Looking below the surface using Ion Beam and DualBeam Techniques

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Micro Advertising

Micro labeling

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Presentation overview

- Looking below the surface – why?
- Focused Ion Beam main use
- Benefits of an SEM column on the FIB
- Application examples

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Why look below surface?

- 3D high resolution materials characterization
- Sub-surface Failure Analysis – Quality Control (incl. Critical Dimensions)
- To bridge the gap between surface microscopy (SEM) to higher resolution sectional microscopy ((S)TEM)

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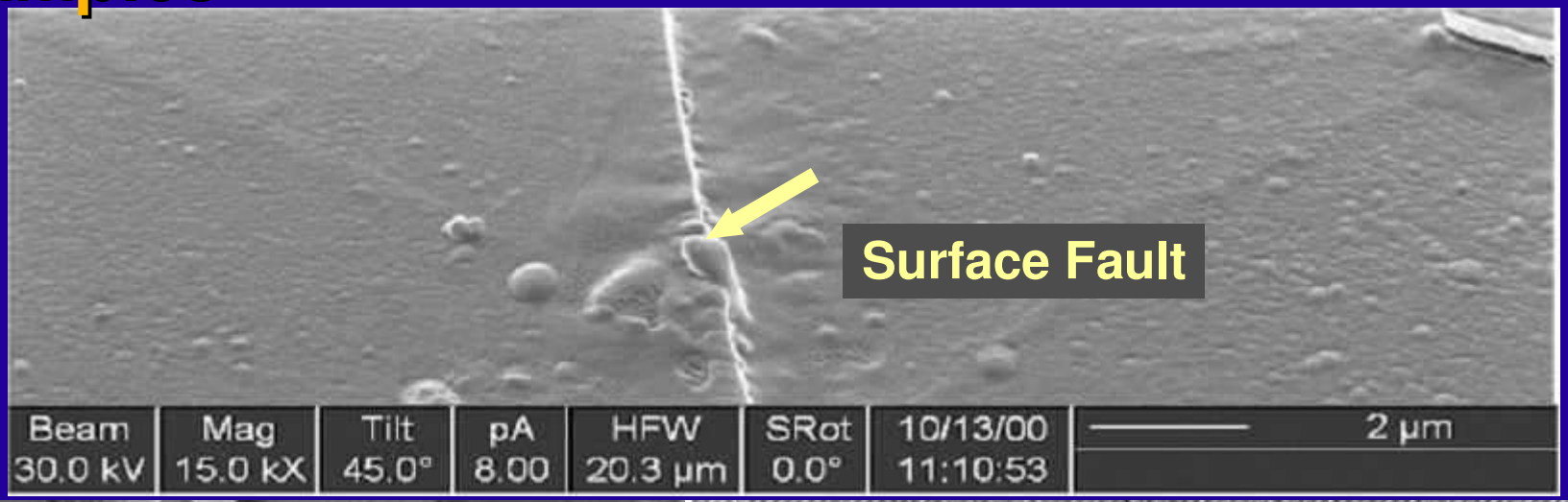
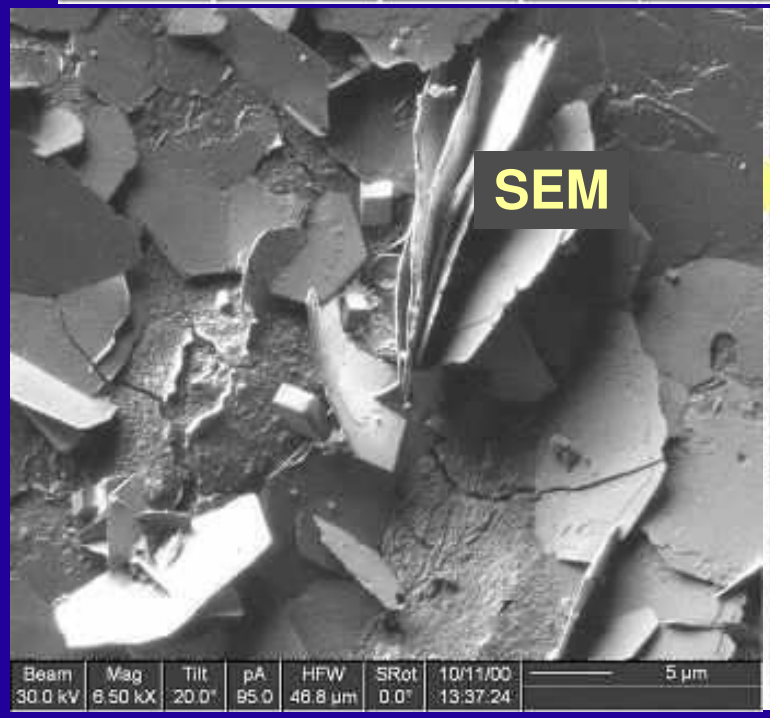
Examples


Surface Fault
Beam 30.0 kV
Mag 15.0 kX
Tilt 45.0°
pA 8.00
HFW 20.3 µm
SRot 0.0°
10/13/00 11:10:53
2 µm


SEM
Beam 30.0 kV
Mag 6.50 kX
Tilt 20.0°
pA 95.0
HFW 46.8 µm
SRot 0.0°
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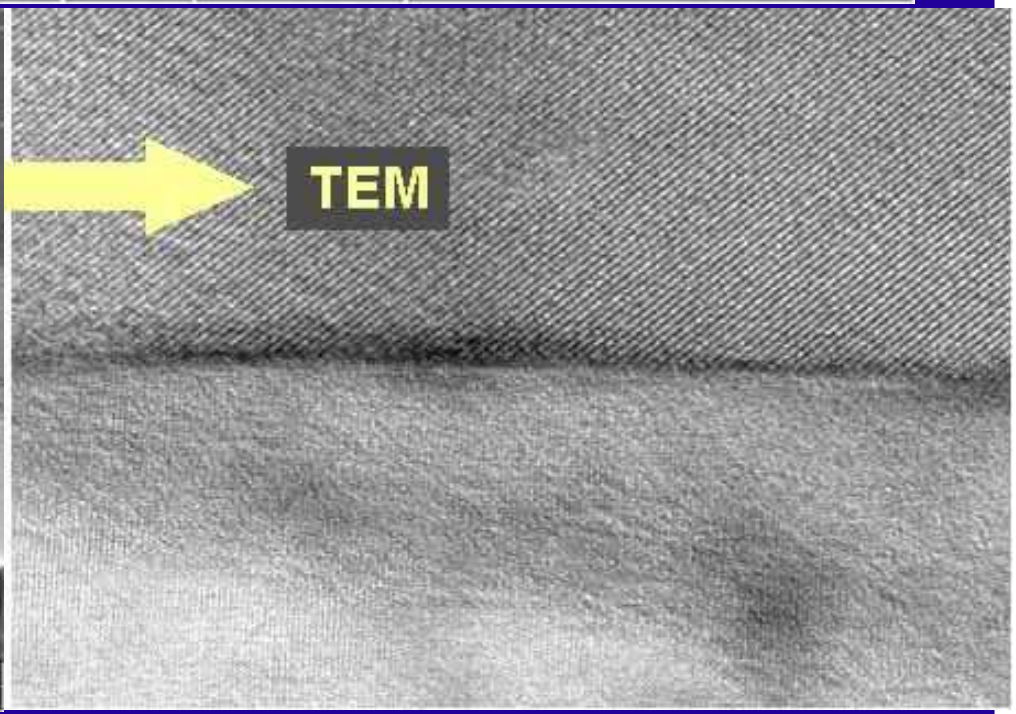
5 µm


TEM

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Focused Ion Beam – Main use

- Removal of material:
  - Expose 3rd dimension: cross sectioning, slice & view
  - Foil preparation for STEM and TEM
  - Circuit edit, nano machining, creation of structures
- Deposition:
  - Circuit edit, nano fabrication such as proto typing, creation of connects to CNT
- Contrast mechanism: ion channeling (grain contrast)
- SE imaging

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SEM + FIB = DualBeam benefits

- All that of an UHR FEG-SEM
  - Non-destructive imaging & microanalysis, bulk sample or foil (STEM)
- All that of a FIB
  - Milling, deposition, channeling contrast
- UHR end-point detection of milling
  - Monitor the progress and accuracy of milling with an UHR e-beam

