Flat and Cross-Sectional Milling with the New Hitachi IM4000II Ion Mill

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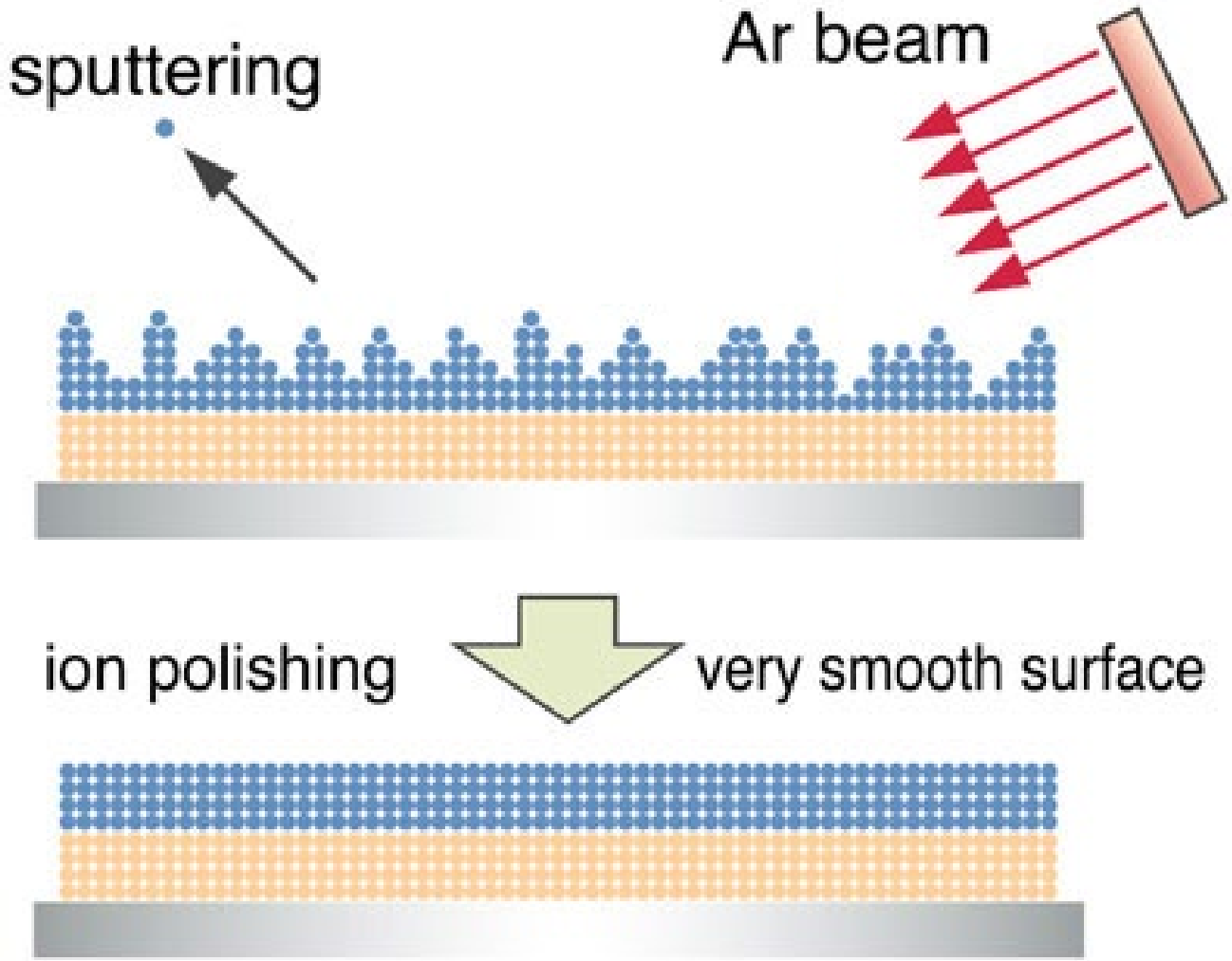
Northwestern
EXPLORING INNER SPACE

Ion Milling
What is it?

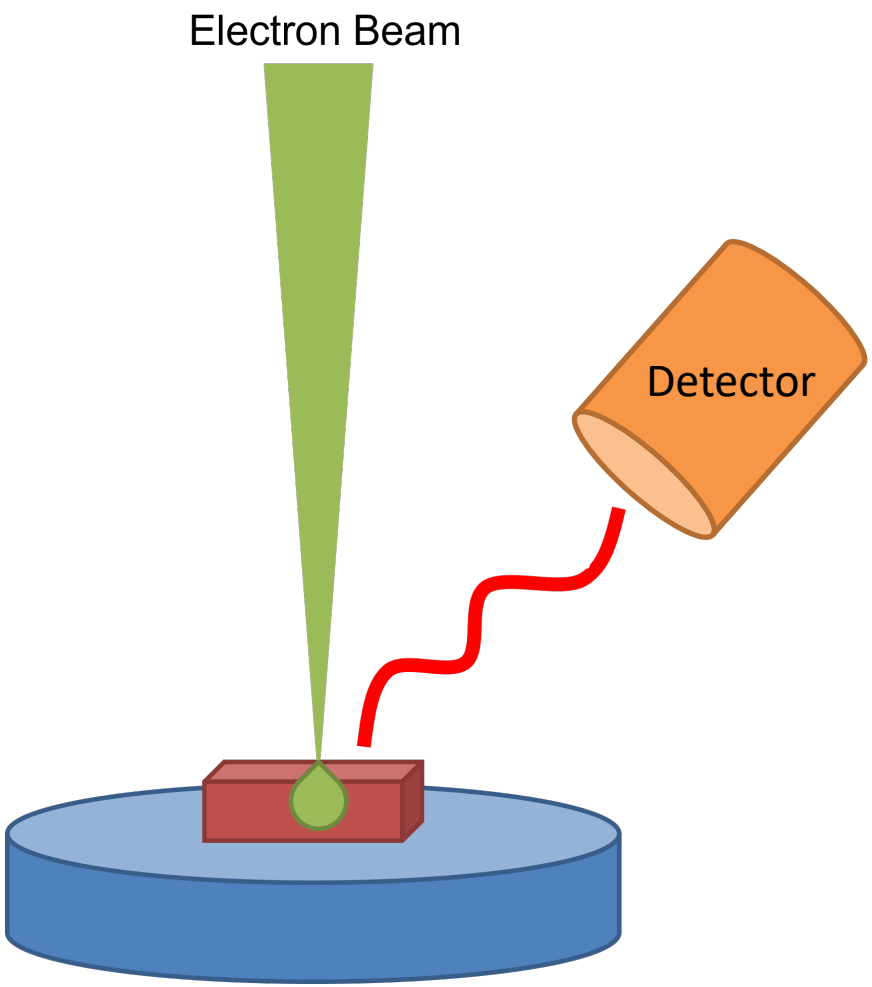
- **Ion milling**: a general term for sample preparation methods that involve removing sample material by bombarding the surface with ions, in a process called **sputtering**.

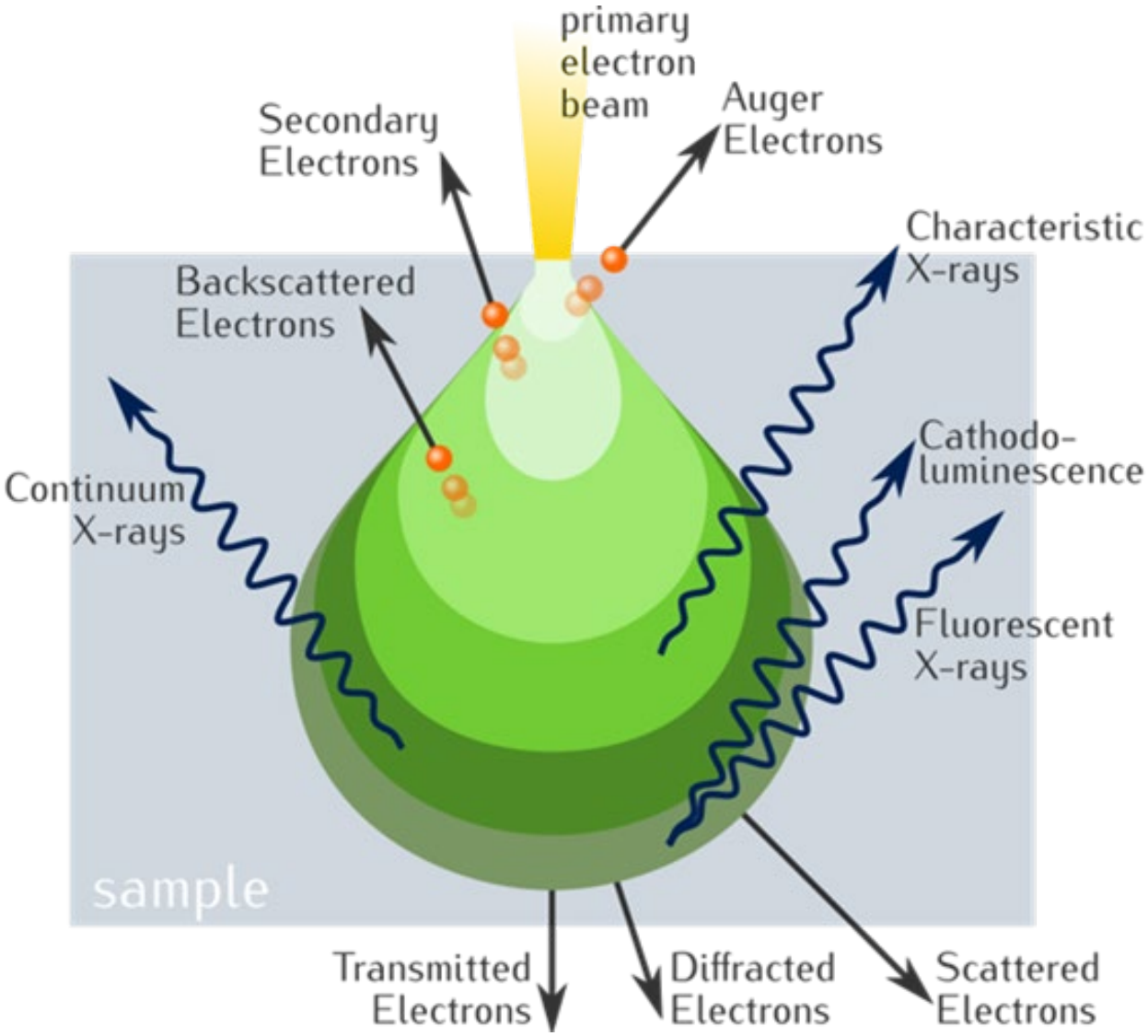
- An **ion mill** typically refers to instruments that use a **broad** beam of **Argon** ions to gently smooth sample surfaces with minimal defects or artifacts compared to other techniques. Broad Ion Beam (BIB)

