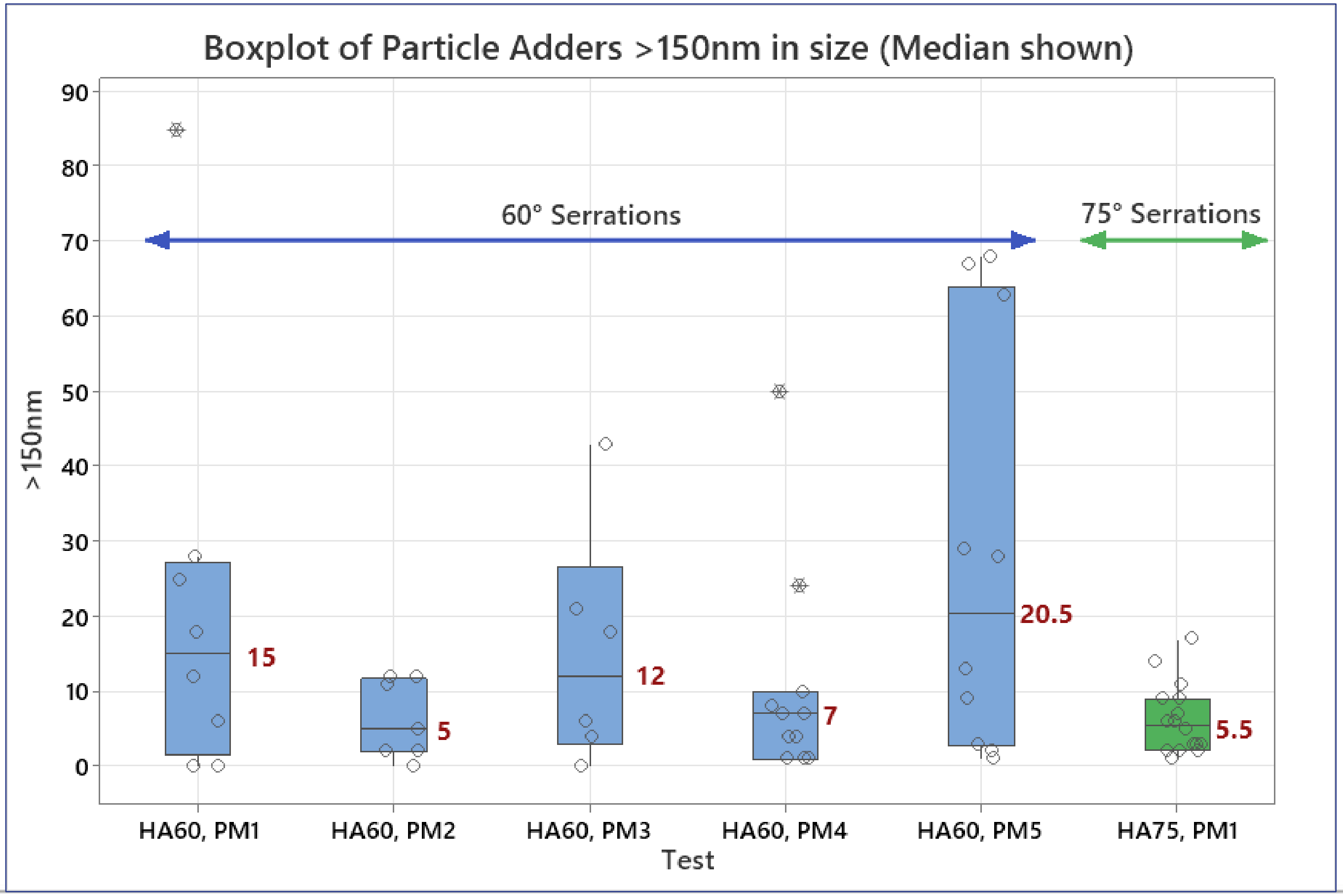




Particle Field Data with 60° & 75° Angle Serration Graphite

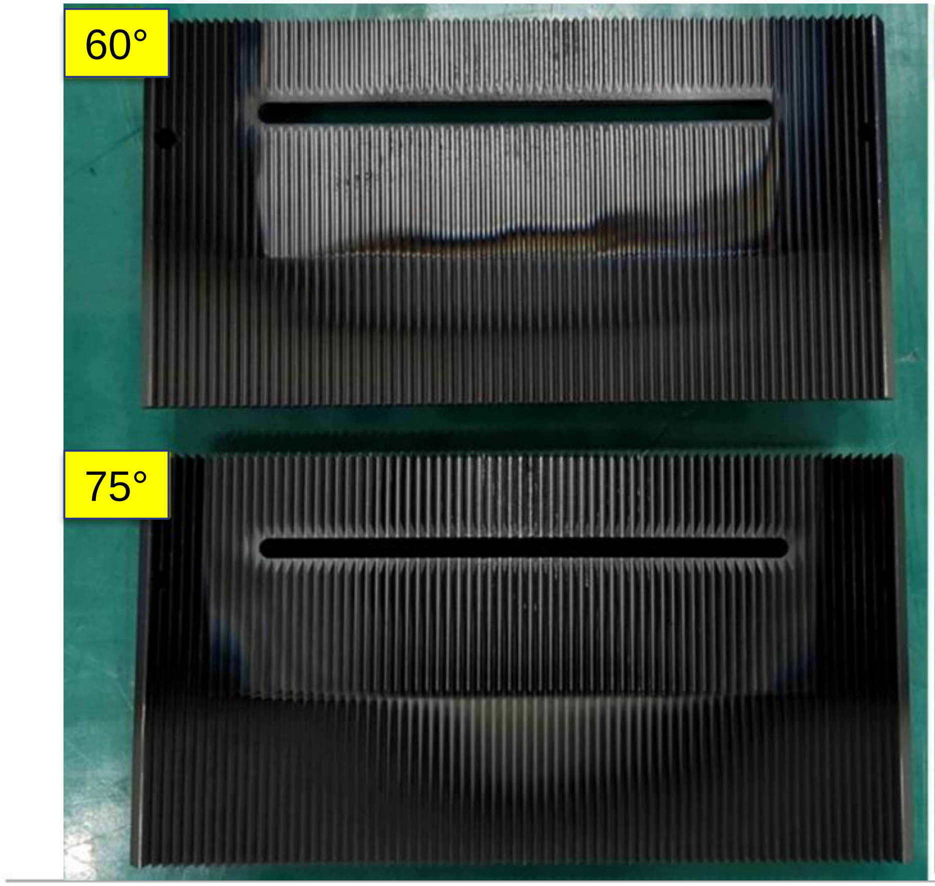
- Box plots of particles measured during regular intervals between 17 and 21 days. Graphite was replaced after each PM.
- The first 5 sets had the 60° (HA60) serration graphite. Then the 60° graphite was replaced with 75° (HA75) graphite.
- Both small (> 21nm) and large (> 150nm) particles improved and remained 100% within compliance, so the 75° graphite PM period was extended to 36 days.