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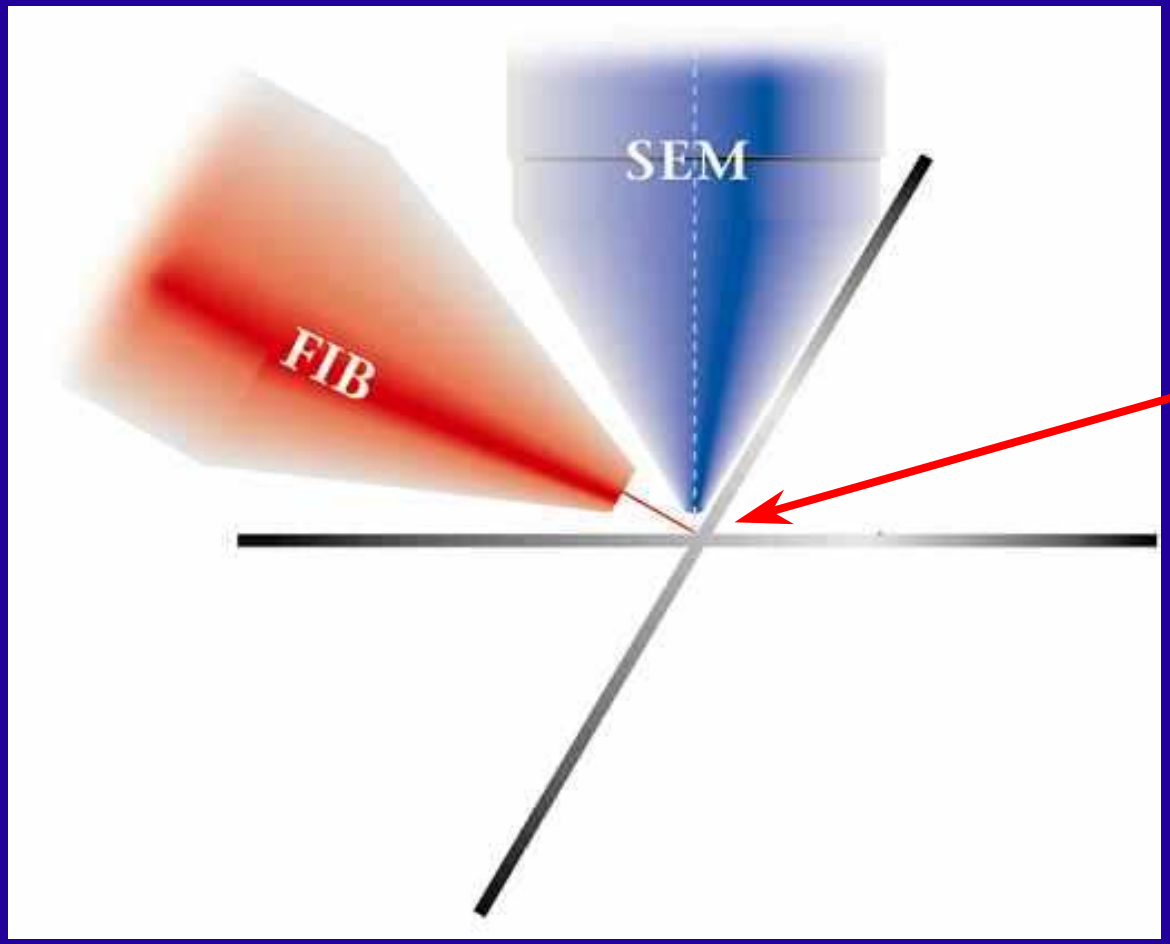
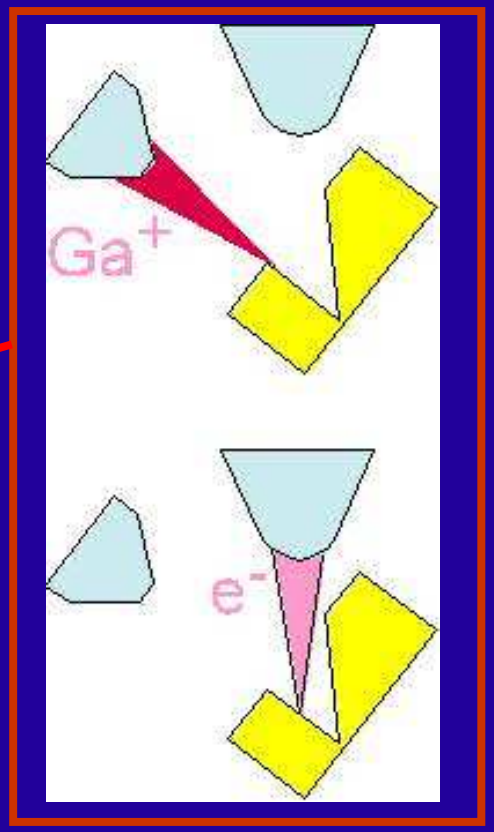
DualBeam geometry





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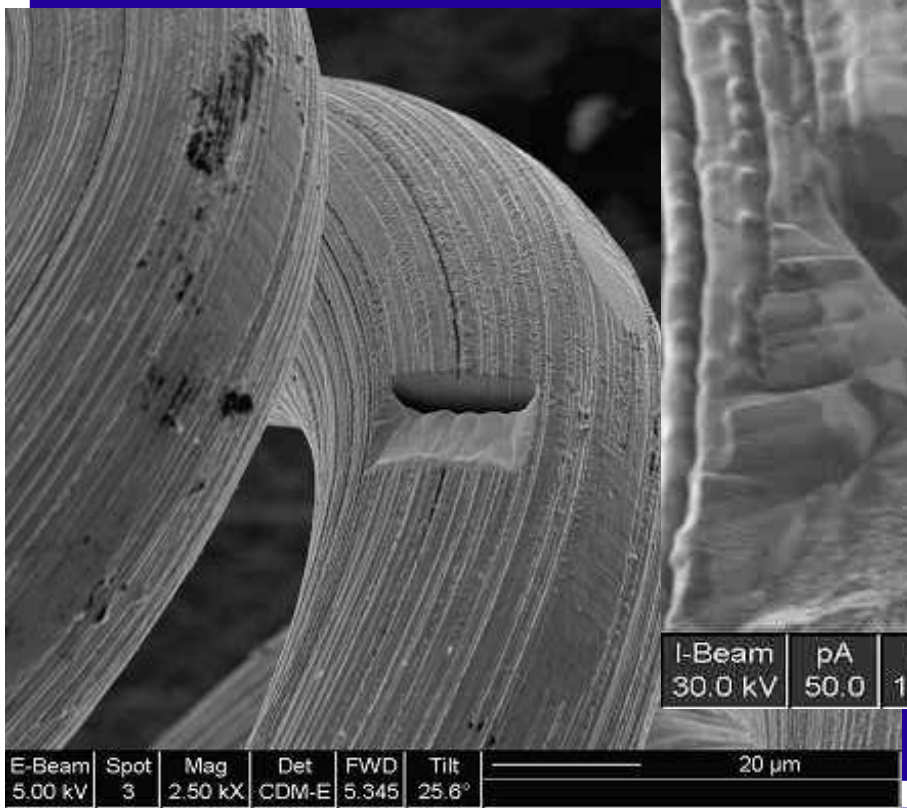
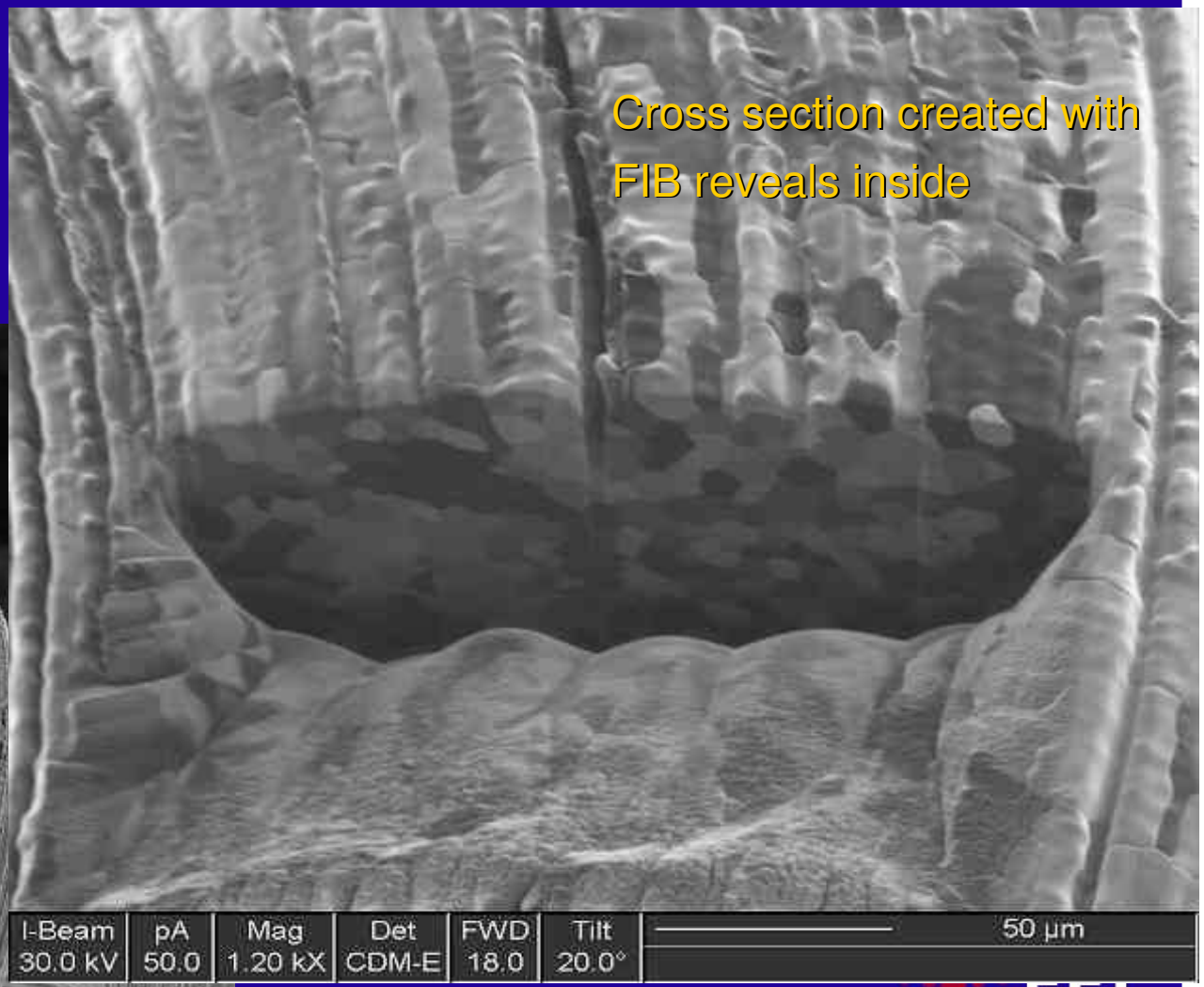
FIB cut -> 3D imaging