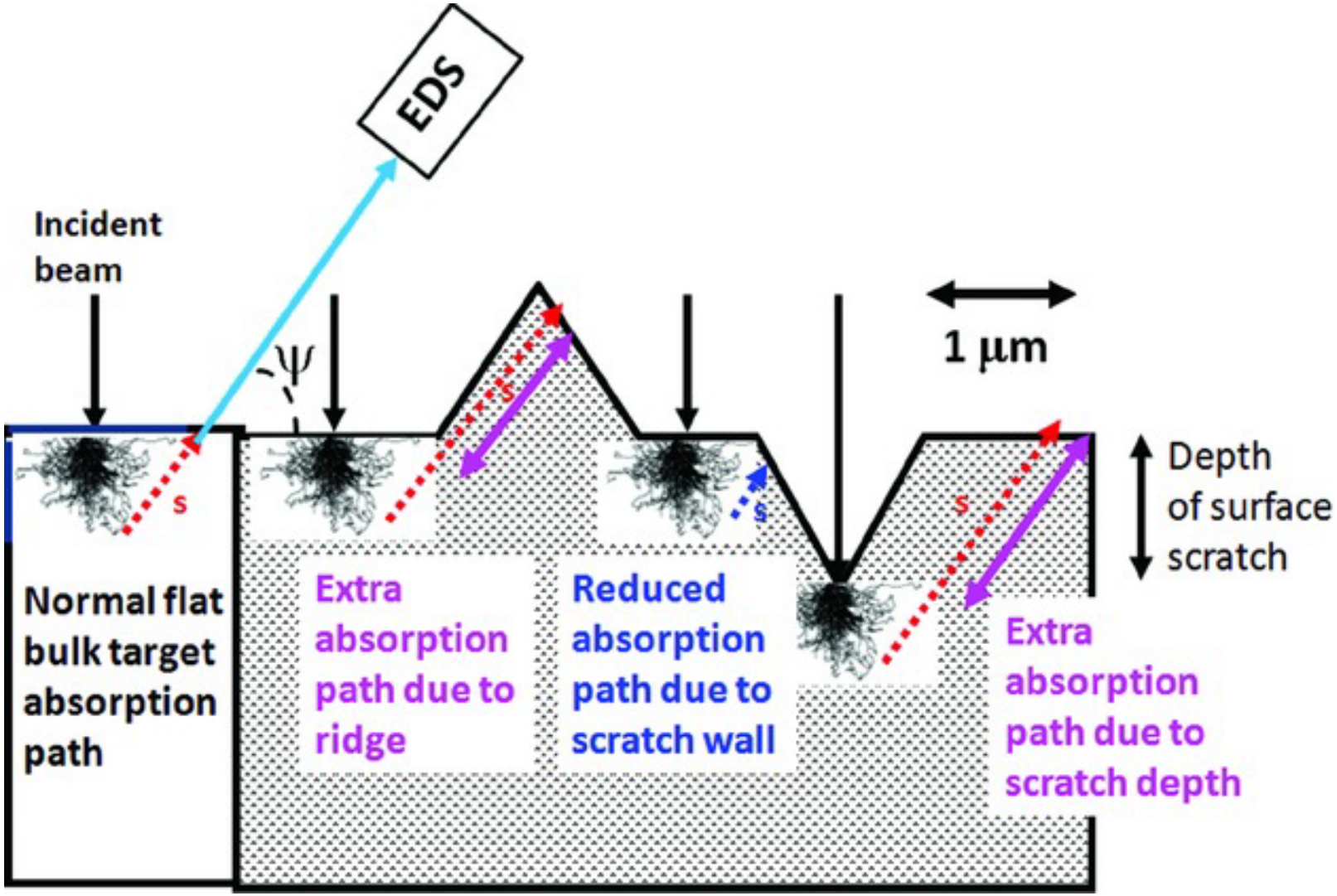
Hitachi IM4000II



Img: Japan Atomic Energy Research Institute

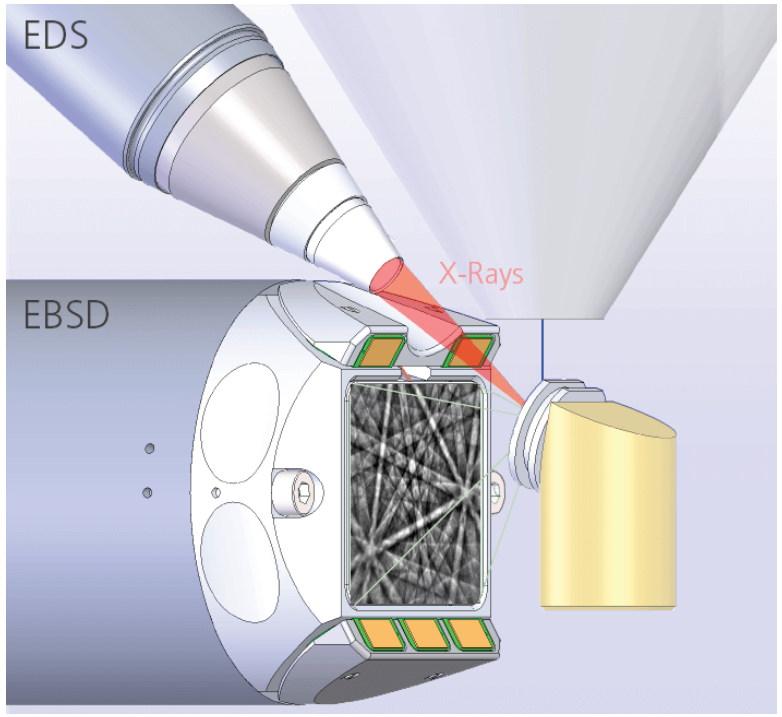

Electron Beam
Detector


primary electron beam
Secondary Electrons
Auger Electrons
Characteristic X-rays
Backscattered Electrons
Cathodo-luminescence
Continuum X-rays
Fluorescent X-rays
sample
Transmitted Electrons
Diffracted Electrons
Scattered Electrons



