Nanometer Scale Patterning and Processing

Spring 2016

Lecture 25

Nanofabrication with Focused Ion Beams – Scanning Ion Beam Imaging

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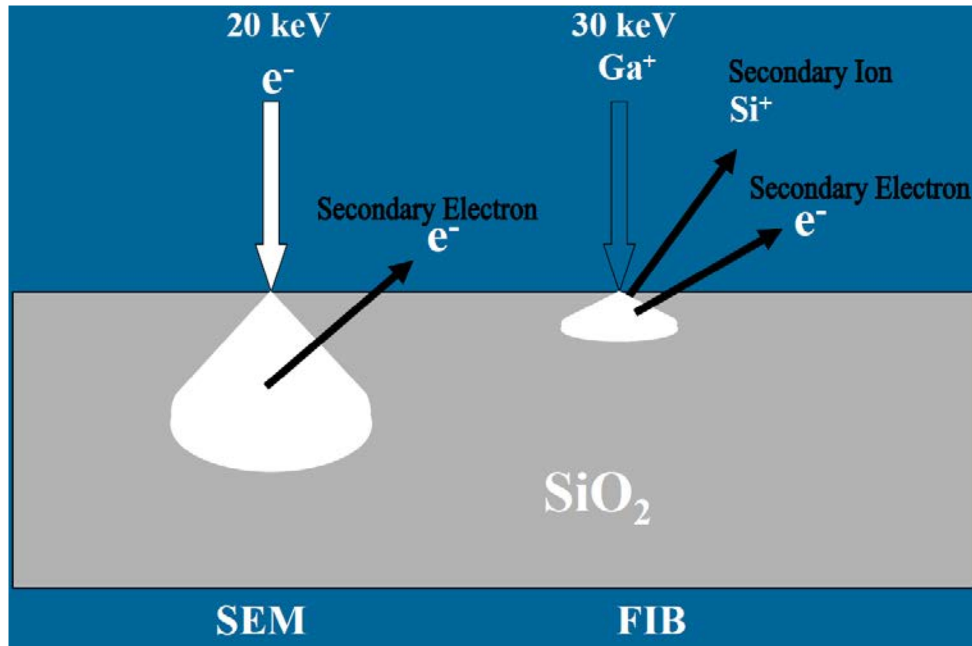
Focused ion beam (FIB)

1. Overview.
2. Ion source and optics.
3. Ion-solid interaction, damage.
4. Scanning ion beam imaging.

Ion Beam Imaging

- FIB imaging is destructive, yet may be used to remove (insulating) oxide layer.
- Topographic contrast.
- Secondary electron and secondary ion images.
- Ion channeling contrast for grain size measurements.
- Material contrast - local compositional differences.
- Voltage contrast - electrical state differences - passive and active voltage



Scanning ion microscope (SIM)

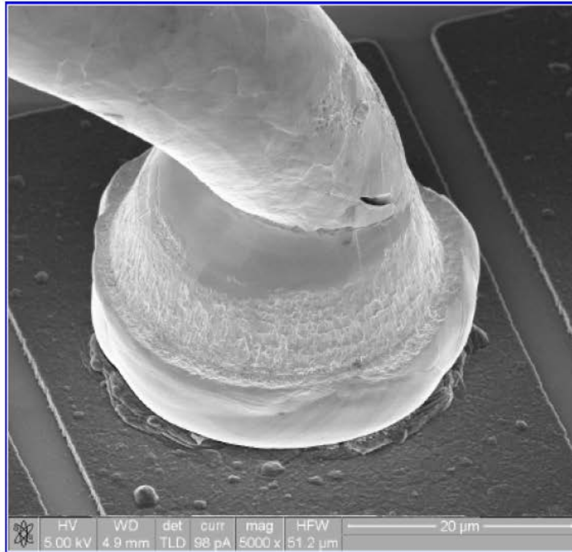
Secondary electron mode

- Detector biased positive
- Emitted from top 5-10 nm
- Typically 30kV 40pA for optimal resolution and signal
- Only charging up a few volts to go dark (electrons cannot escape)
- Grounded metals very bright, oxides dark