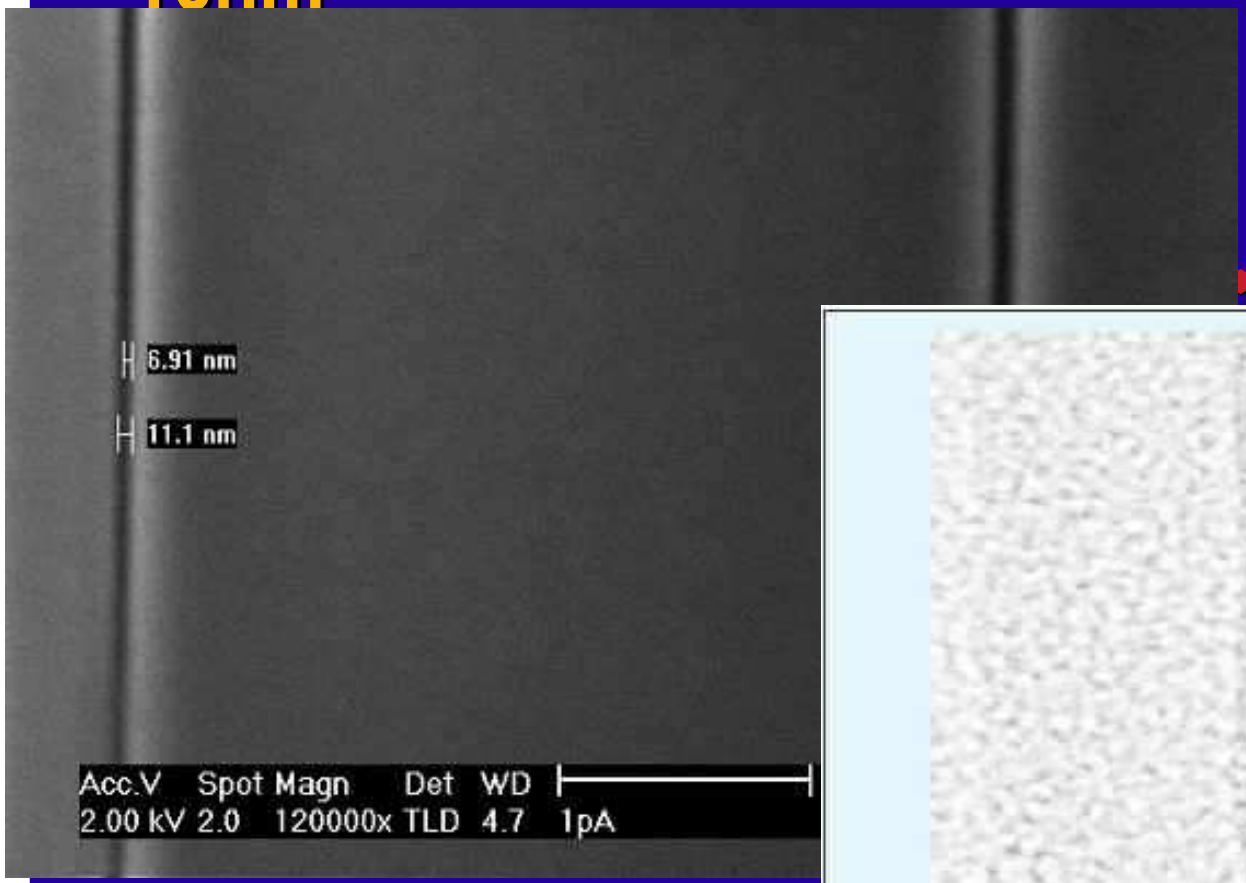
Helix W wire for light bulb





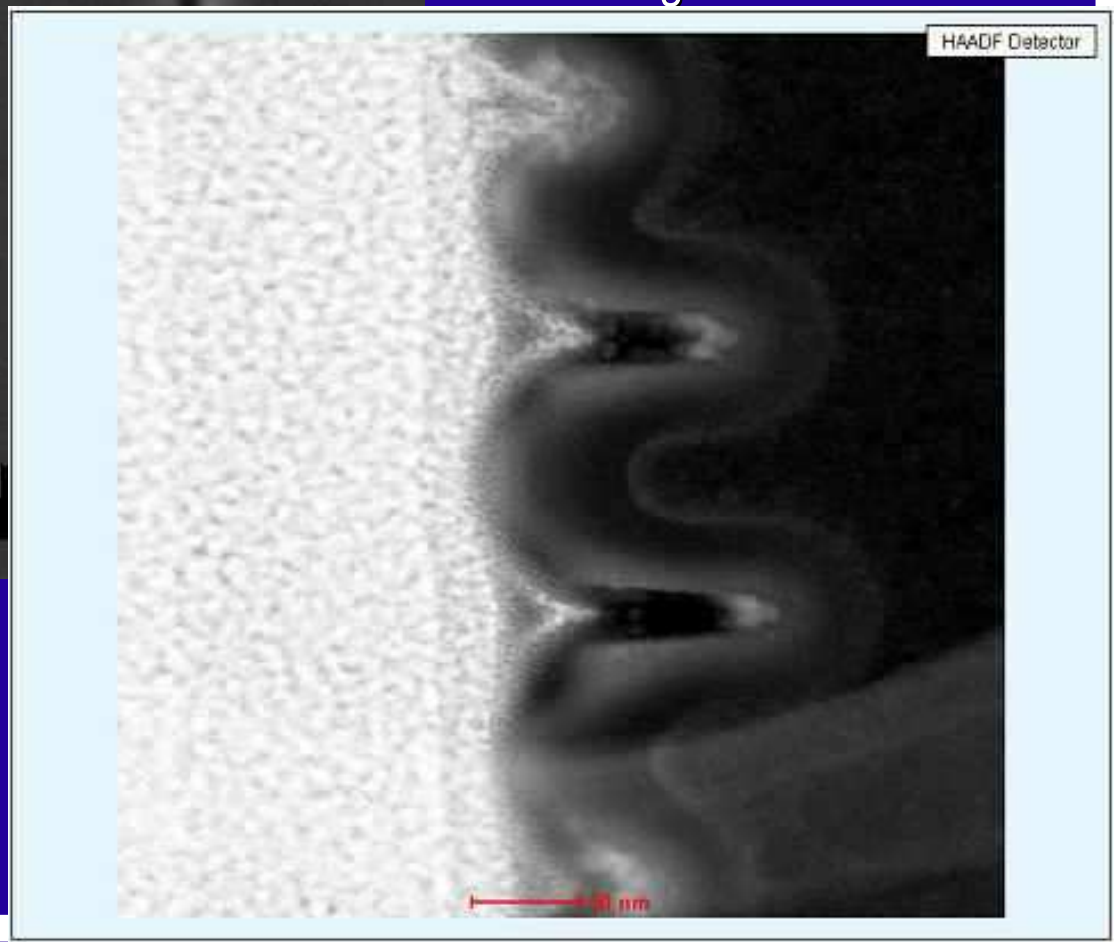
Cross section created with FIB reveals inside