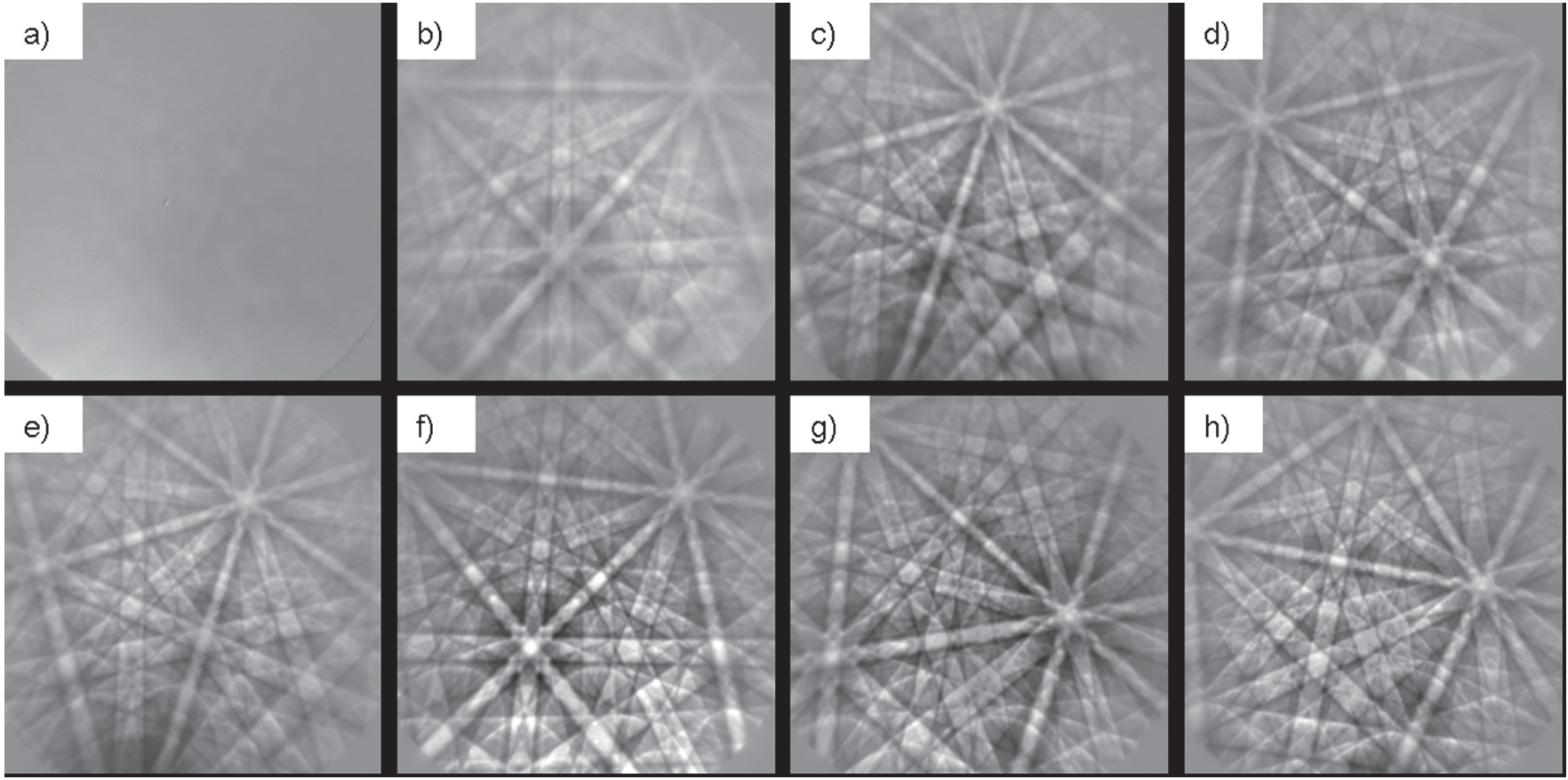
Newbury and Ritchie 2012

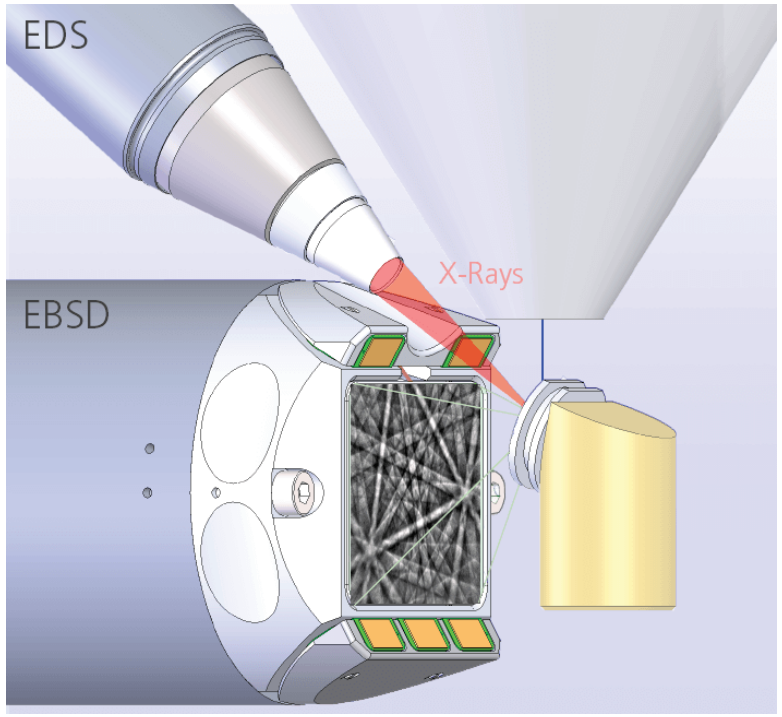
EBSD Pattern Quality vs Surface Quality



Oxford Instruments

Nowell et al. 2005





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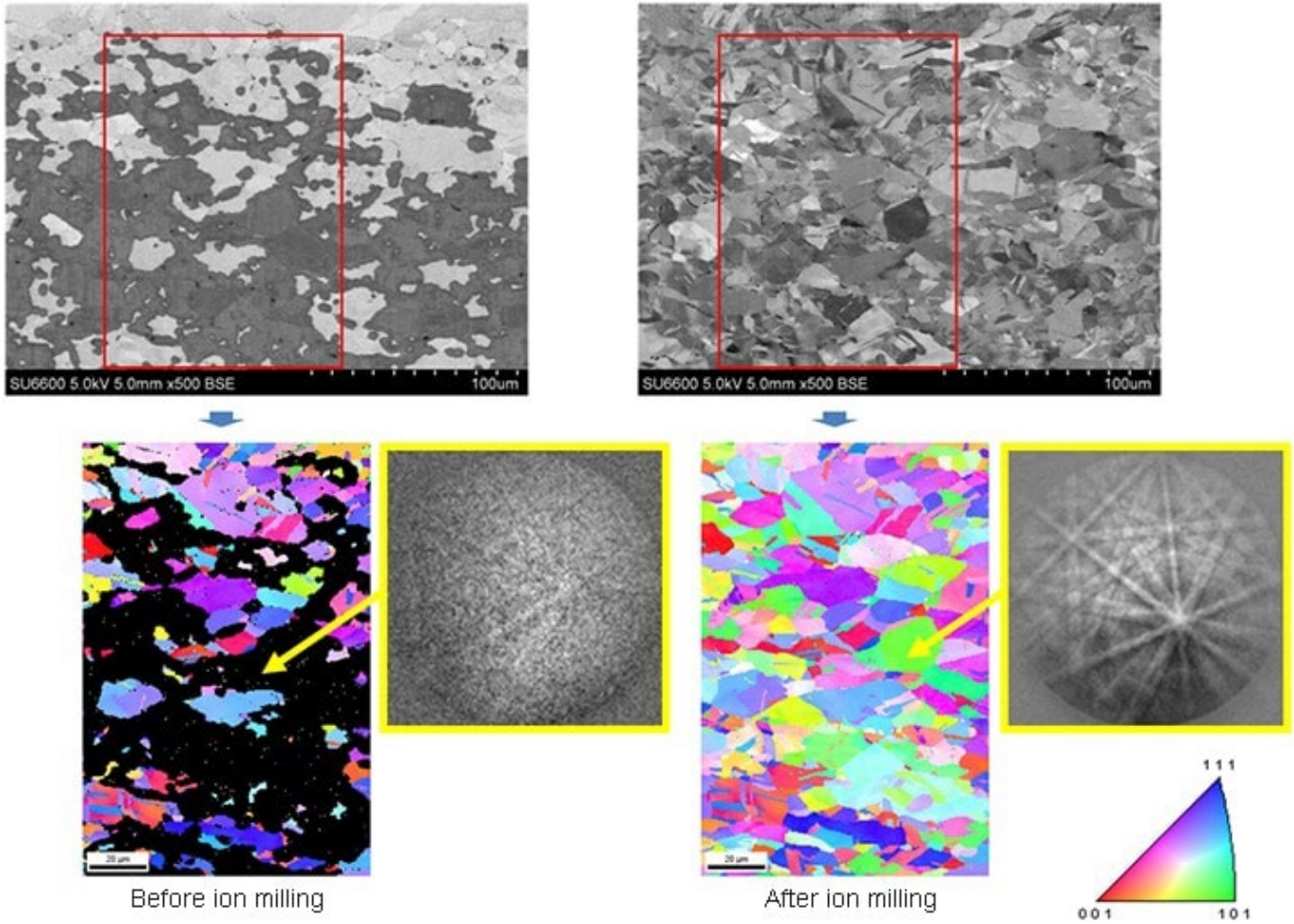

Before ion milling

After ion milling

Hitachi High Tech

Sample preparation methods

- Cutting/Slicing
- Cleaving
- Grinding / Polishing
- Microtomy
- Focused Ion Beam (FIB)
- Broad Ion Beam (BIB)