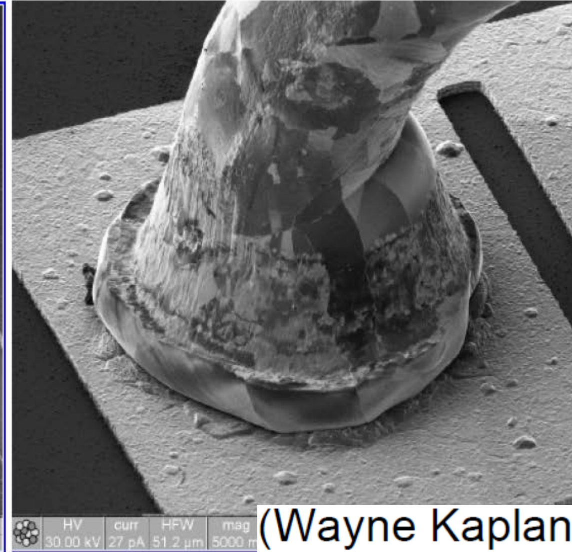
Secondary ion mode

- Detector biased negative
- Emitted from top 0.5-1nm (very surface sensitive)
- No voltage-contrast
- Oxides brighter
- Lower yield, so images noisier.

Comparison of SIM and SEM images

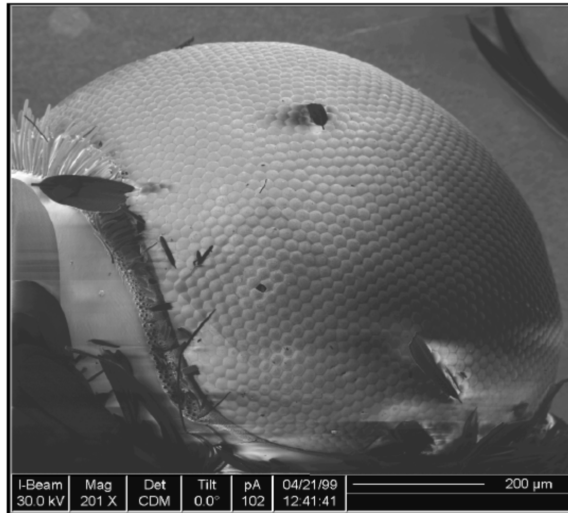


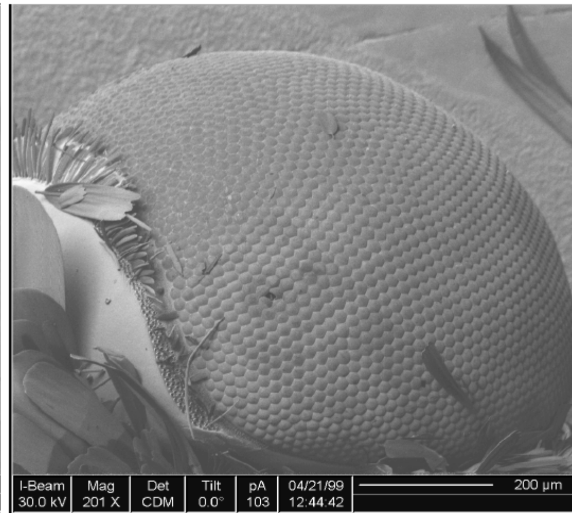
secondary electron image



(Wayne Kaplan)

