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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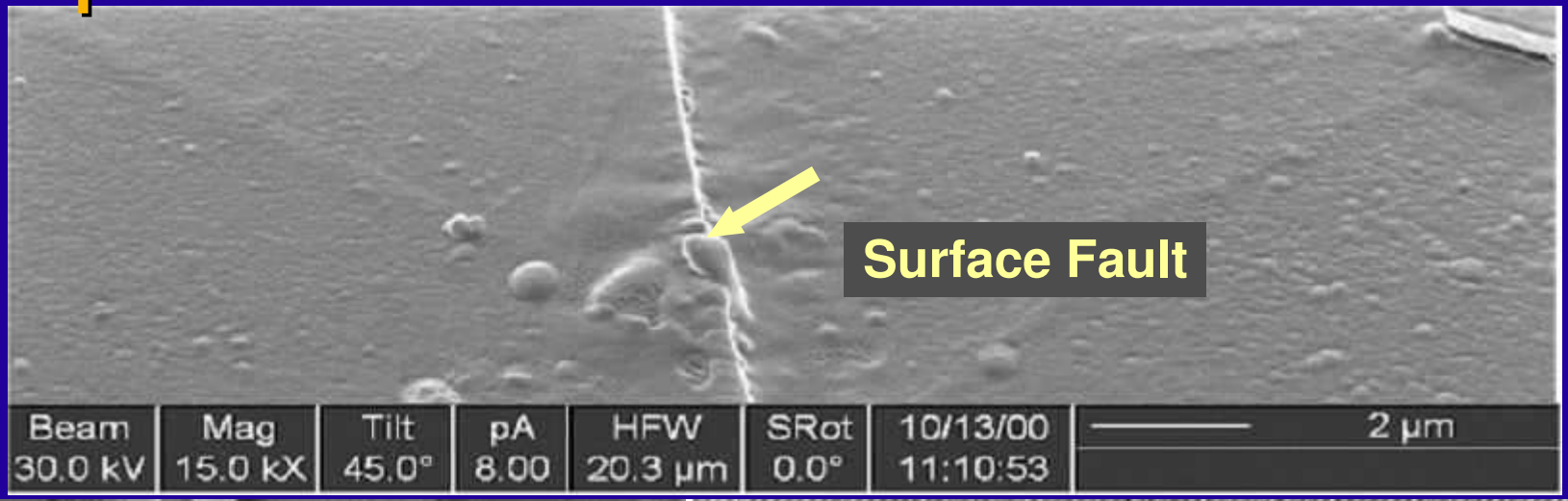