Nano-machining Channel Width ~10nm

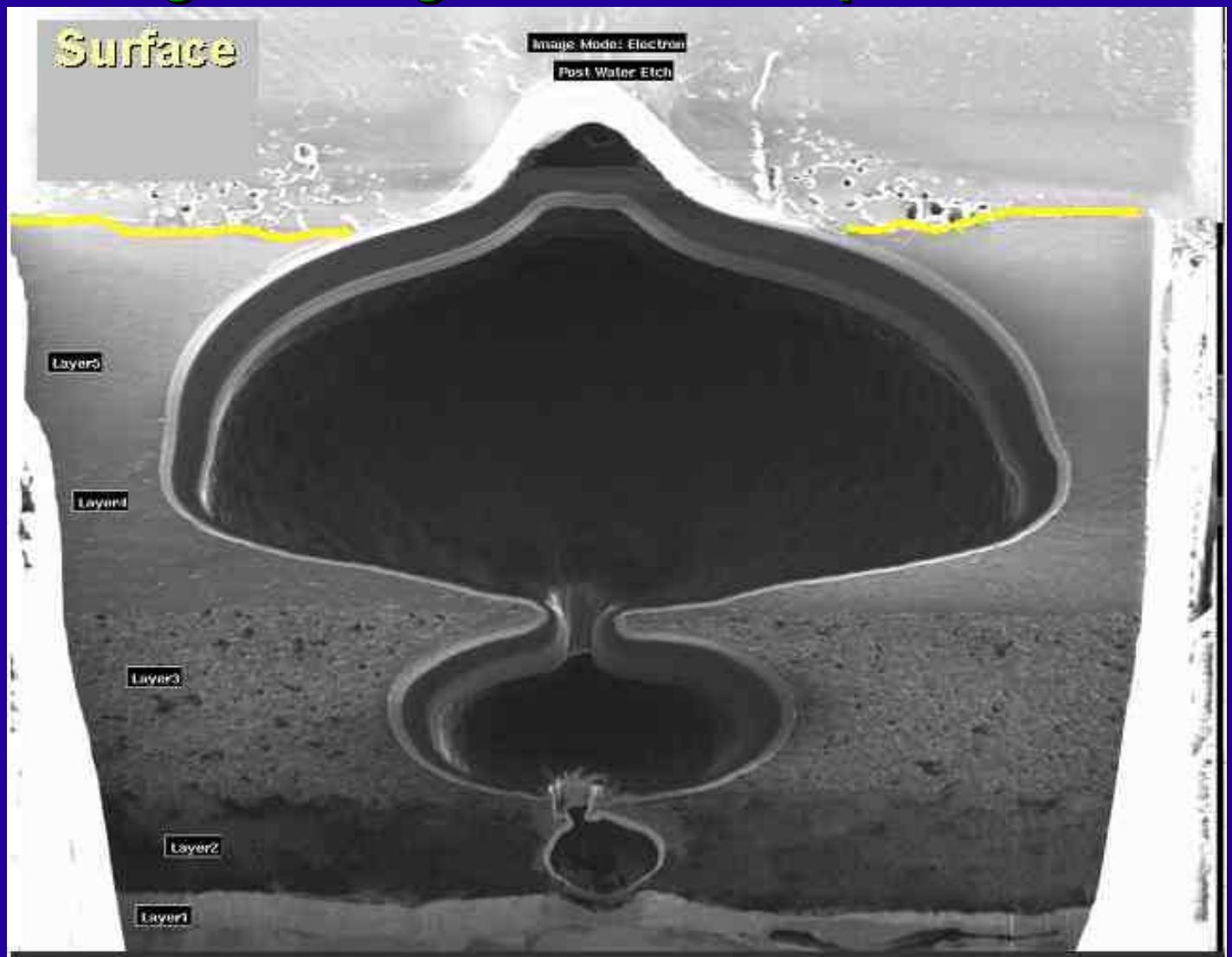


- SEM image of lines milled with 1pA Ga^+ ion beam

- TEM image of cross section



Micro Engineering ~1.4 million µm^3 Removed



Auto paint film defect **Field of View 140 microns**

Courtesy MPA

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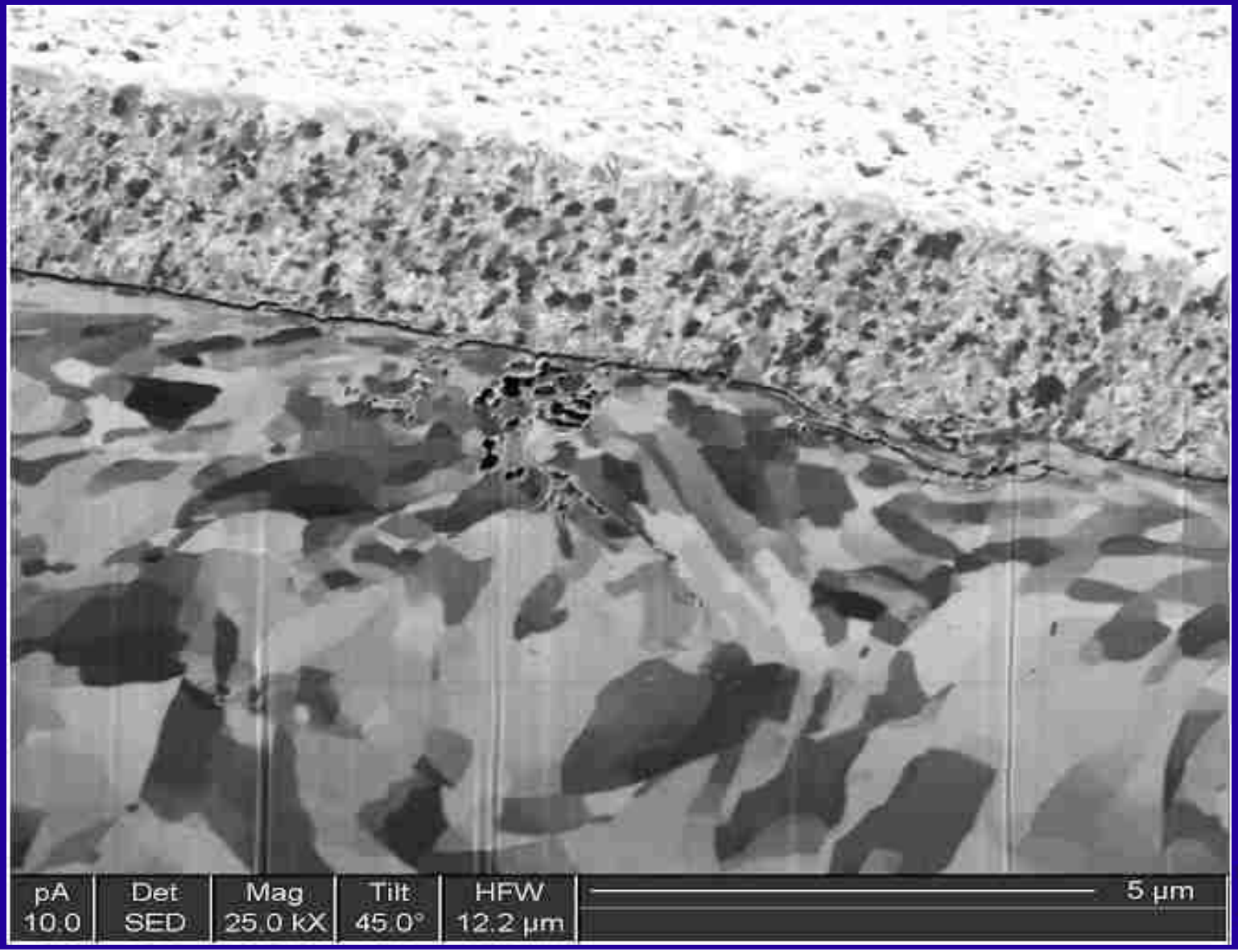
Channeling image contrast



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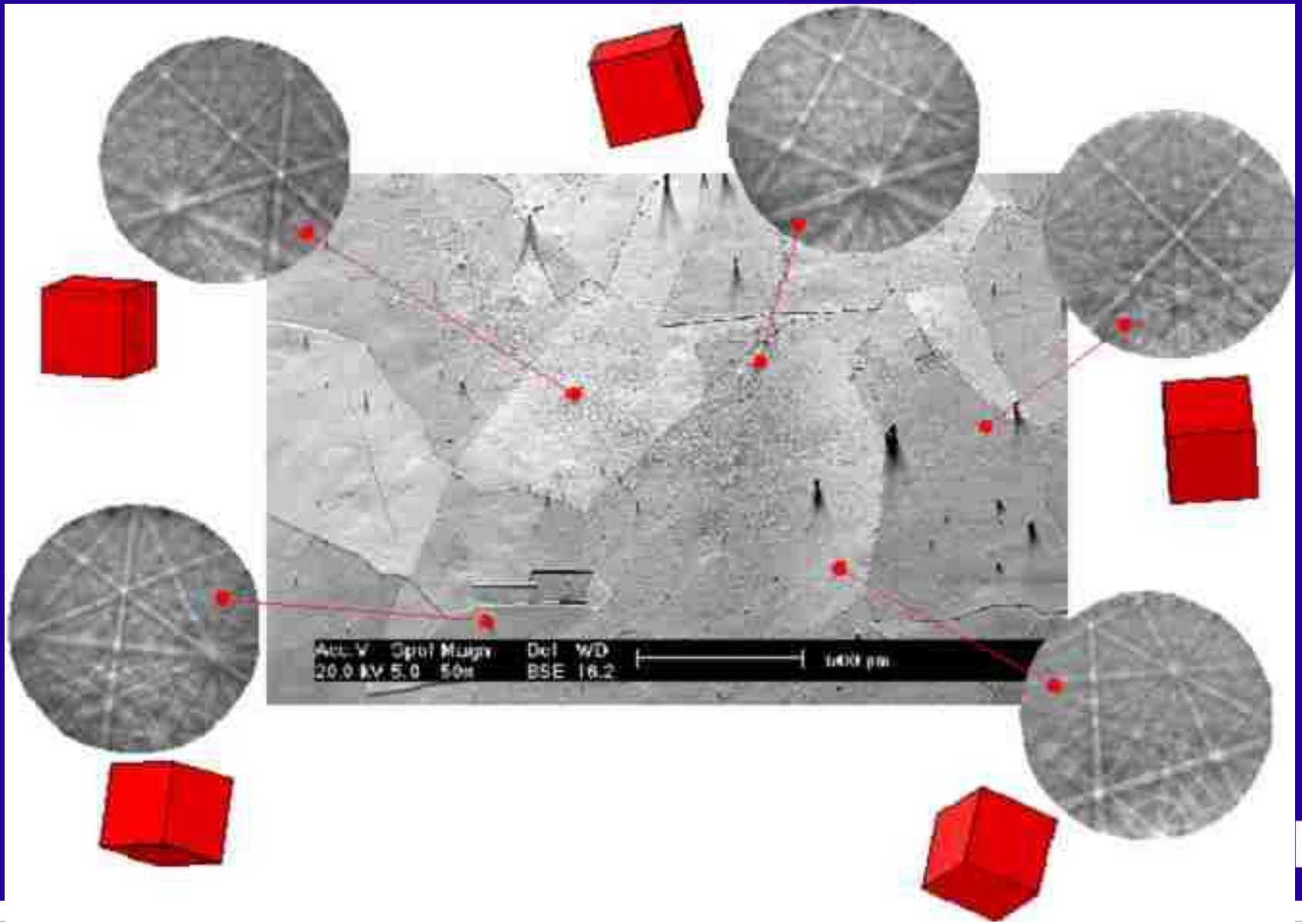
Quantitative micro crystallography - OIM



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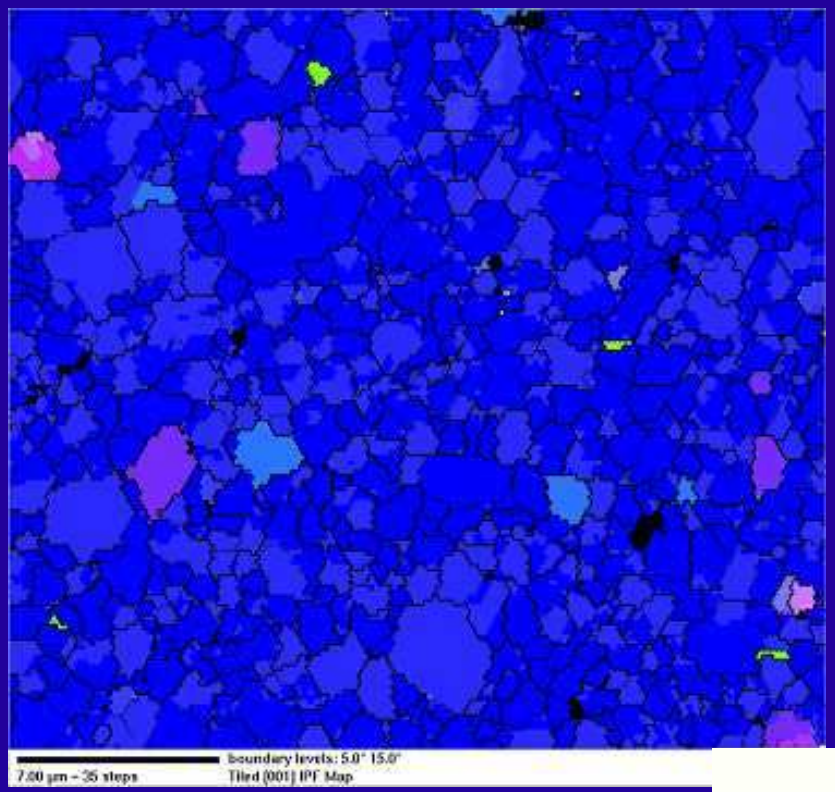
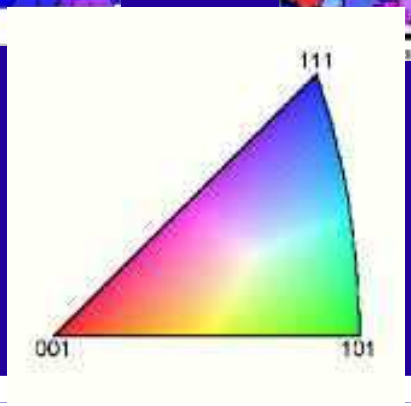
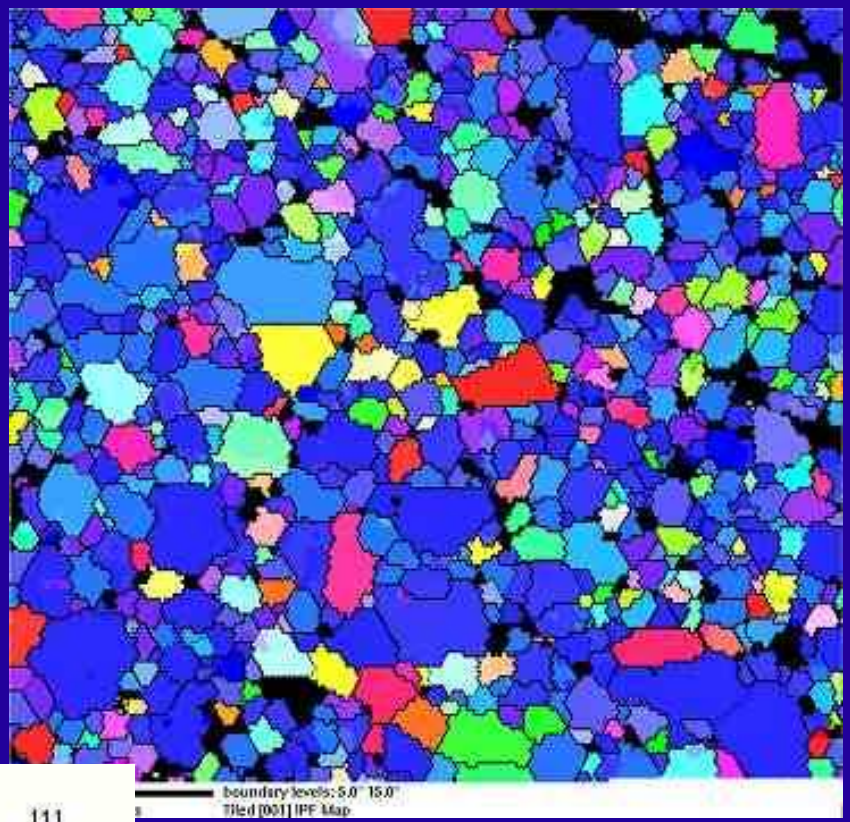
Semi-conductor: Al film for SC