secondary ion image

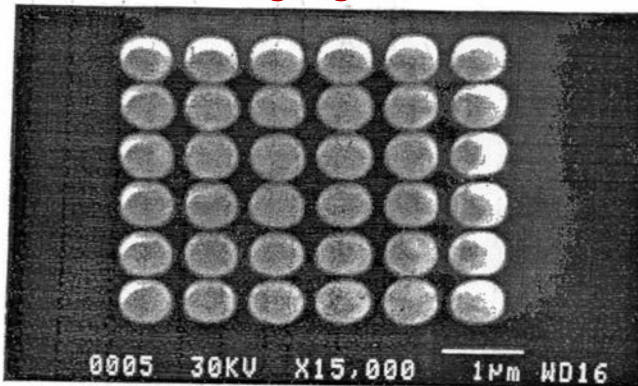




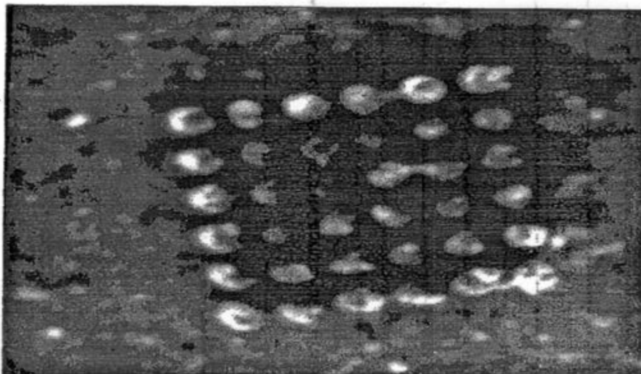
Imaging resolution vs. sputtering yield

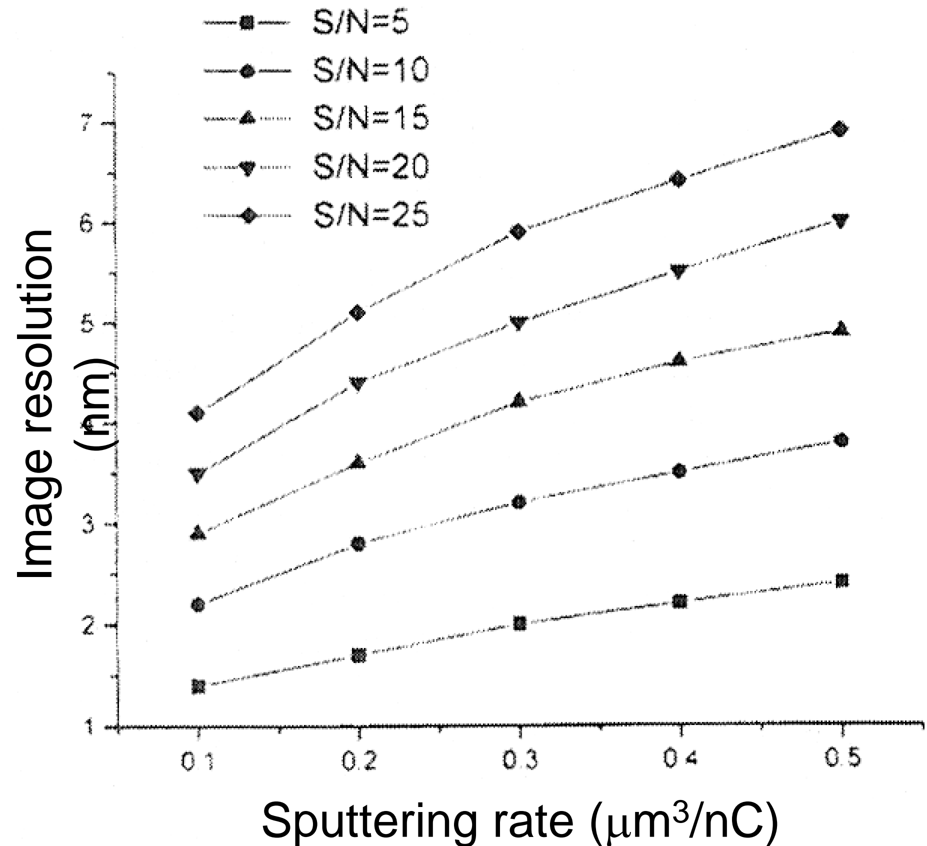
Problem with FIB imaging resolution: if an object is small enough, it will be sputtered away before sufficient signal (secondary electrons) can be collected to resolve it.