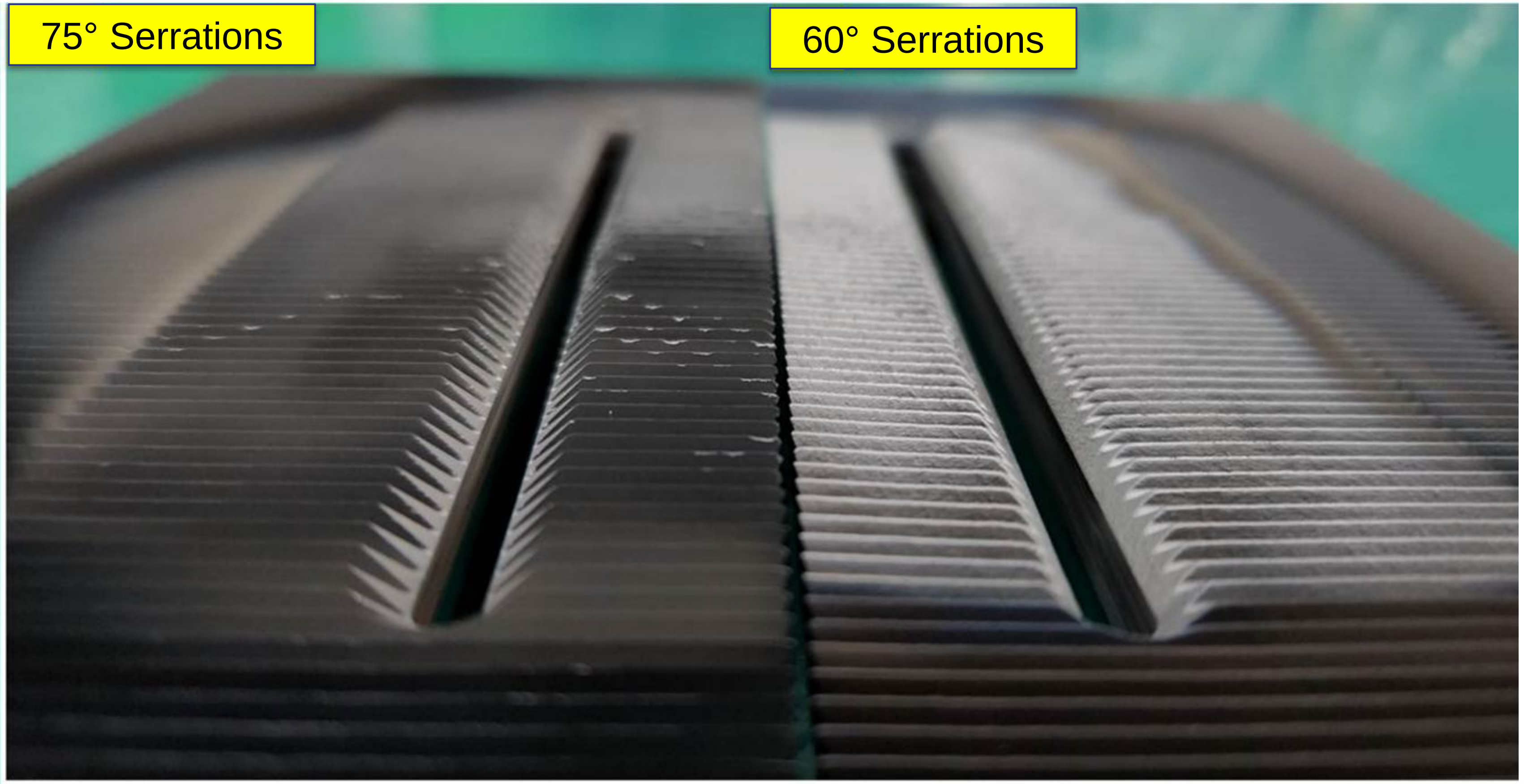




Field Results of both 60° and 75° Angle Serration Graphite

- High Angle Serration (60°) graphite had significant deposition after ~20 days
- The Higher Angle Serration (75°) graphite remained clean after ~80 days





Summary

- When implanting dedicated low-energy boron, boron films develop on surfaces that see direct beam-strike
- High angle serrations allow the beam to sputter away films and keep surfaces clean
- Slowing the rate of film buildup reduces delamination
  - Reduces particles which improves yield
  - Extends the time between preventative maintenance which increases uptime
  - Reduces cost of ownership