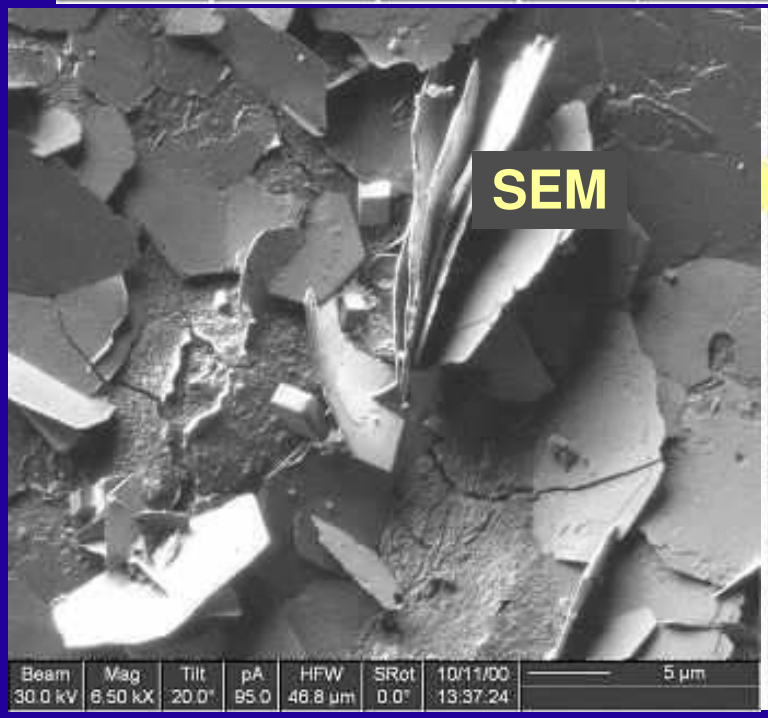
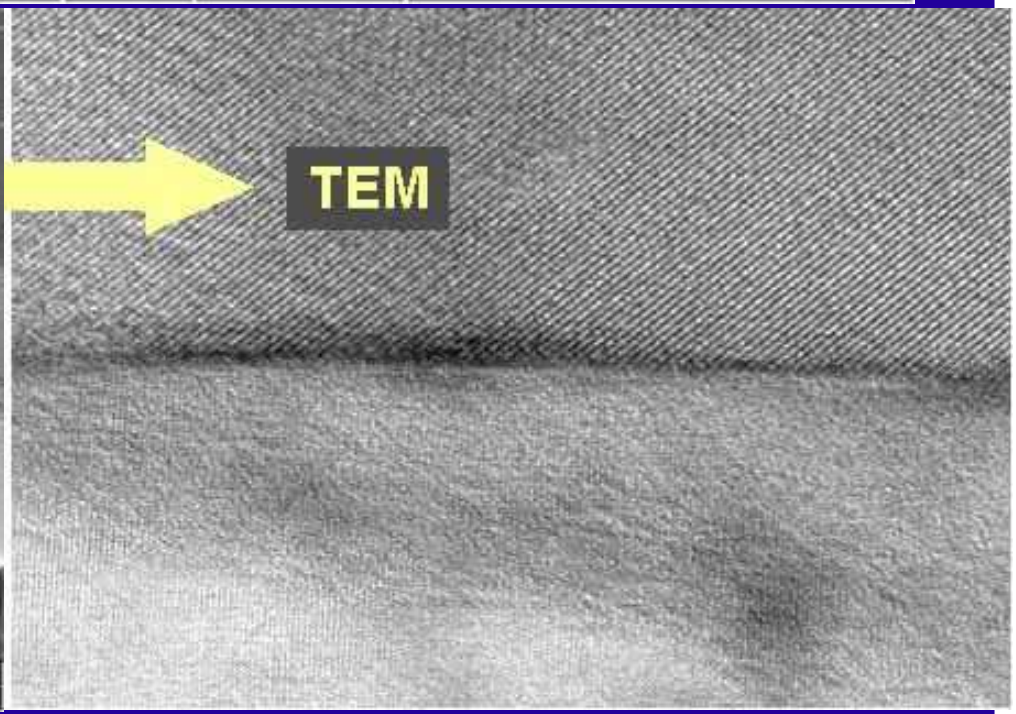
Examples


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°