Before imaging



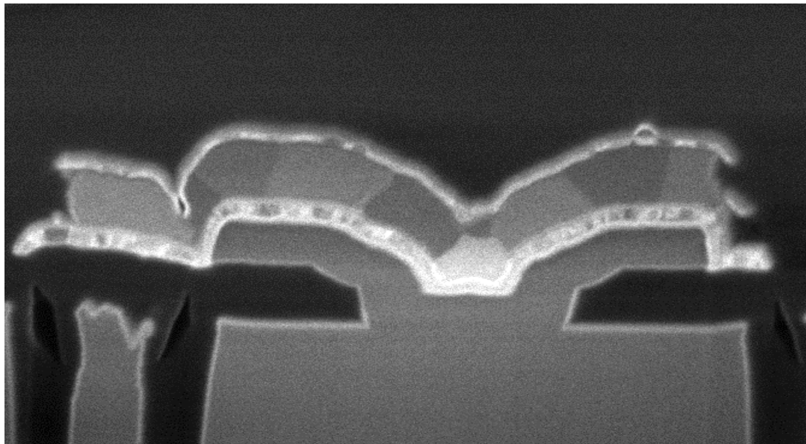
After 1min imaging



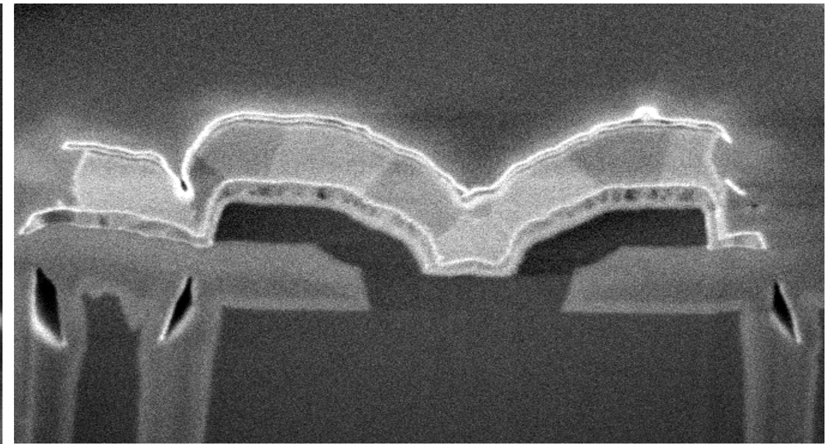


Orloff et al., JVST (1996)

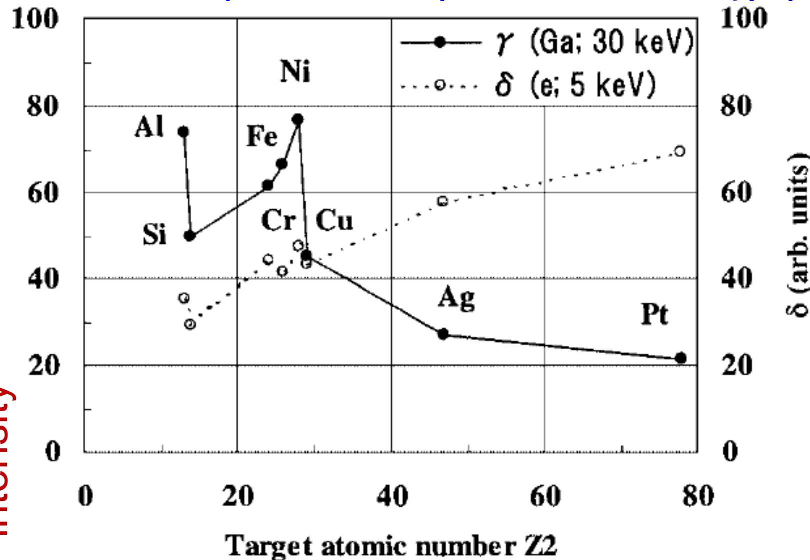
Materials contrast



SEM (secondary electron image)