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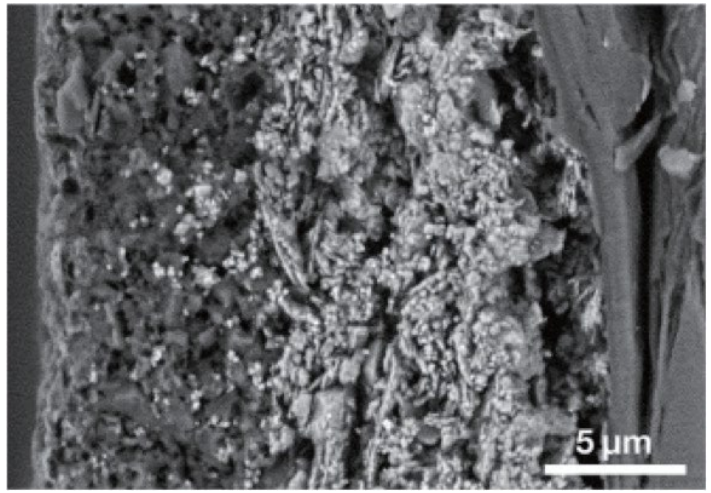
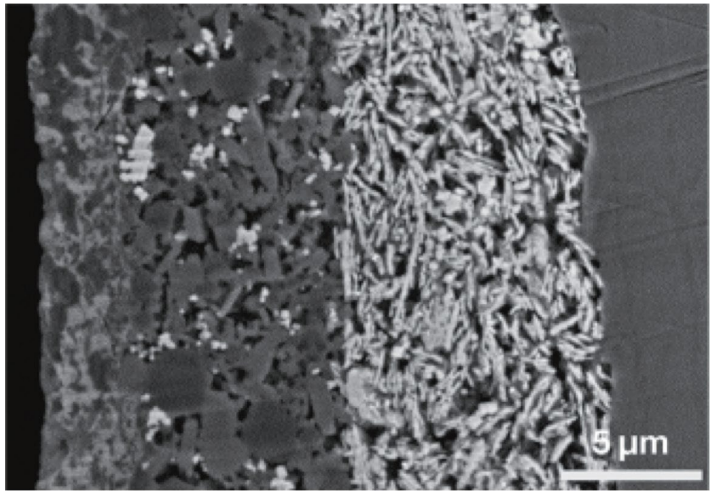


Razor blade



Ion Mill

Hitachi High Tech

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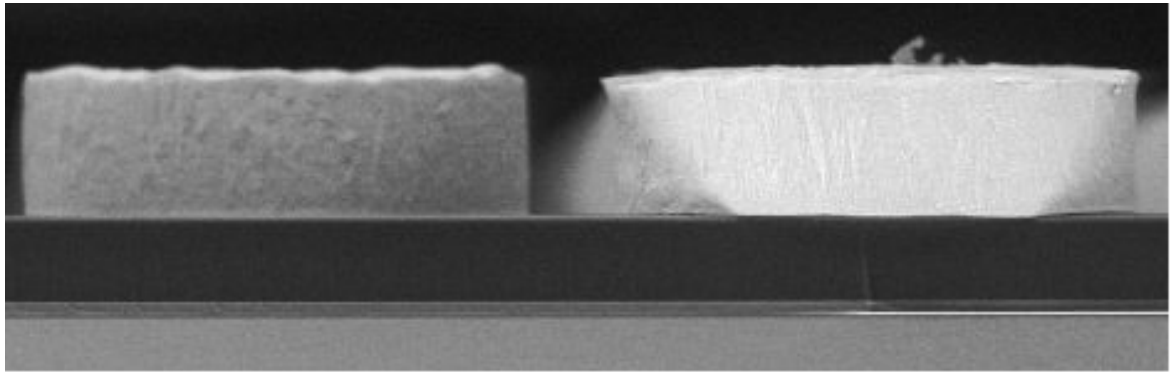
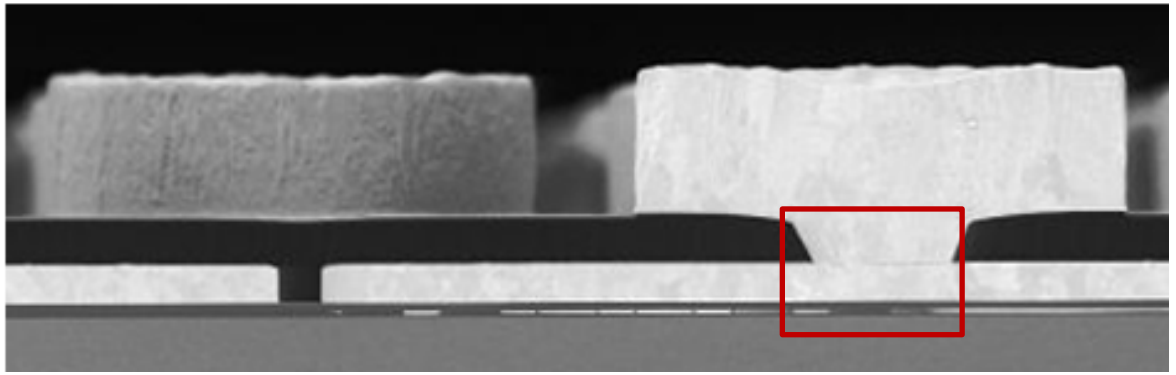
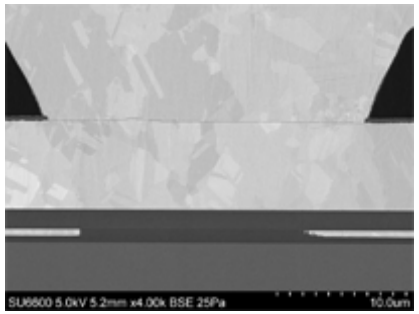


Cleaved



Ion Mill

https://www.latticegear.com



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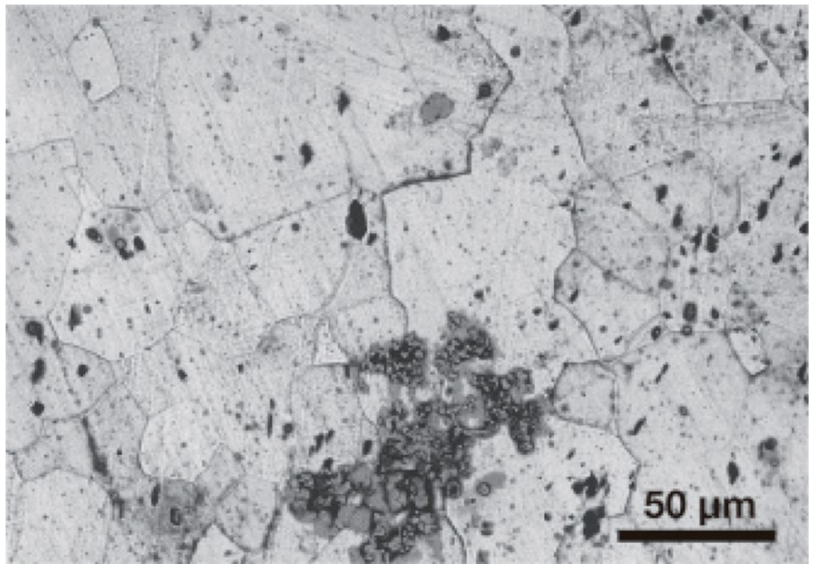