10/11/00
13:37:24
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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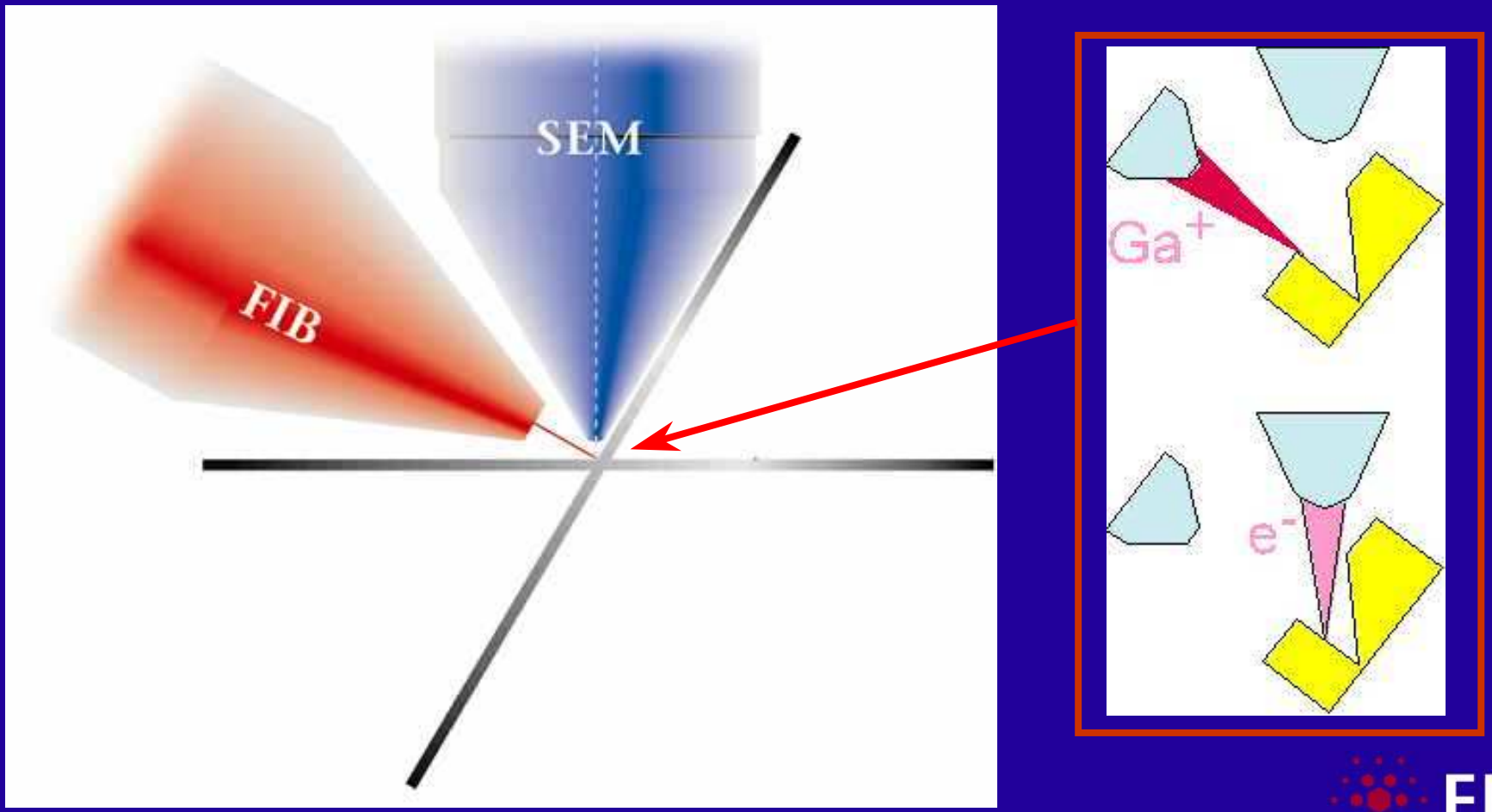