Scanning ion microscopy (SIM)
Secondary electron image



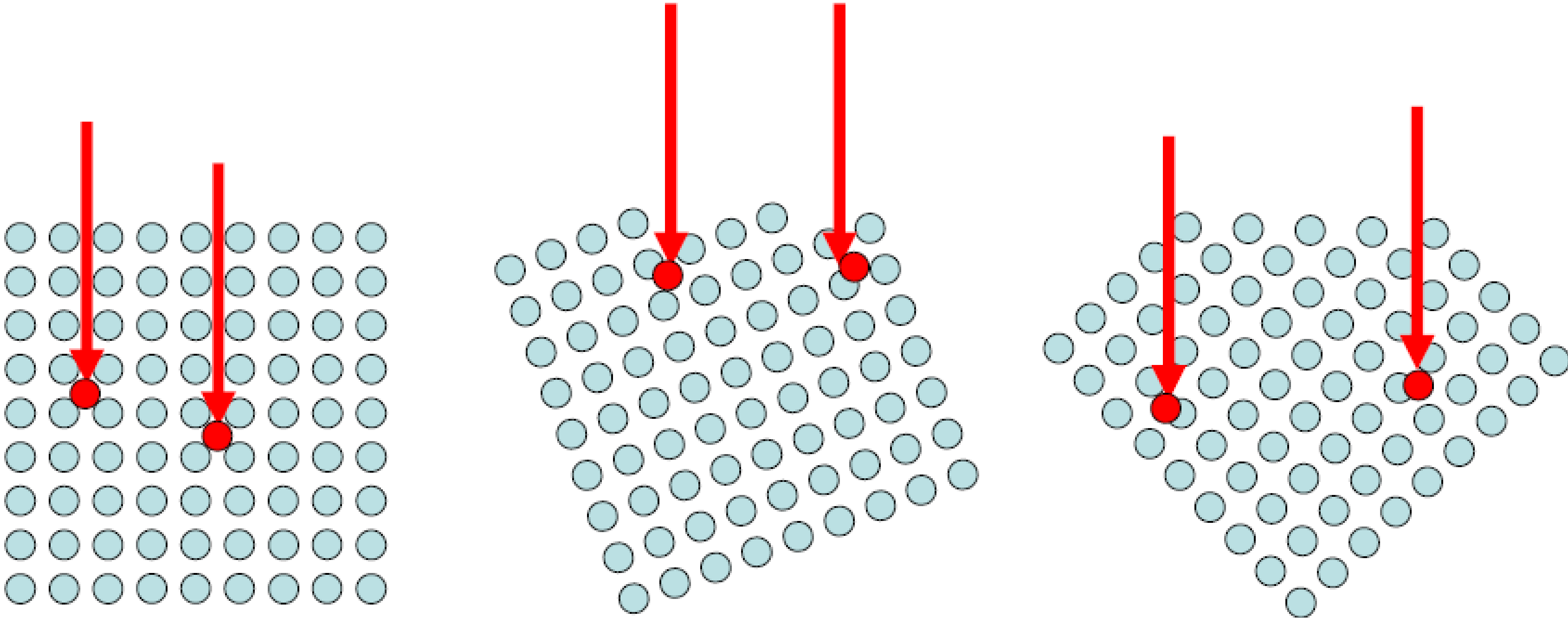
Relative secondary electron (not ion) intensity

Fig. 1 Relative SE intensities as a function of Z_2 for the Ga-SIM and SEM images.

- SIM image has higher material contrast than SEM image, and with fine structure (peaks and valleys in the curve).
- Unlike SEM, the signal brightness is lower for heavier materials (larger Z).
- For SEM, heavier materials have higher SE yield since there are more electrons for high Z materials.