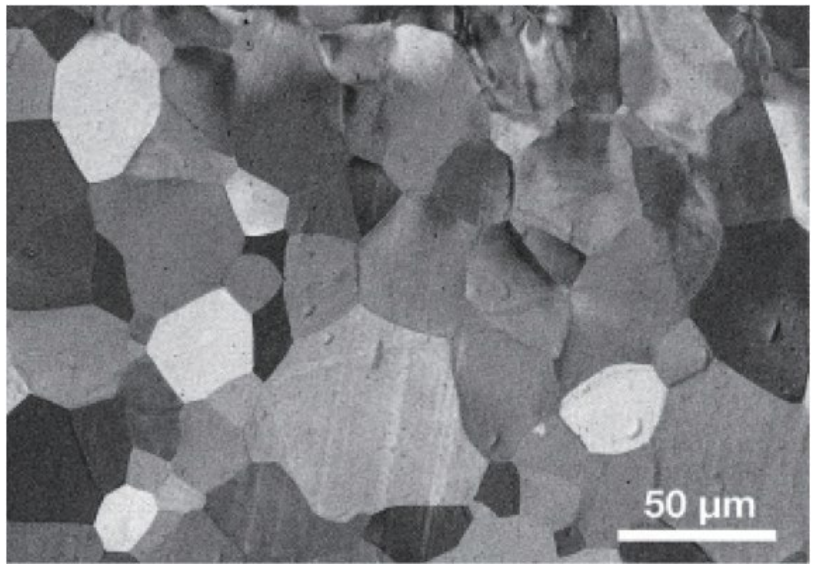

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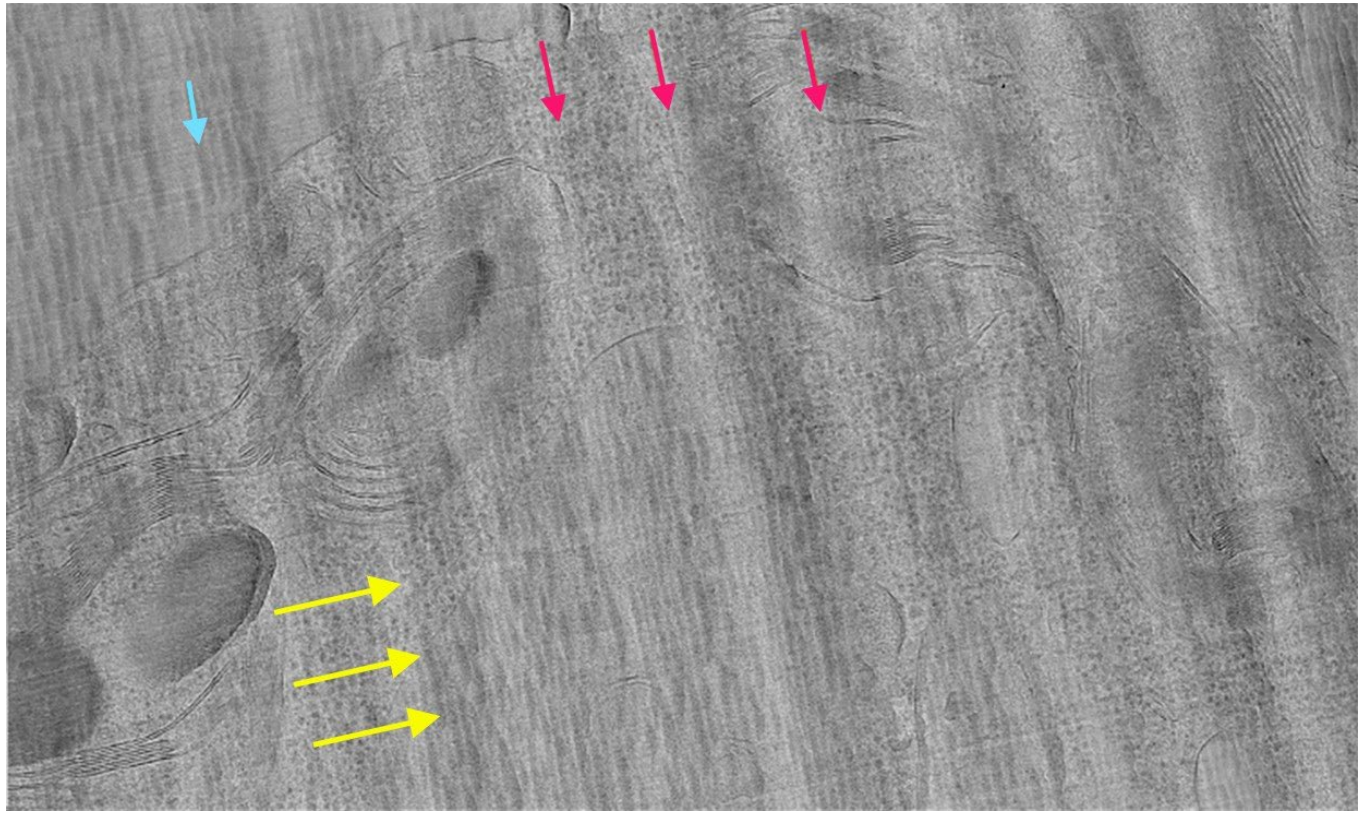

Microscopy Australia, Myscope.Training

Sample preparation methods

- Cutting/Slicing
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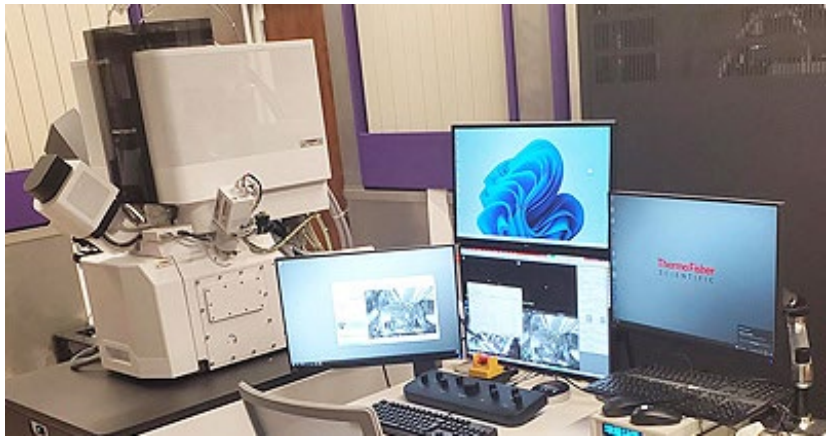
- **Focused Ion Beam (FIB)**
- **Broad Ion Beam (BIB)**

Sample preparation methods

Focused Ion Beam (FIB)



Helios 5 Hydra CX PFIB

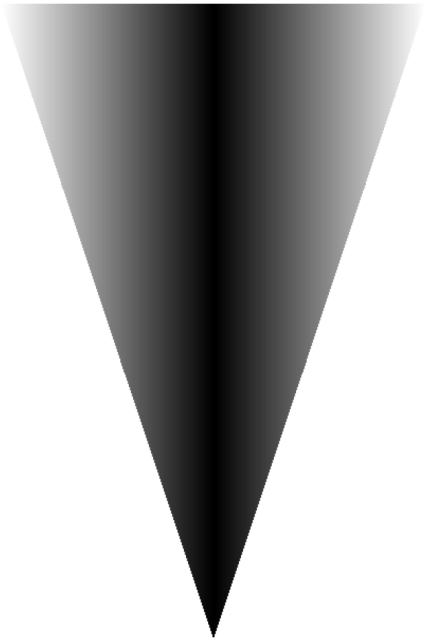
Fischione 1040 NanoMill

Broad Ion Beam (BIB)

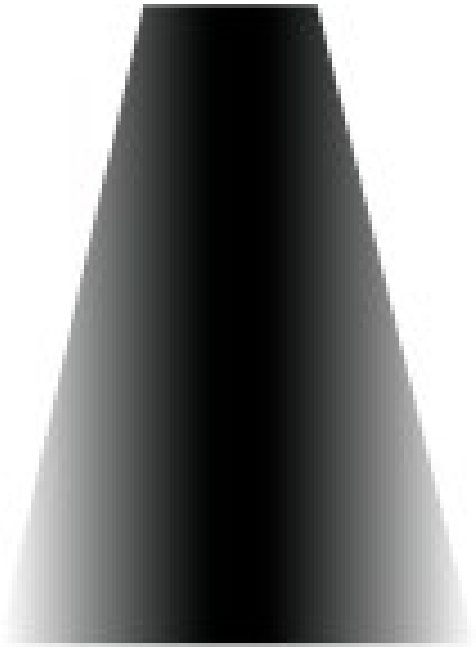
Hitachi IM4000II

Sample preparation methods

Focused Ion Beam (FIB)



Broad Ion Beam (BIB)



Sample preparation methods

	Focused Ion Beam (FIB)	Broad Ion Beam (BIB)
Spot sizes	nm-regime, converged beam	mm regime, broad, near parallel beam.
Current	lower current/ higher current density	higher current, lower current density
Acc. Voltage	Usually 30kV, lower for cleaning	Usually < 10kV

Sample preparation methods

Focused Ion Beam (FIB)

- High site specificity
- Relatively slow milling rates
- Implantation damage, amorphization
  - low kV clean up important! (Nanomill)
  - Usually Ga, also Xe, O, N, and Ar options and more.
- **Great for:**
  - TEM liftouts
  - Atom probe prep
  - nanomachining,
  - 3D tomography/EBSD
  - Cross-sections (tens of μm^2, site specific)

Broad Ion Beam (BIB)

- Low site specificity.
- Relatively fast milling rates,
- Minimal damage
- Usually Ar ions, others less common.

- **Great for:**
  - Polishing for EDS/WDS/EBSD
  - Damage/contamination removal
  - Cross-sections (~10-20 mm^2)