DualBeam geometry



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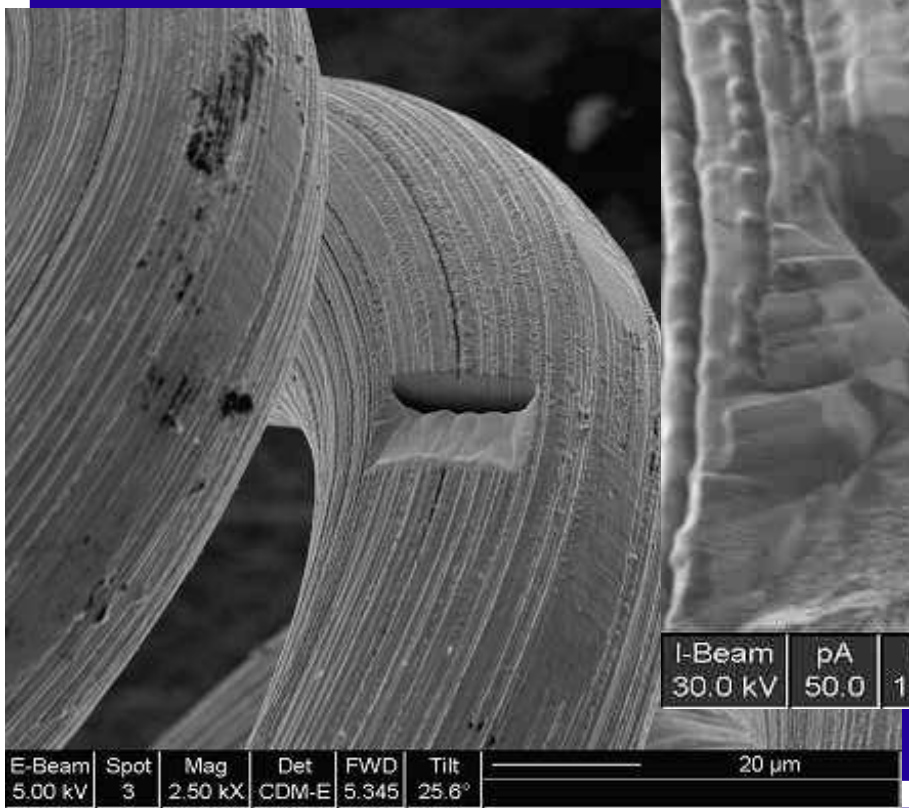