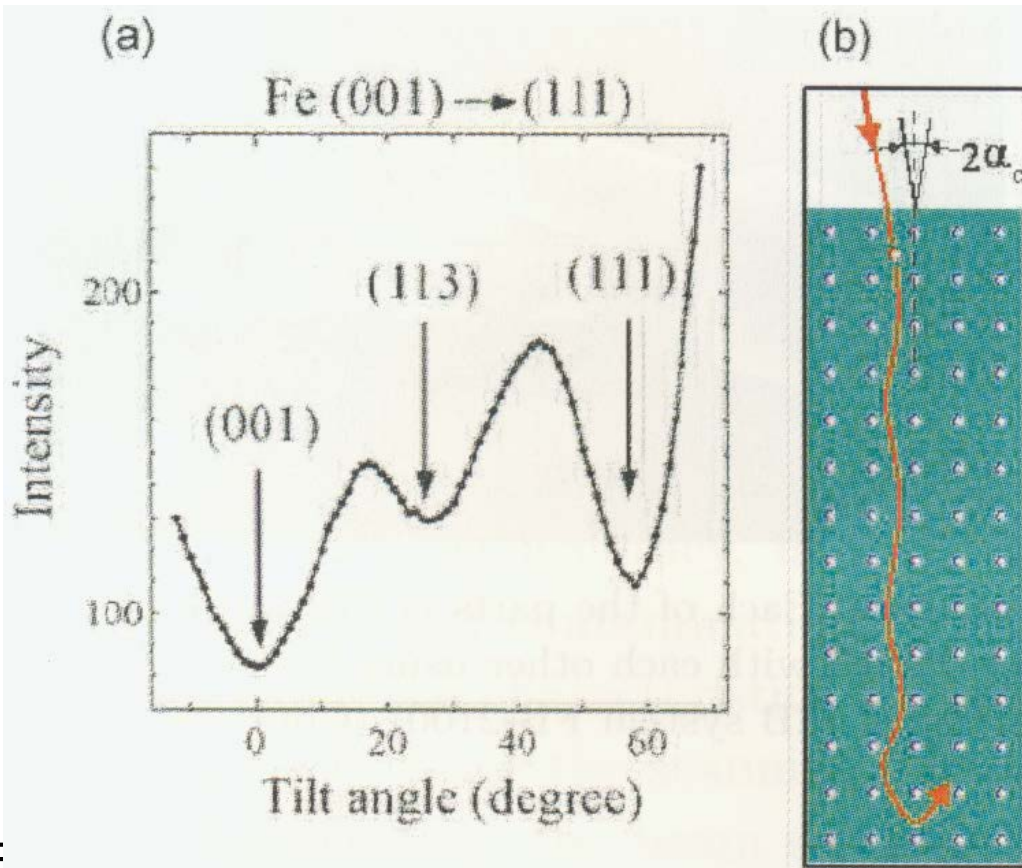
"Origin of material contrast in scanning ion microscope", J Electron Microscopy, 2002.

Ion channeling contrast



Ion channeling contrast

- Ions penetrate deeper in crystalline material for certain grain orientations.
- Those channeled ions have lower sputtering yield (slower milling rate).
- Secondary electron (SE) yields are also lower for areas that channel better.
- Polycrystalline materials have grains with different orientations.
- Grain size can be determined by images at different incidence angles.



Typical SE intensity with respect to tilt angle for Fe single crystal sample under 30keV Ga-FIB bombardment.