Hybrid Milling in the Hitachi IM4000II

Cross-s

ng

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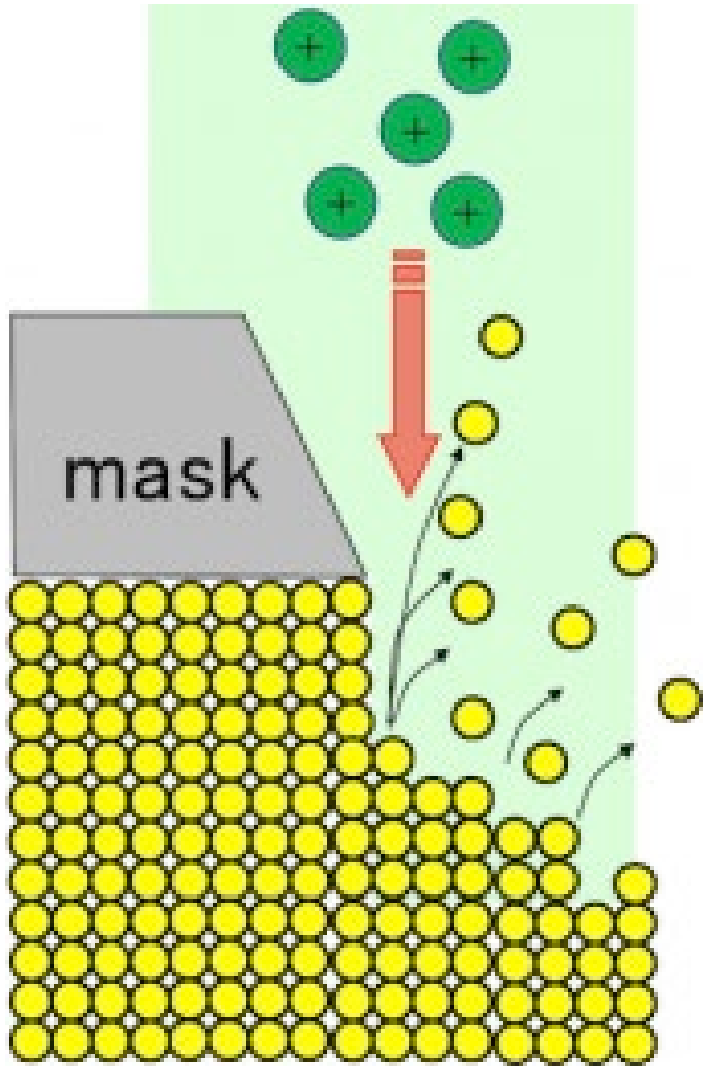
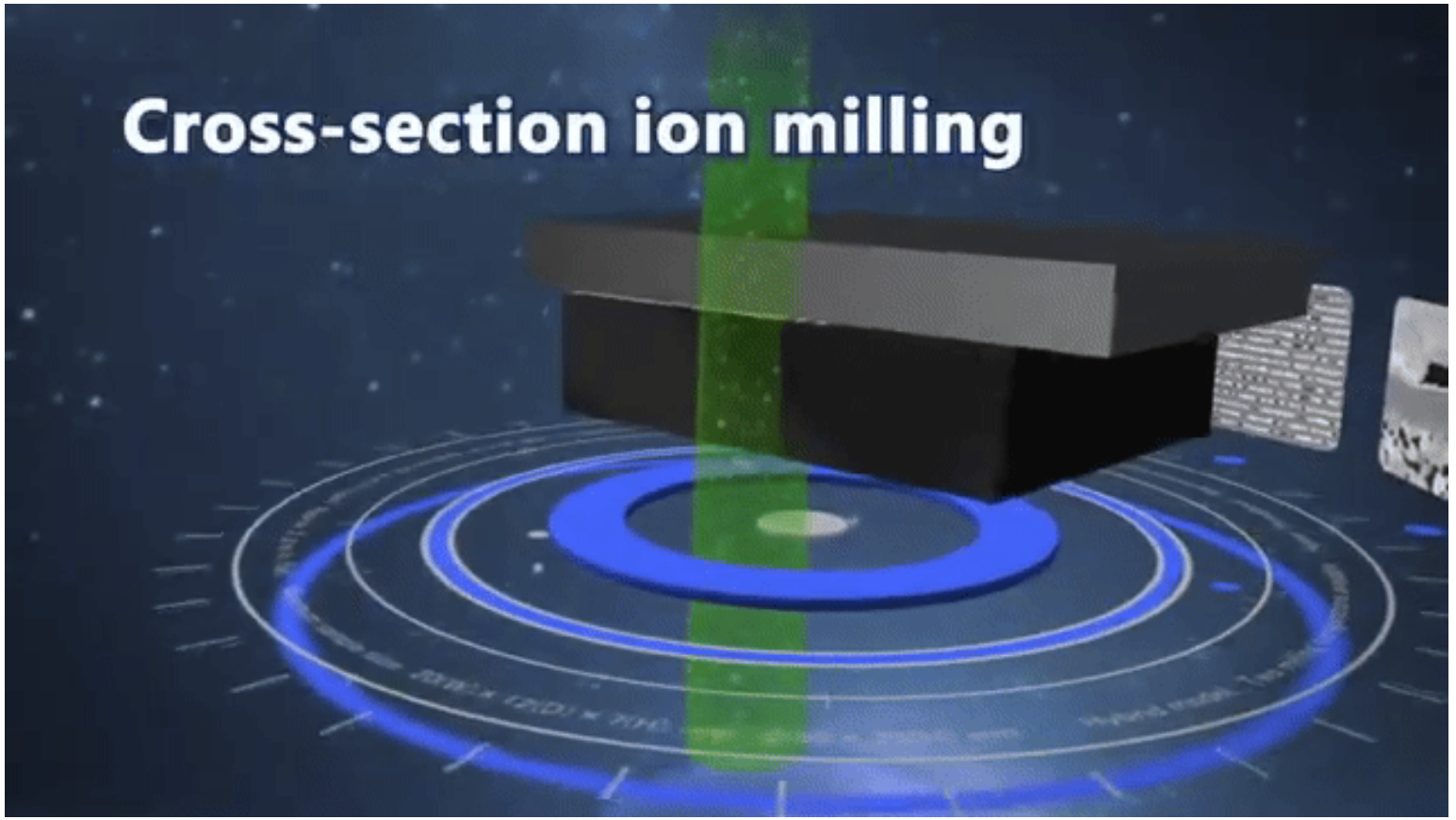
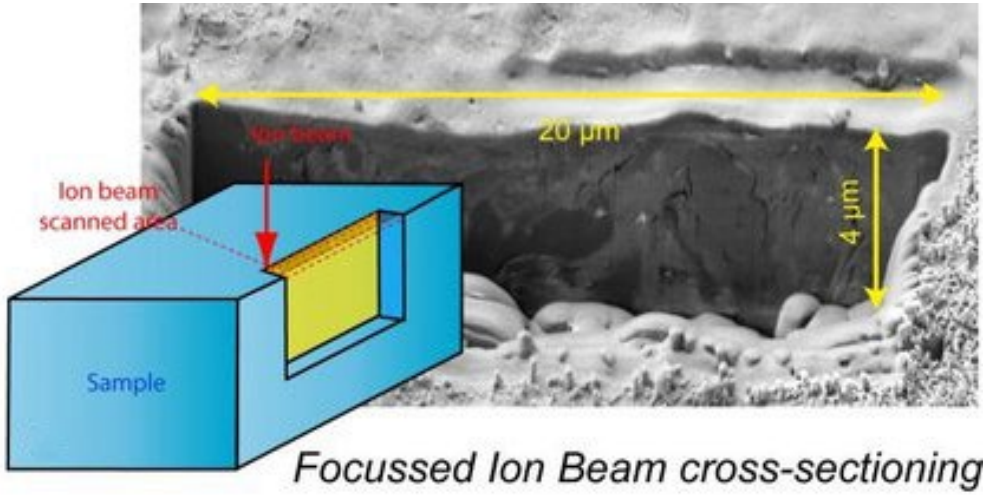




- ± 30 degree swing angle
- 500 µm/h or greater
- 20(W) × 12(D) × 7(H) mm

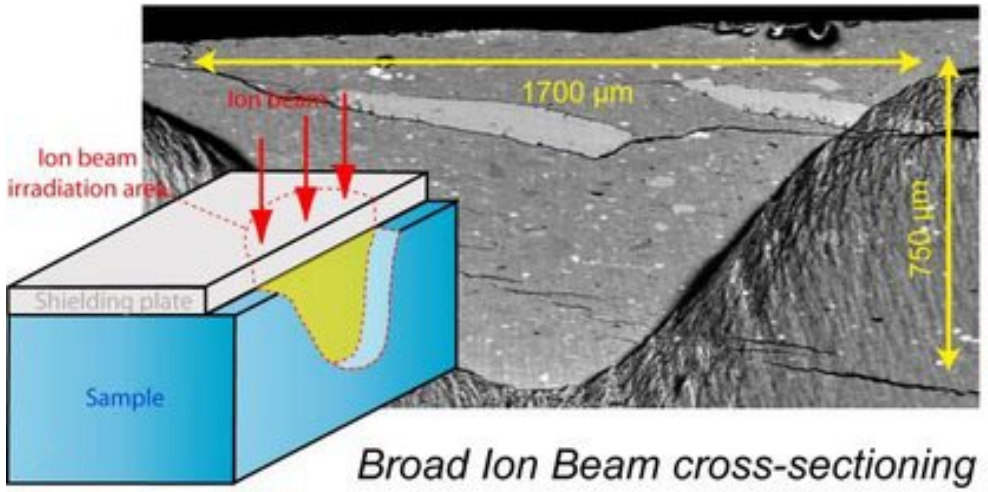
Cross Sections

Focused Ion Beam (FIB)



Focussed Ion Beam cross-sectioning

Broad Ion Beam (BIB)