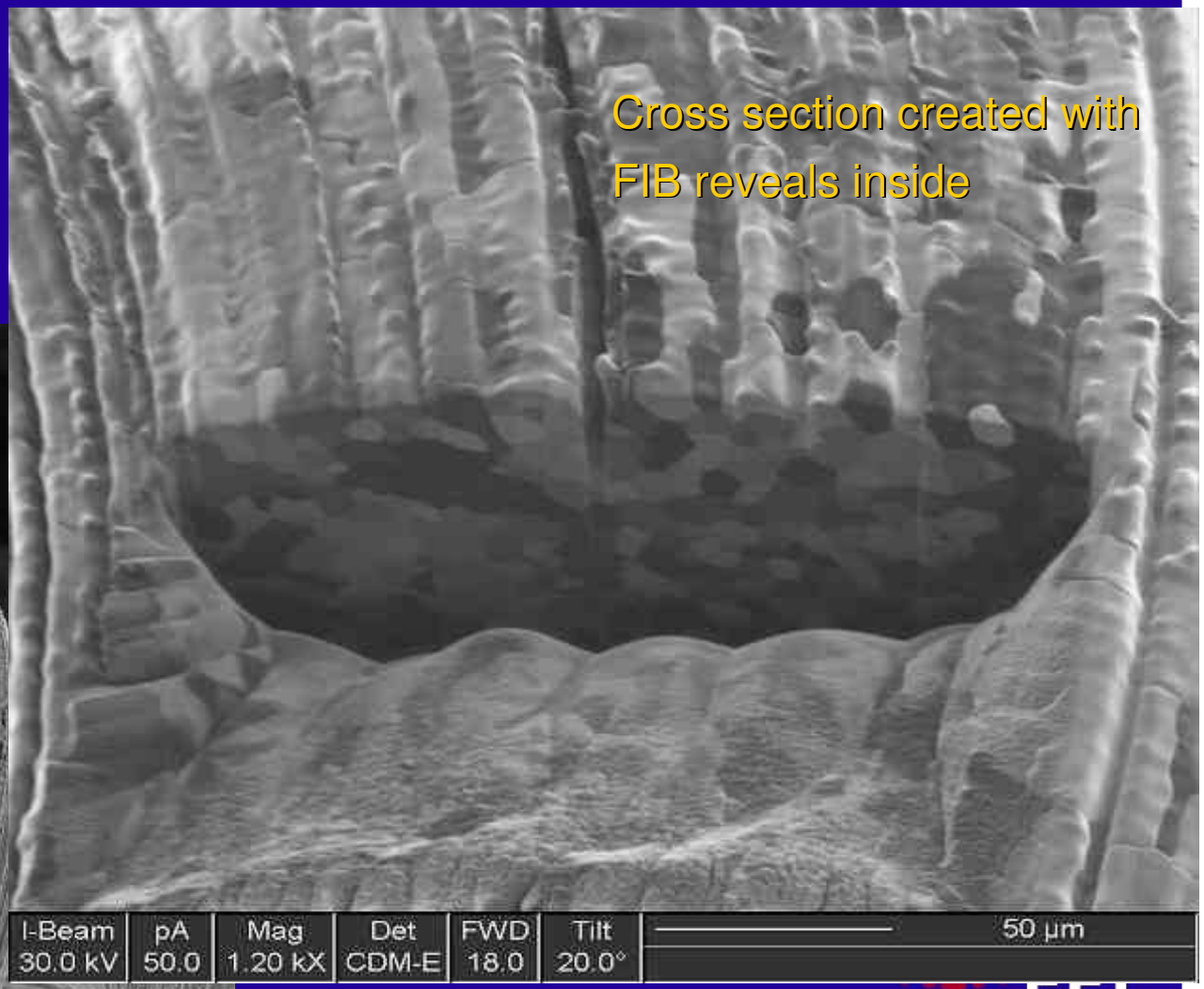
FIB cut -> 3D imaging

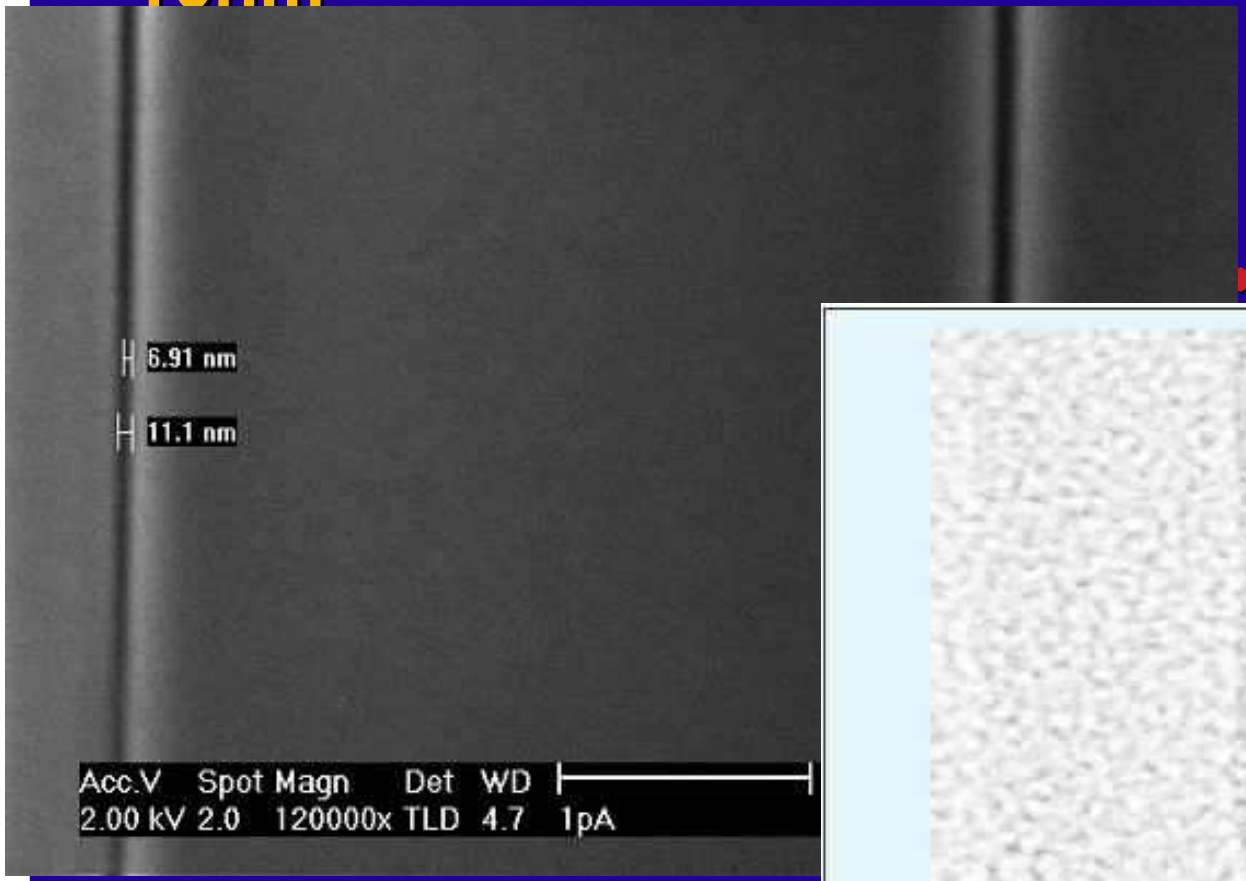
Helix W wire for light bulb



Cross section created with FIB reveals inside