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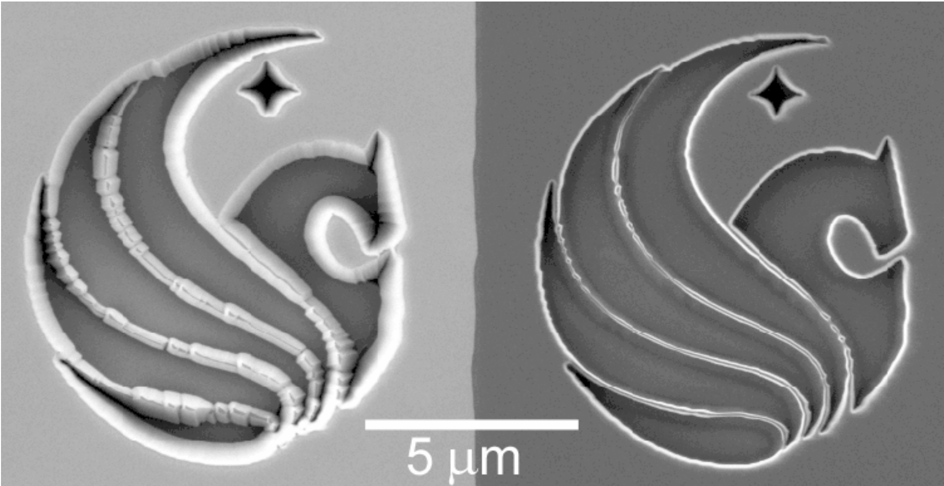
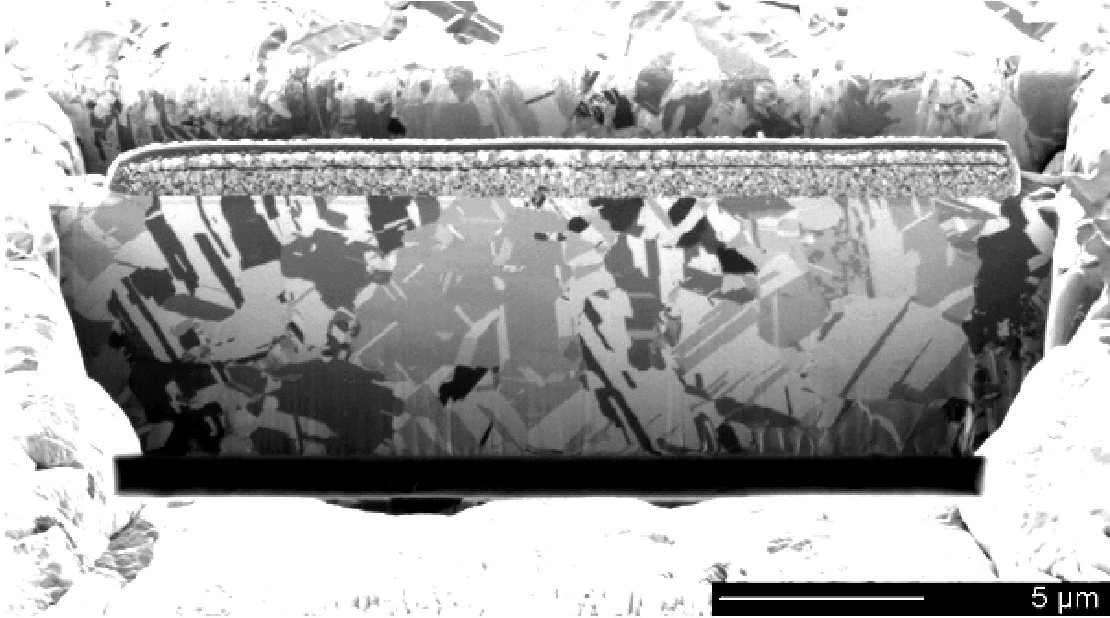
Ion channeling contrast