High Mean Time to Failure





Low Mean Time to Failure

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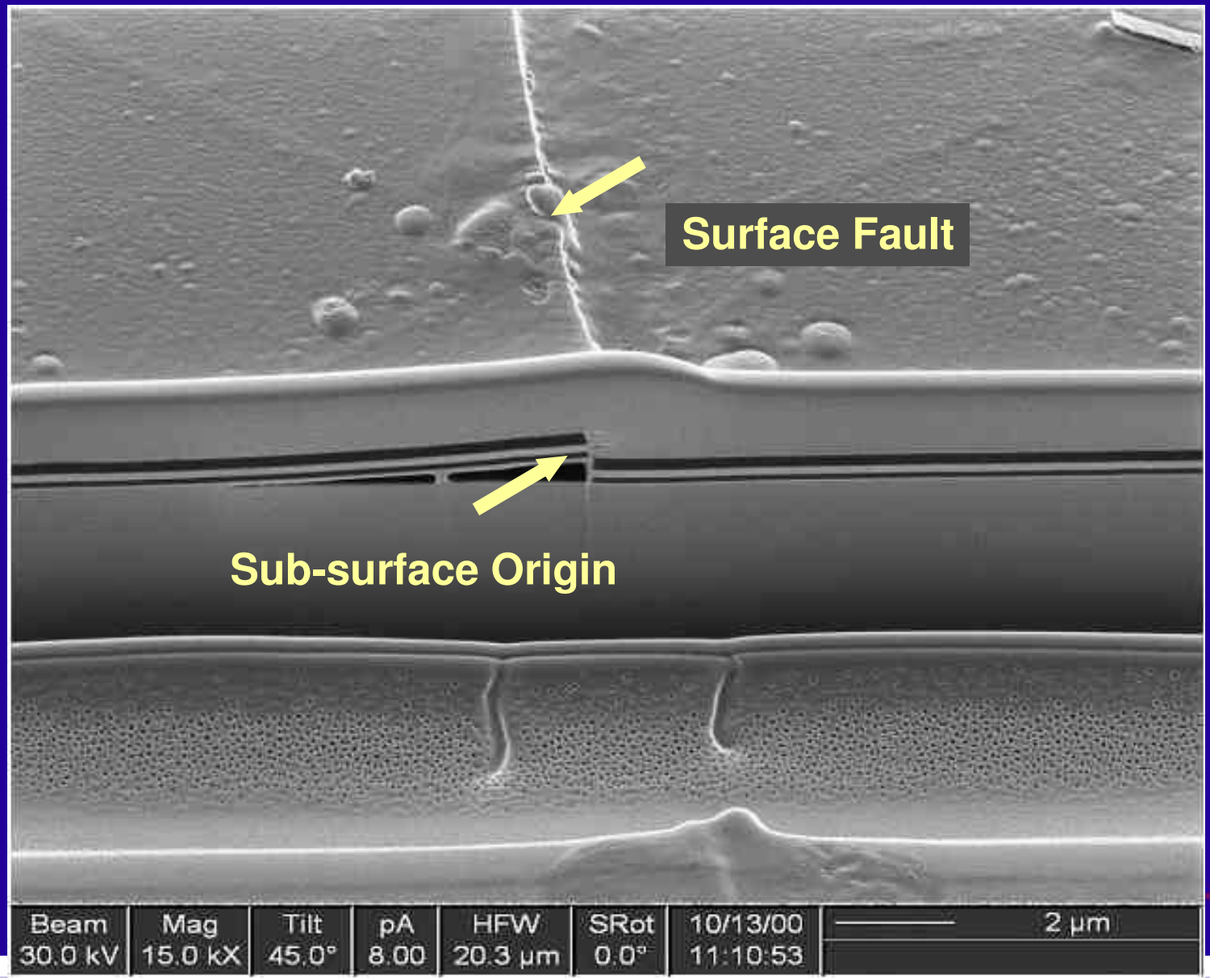
Expose 3rd dimension



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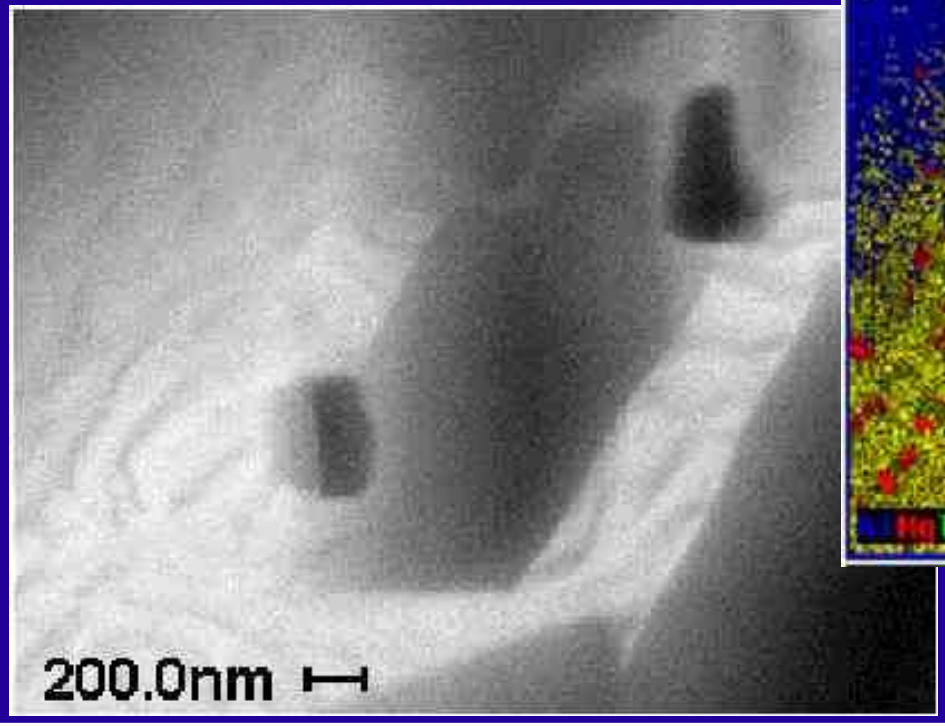
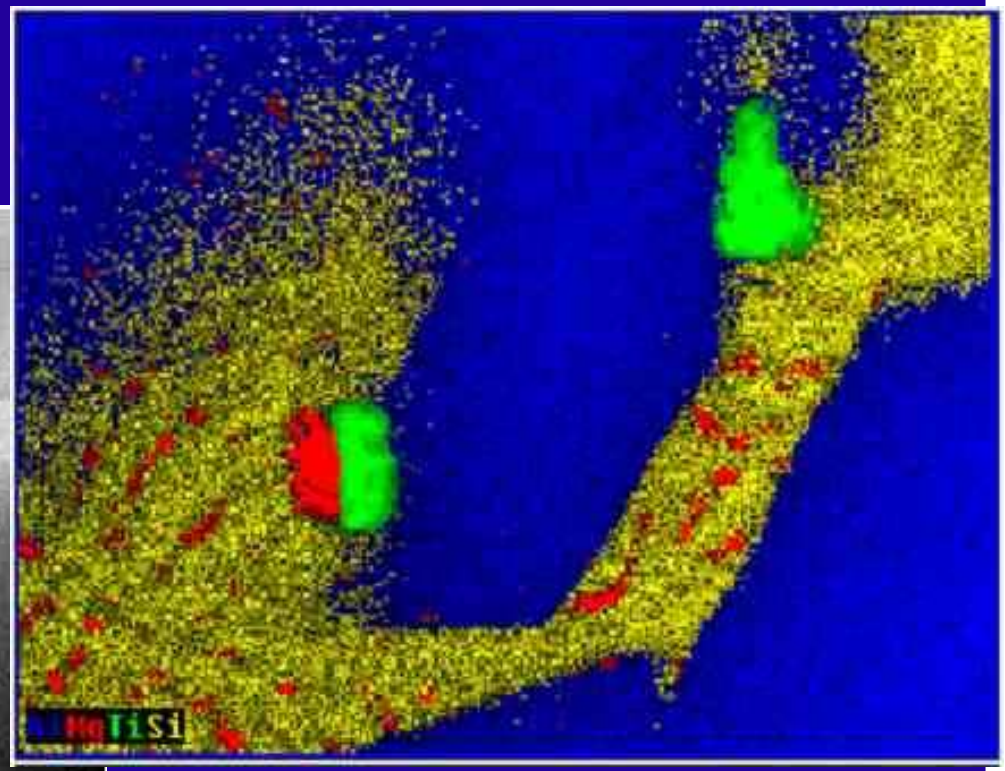
Foil preparation - STEM