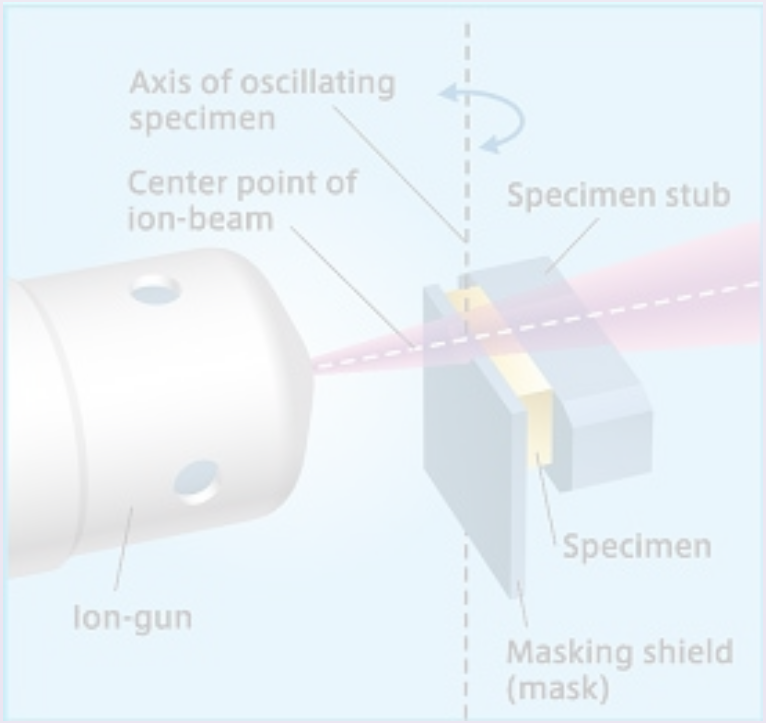
Broad Ion Beam cross-sectioning

Desbois et al 2010

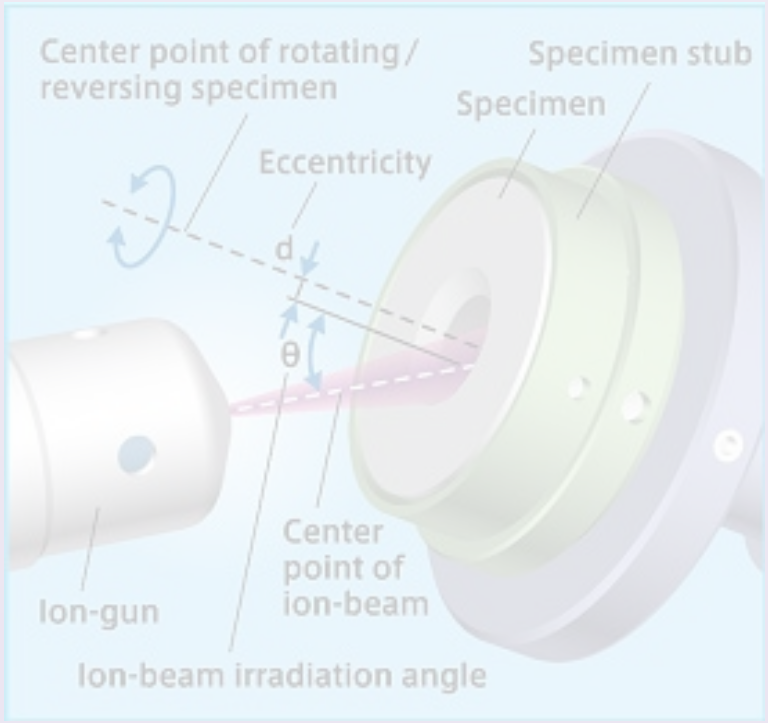
Notice the scale!

Hybrid Milling in the Hitachi IM4000II

Cross-section milling



Flat Milling



Flat Milling

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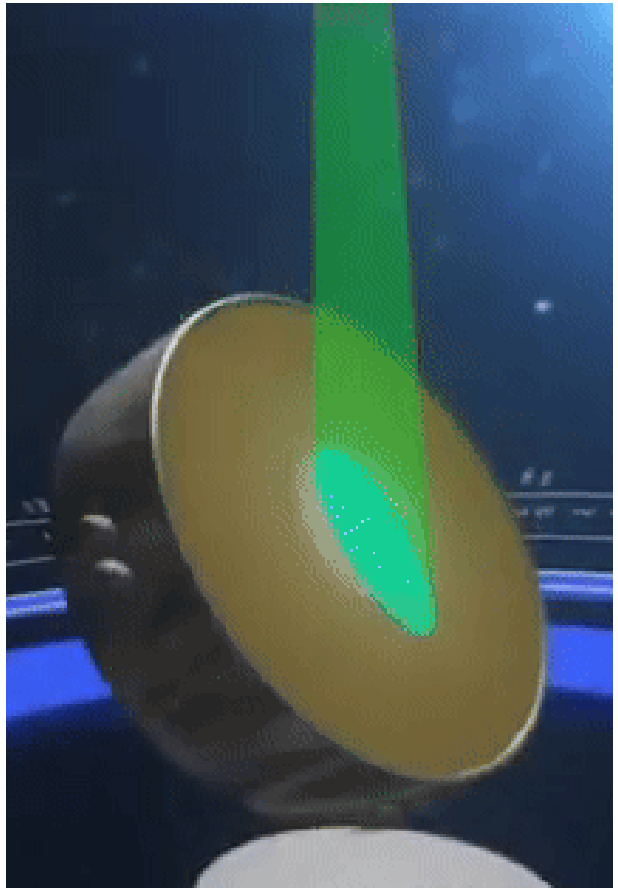
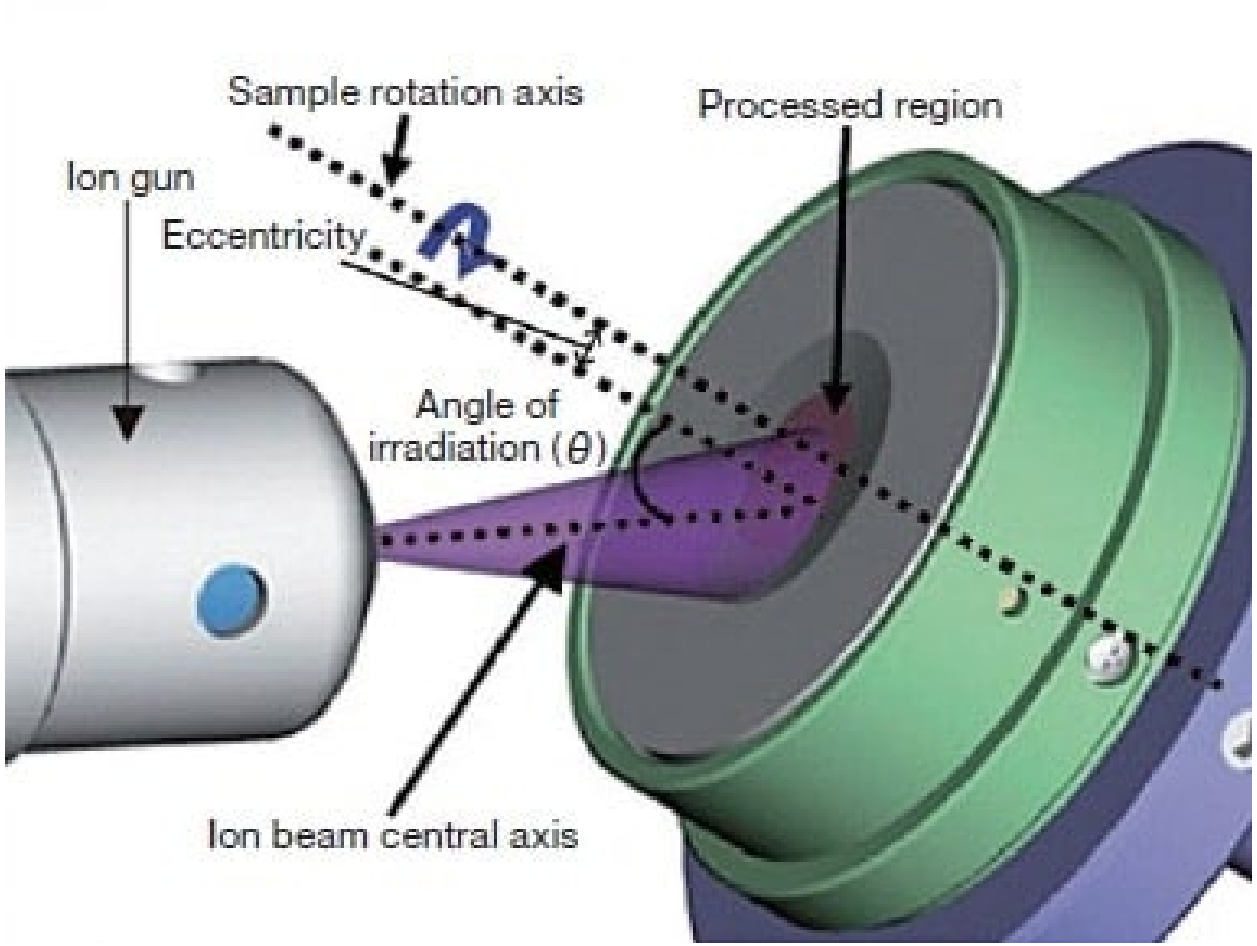
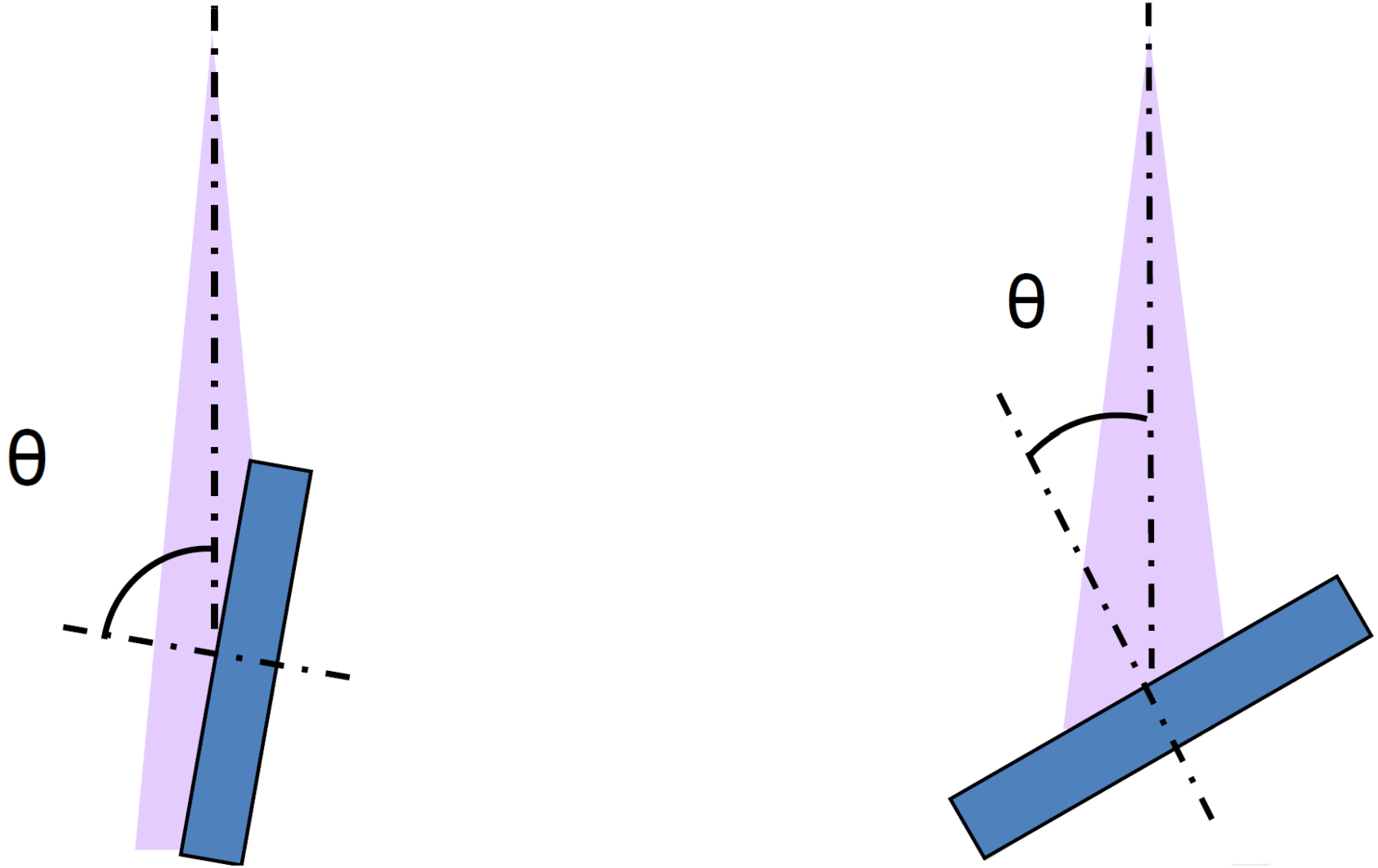