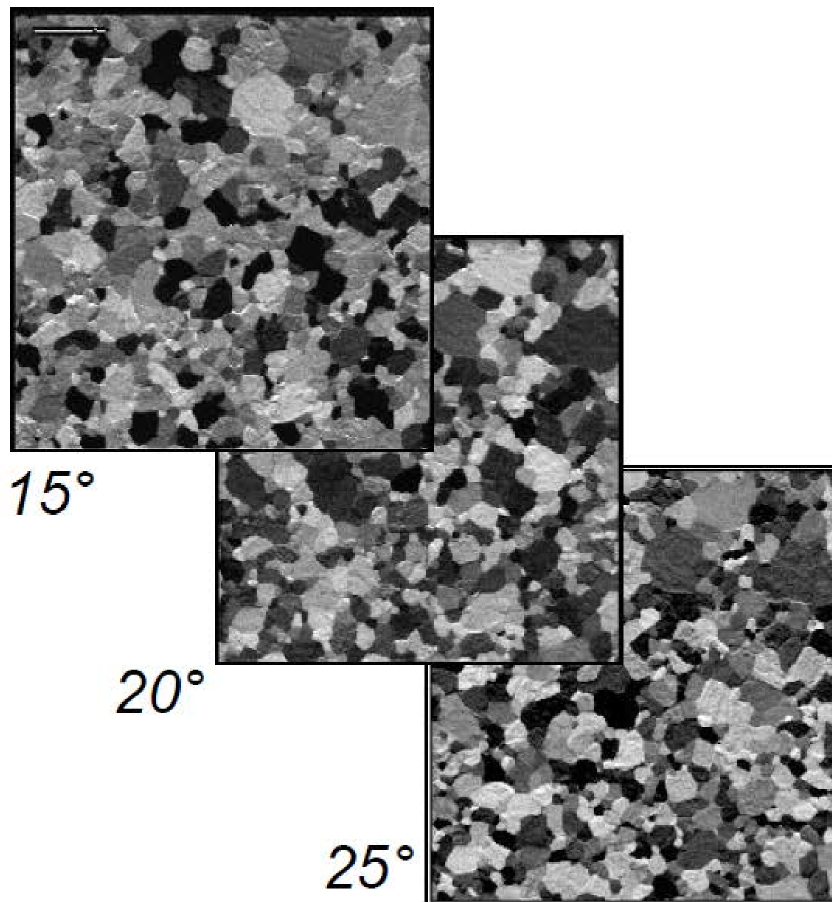
Left: not aligned with crystal direction
Right: channeled (aligned)

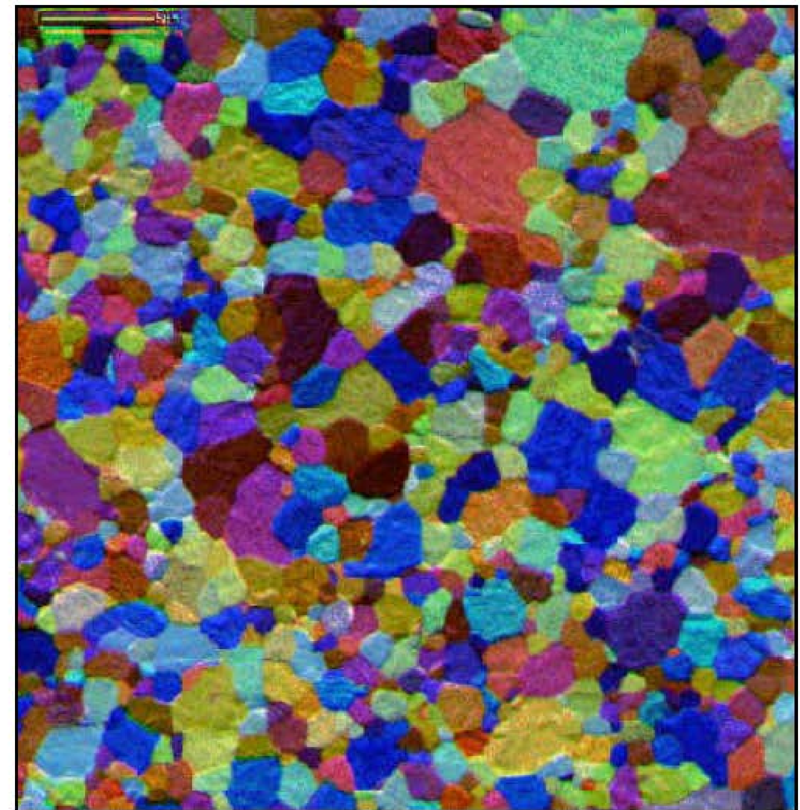




Ion channeling contrast

Channeling contrast for grain size analysis





Color Composite