- Sub-nm resolution SEM
- Dark-field imaging in DualBeam
- UHR elemental mapping





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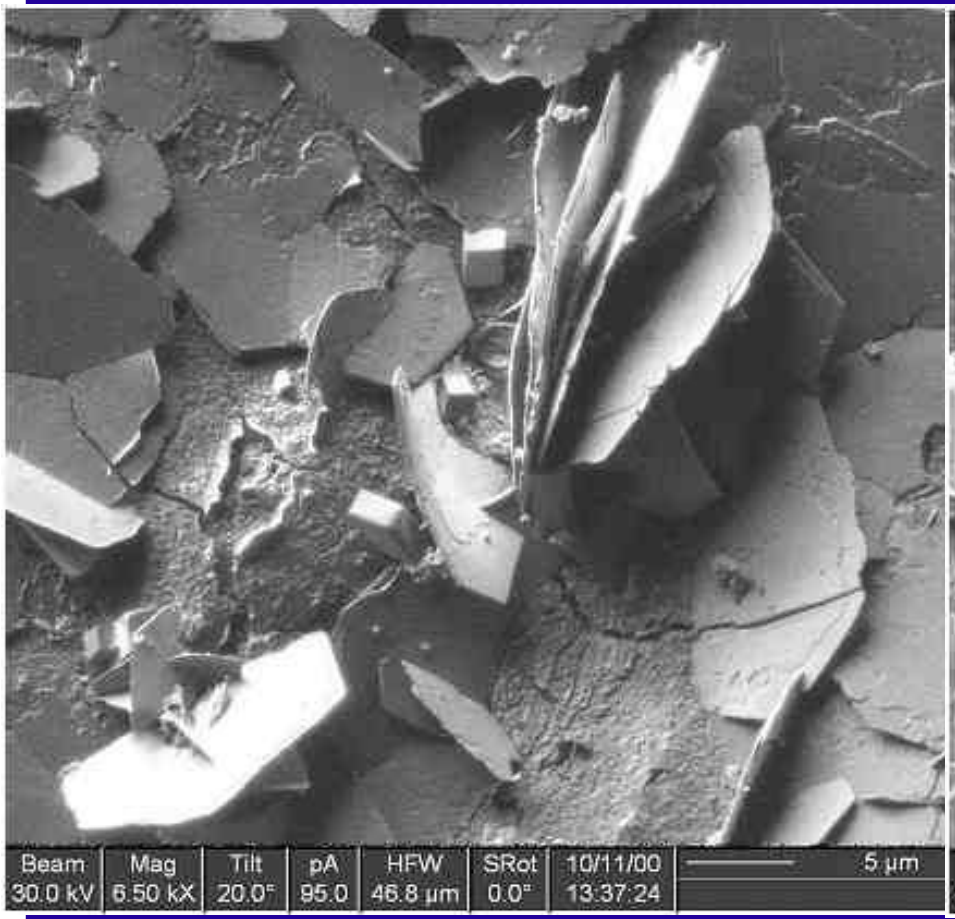
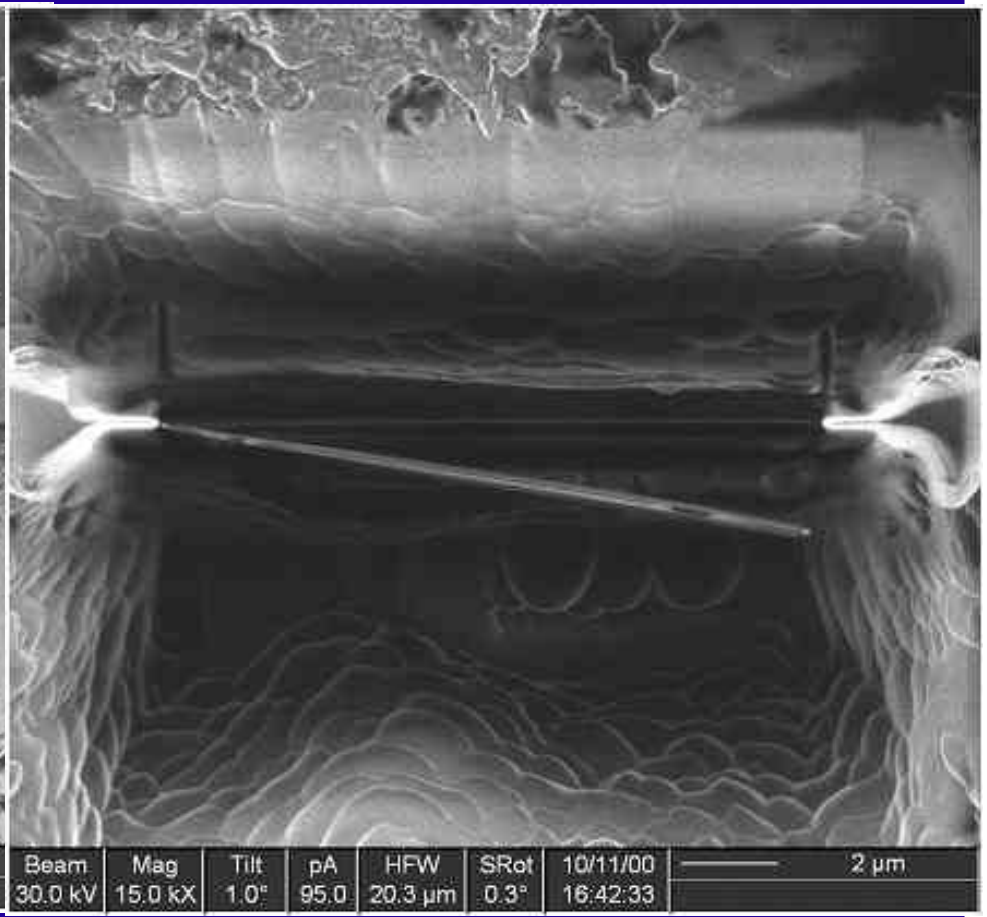
Foil preparation - TEM





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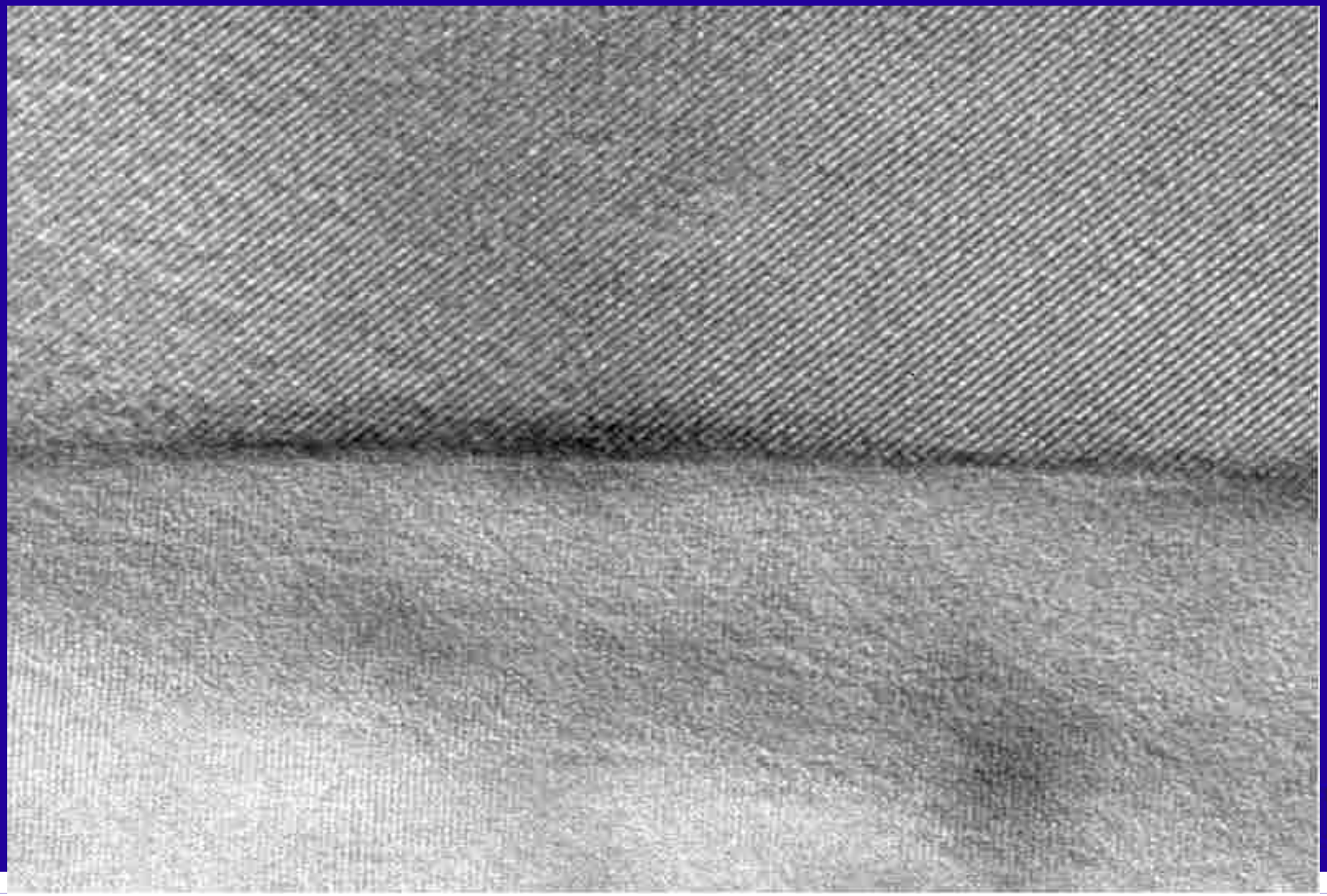
HR TEM image