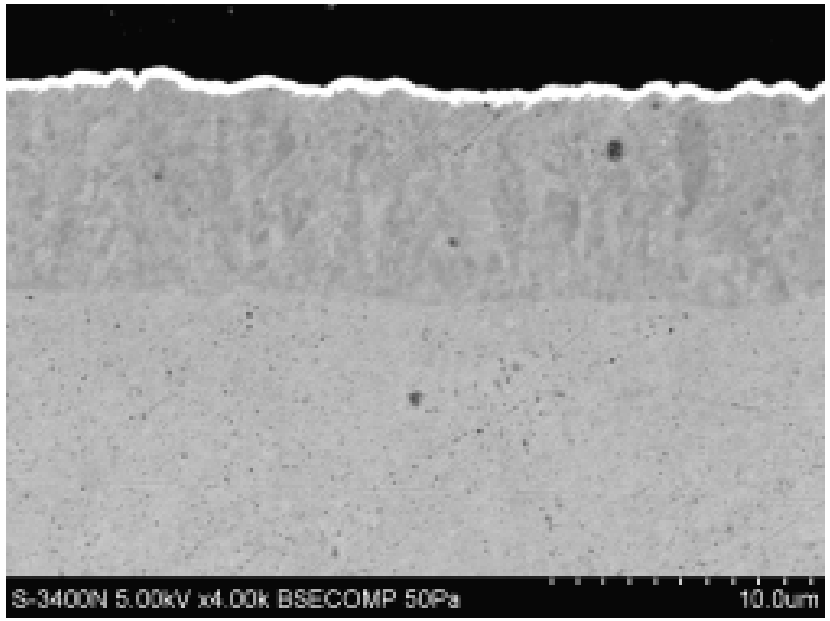


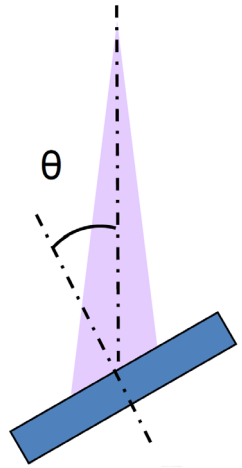
- 50 (W) x 25 (H) specimens
- 32 mm max diameter

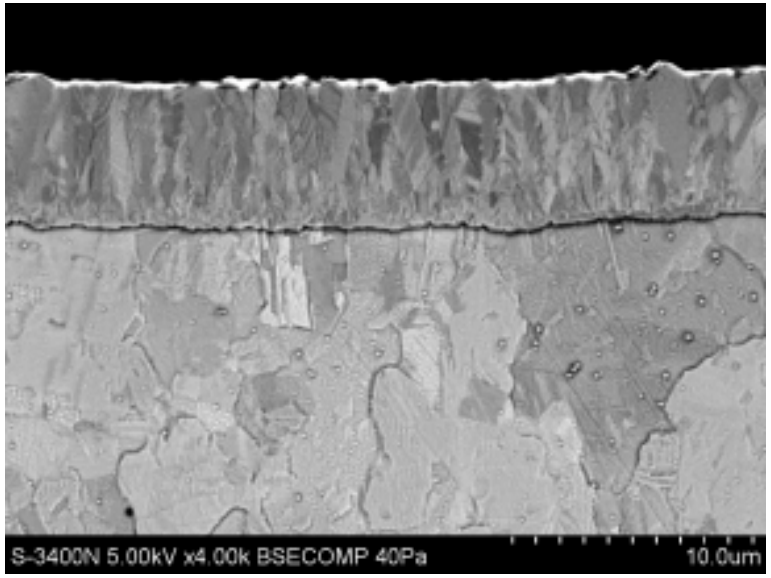
Flat/Relief Milling

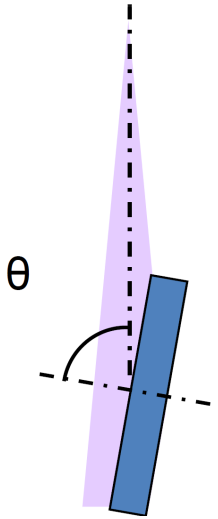


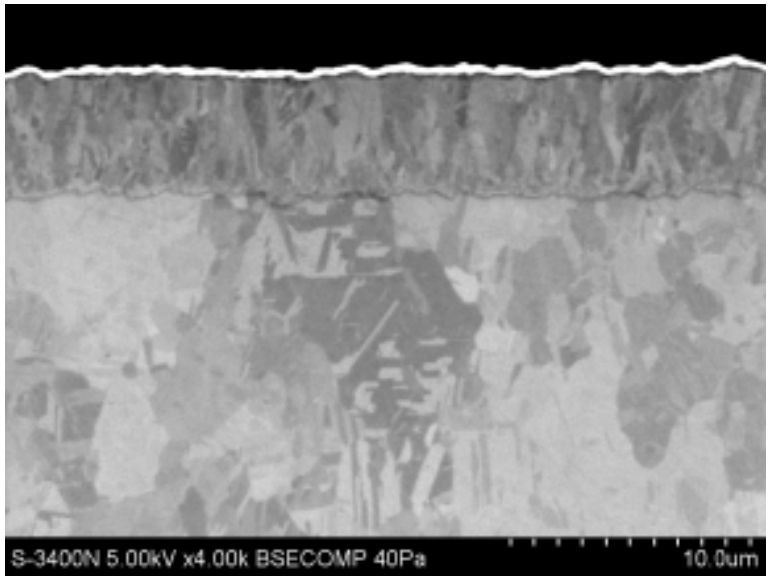
Flat/Relief Milling











Hitachi High Tech

Additional capabilities

Intermittent Settings	• ON/OFF settings from 1sec to ~1 hour • Good for heat sensitive samples
Auto Shut Off	• Energy conservation!
Cross-section adapter	• Special holder compatible with the Hitachi 3400 for direct transfer.
Possible future upgrades	• Cryo temp control unit for heat sensitive samples (down to -100 deg C) • Air protection unit for air sensitive samples

Thank you!

Dr. Krysten Villalon

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Phone: (847) 467-0101

Register for Ion Mill Training!

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