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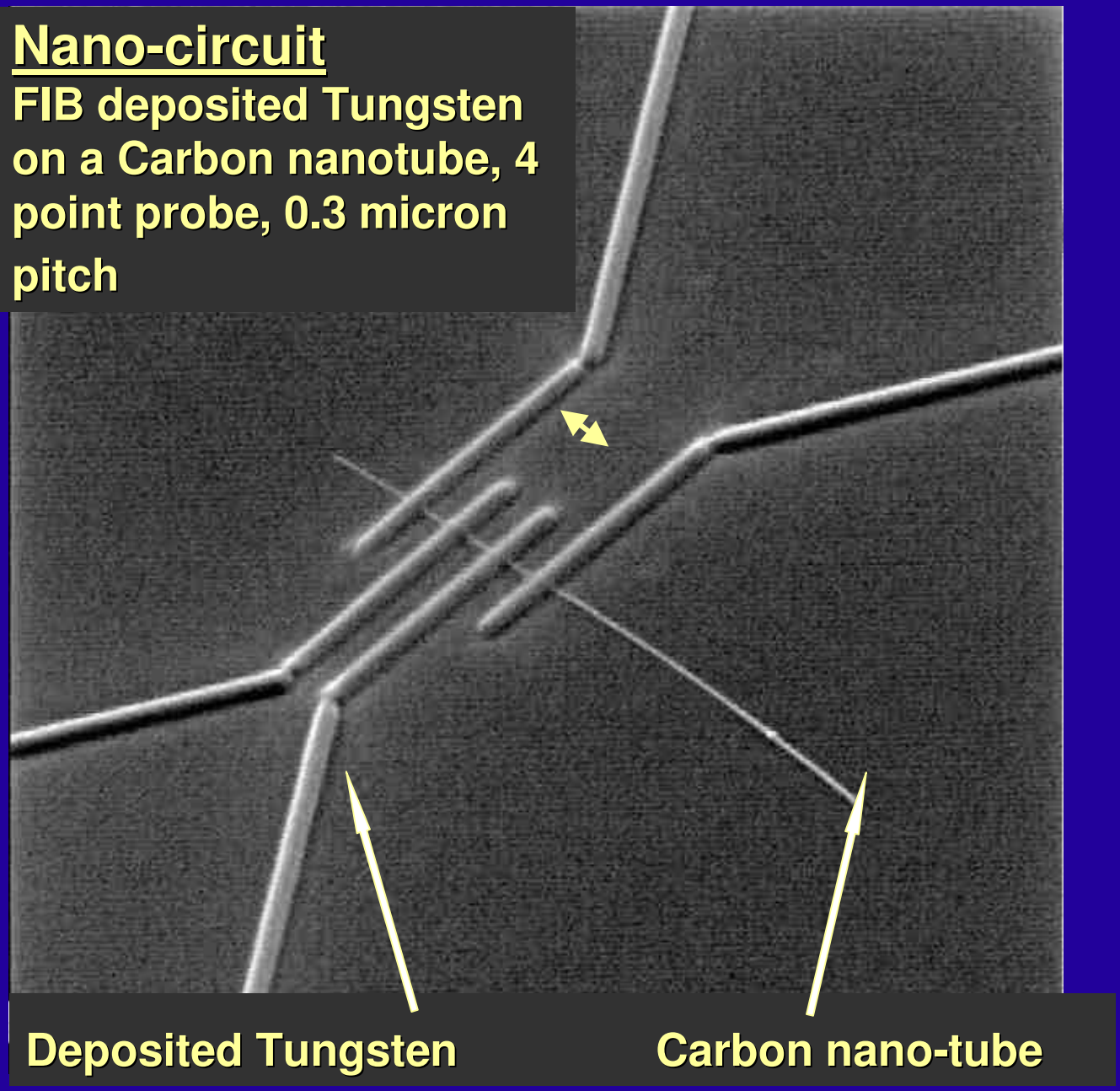
Deposition

- Nanotube probing

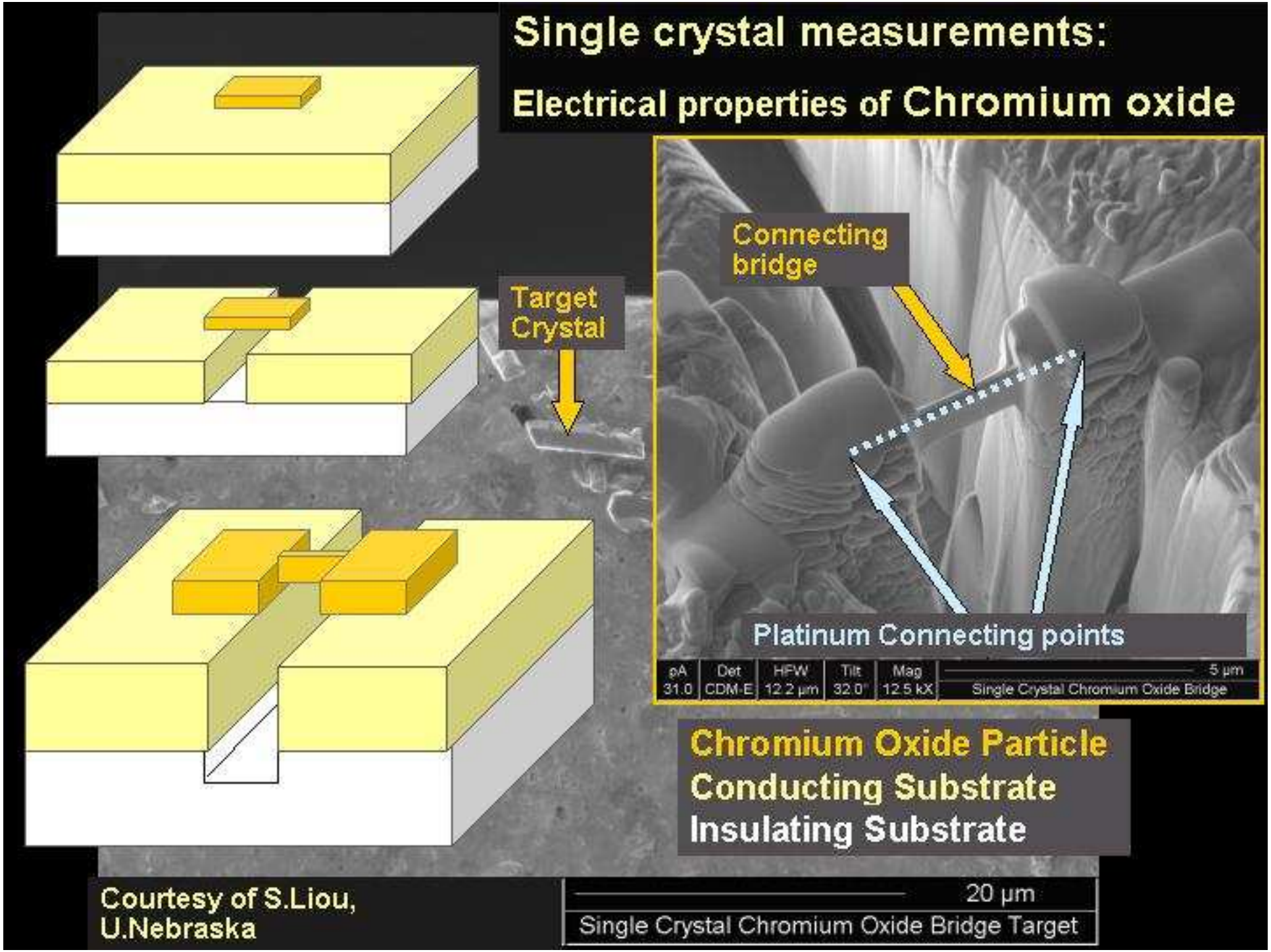


Combined benefits DualBeam - example

- How to measure electrical properties of a 5 um Chromium Oxide single crystal on a conductive substrate?
- The DualBeam as a multipurpose Nano-scale experimental workstation
  - Imaging
  - Milling
  - Depositing
  - Measuring

Single crystal measurements:

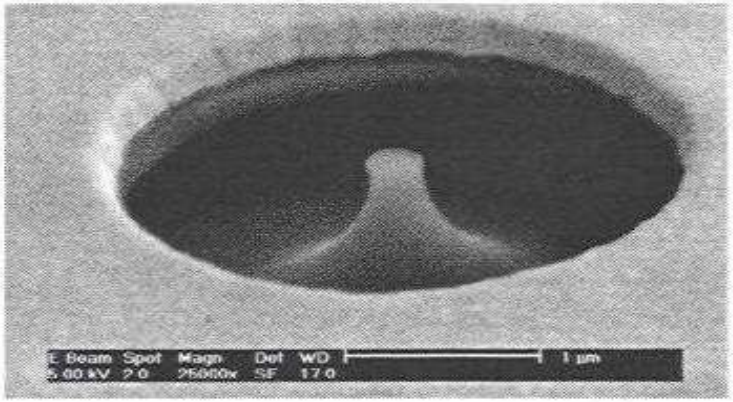
Electrical properties of Chromium oxide



Courtesy of S.Liou, U.Nebraska

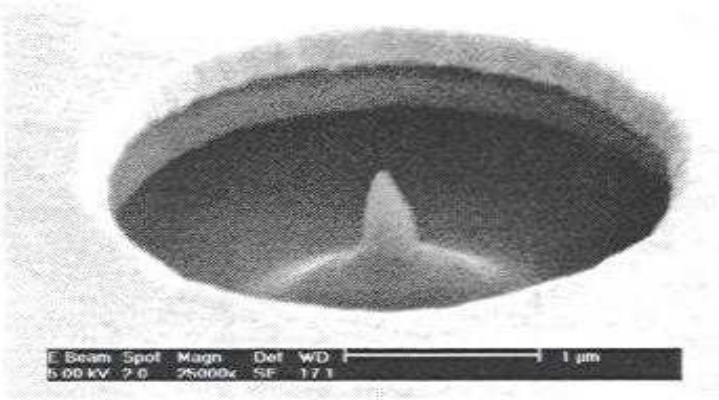
Attempt to sharpen Field emitter array with FIB (Osaka University)

Si FEA after FIB Sharpening

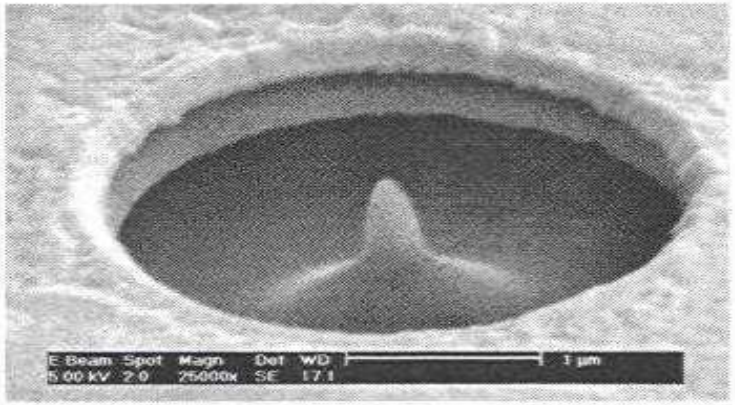


t = 0 s

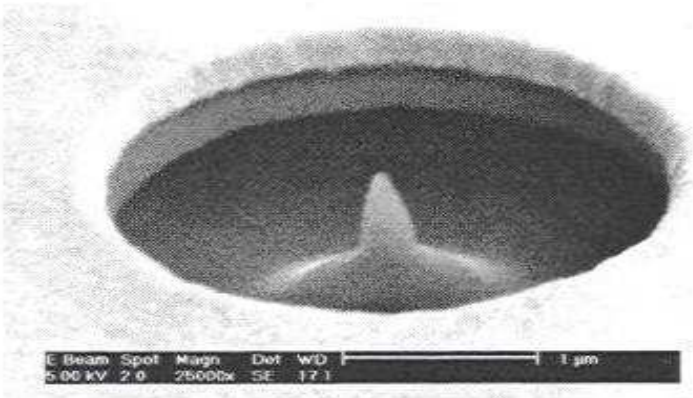
i = 7 pA



t = 10 s



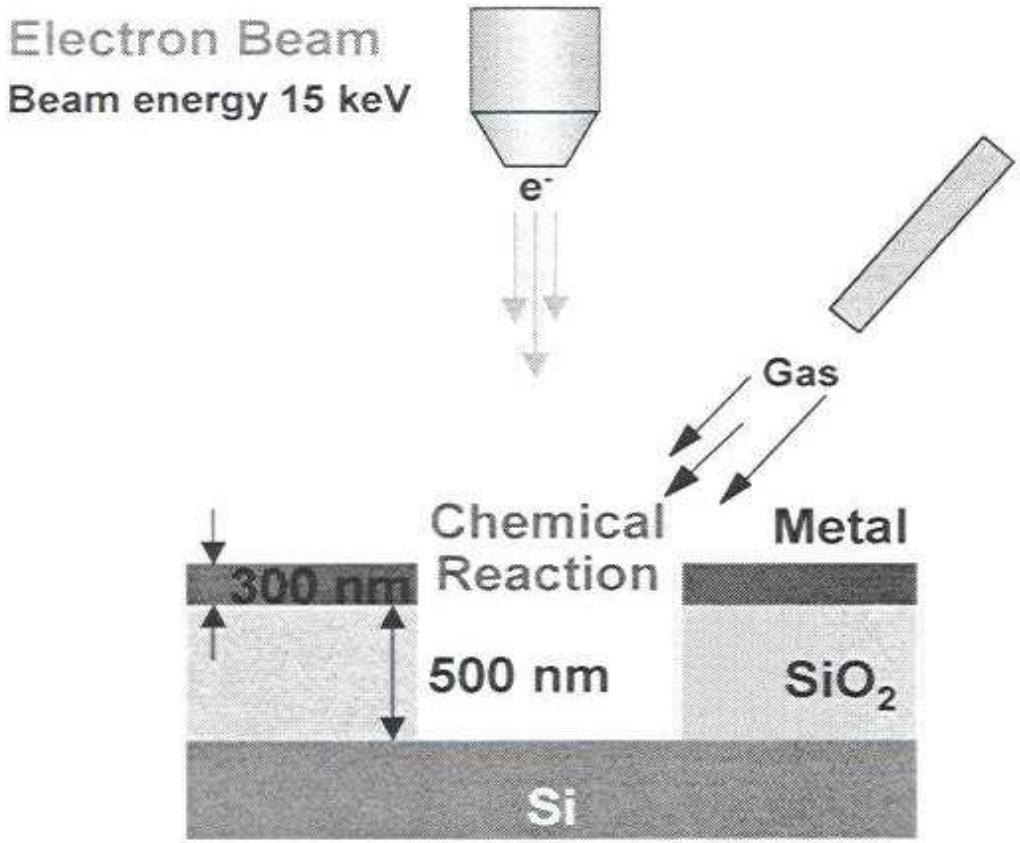
t = 5 s



t = 15 s

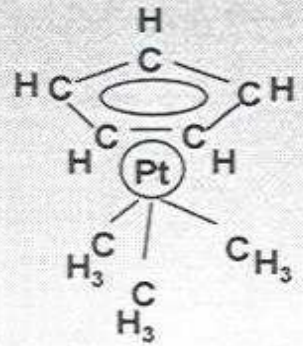
Nano technology: new EDIB

Pt Deposition



Gas Injection System

Gas : $C_5H_5Pt(CH_3)_3$



gas flow

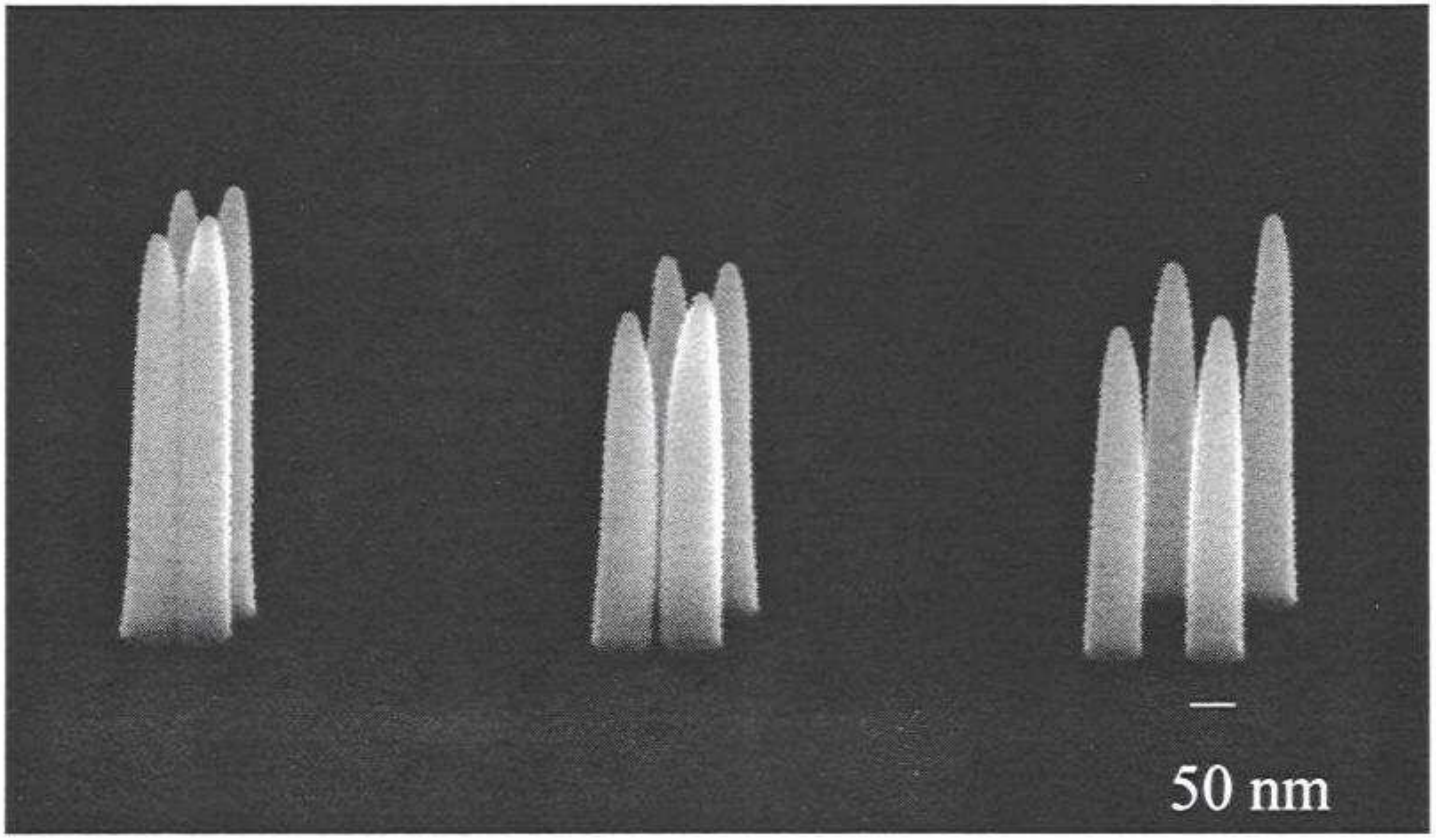
$10^{18} \sim 10^{19}$ molecule / $cm^2 \cdot s$

vapor pressure : 53 mTorr

melting point : 30~31 °C

Nano technology: new EDIB

Pt Pillars by E-Beam Induced Deposition



DualBeam: best of both worlds

- FIB for machining - milling deposition
  - Use a little for imaging
- SEM for imaging, analysis and measuring
  - Used a little for machining - deposition
- Applications in nano technology, polymers, metals, life-science, pharmaceuticals.

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