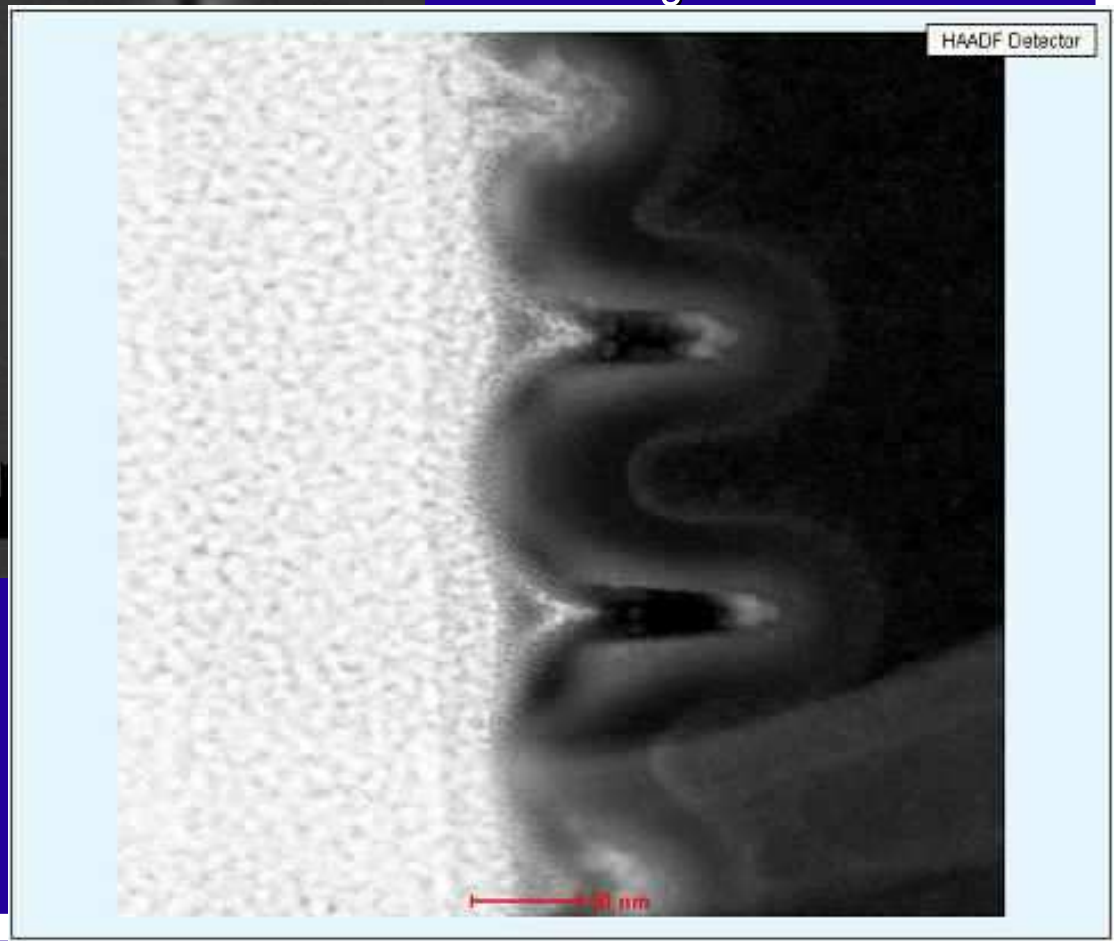


Nano-machining Channel Width ~10nm

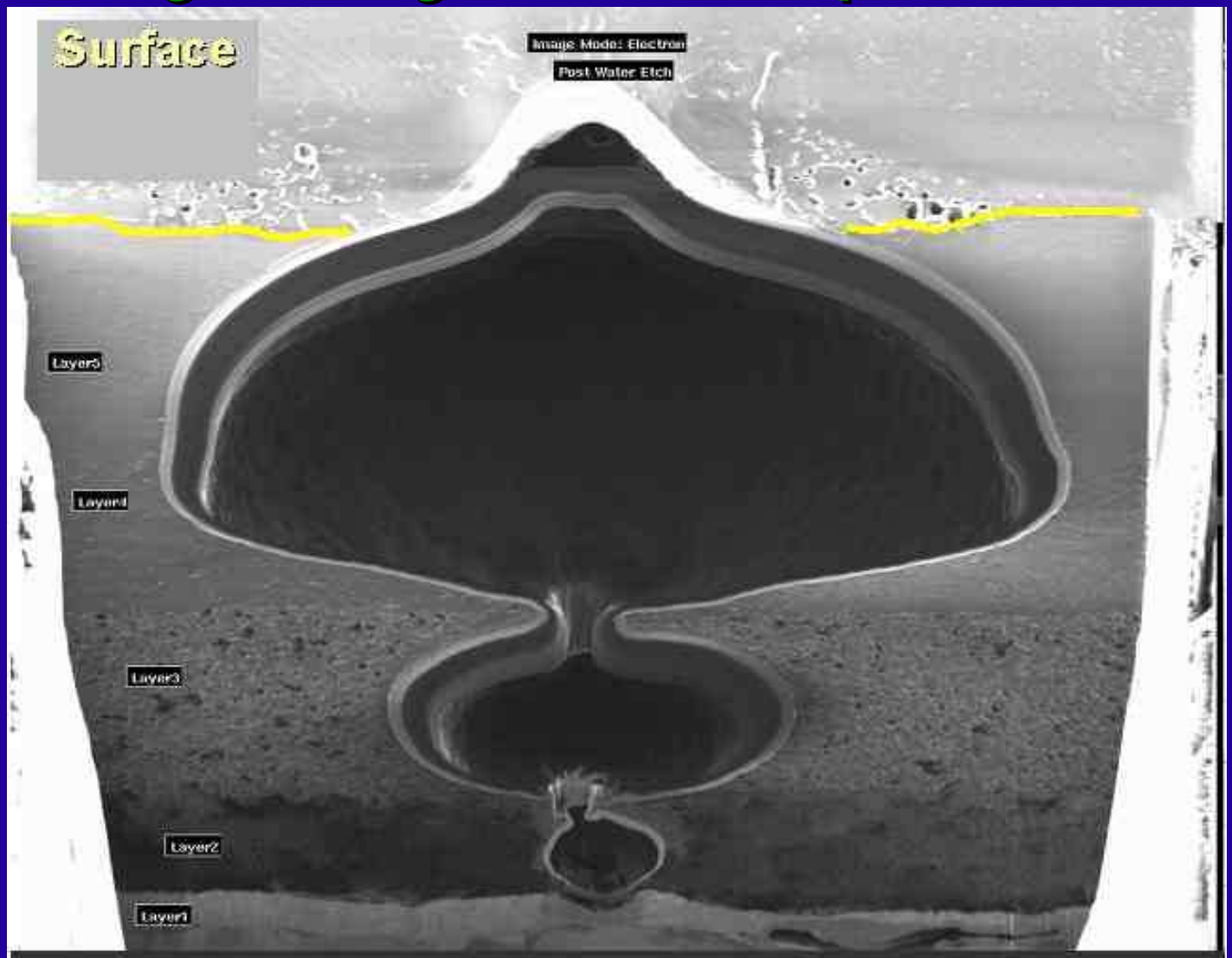


- SEM image of lines milled with 1pA Ga^+ ion beam

- 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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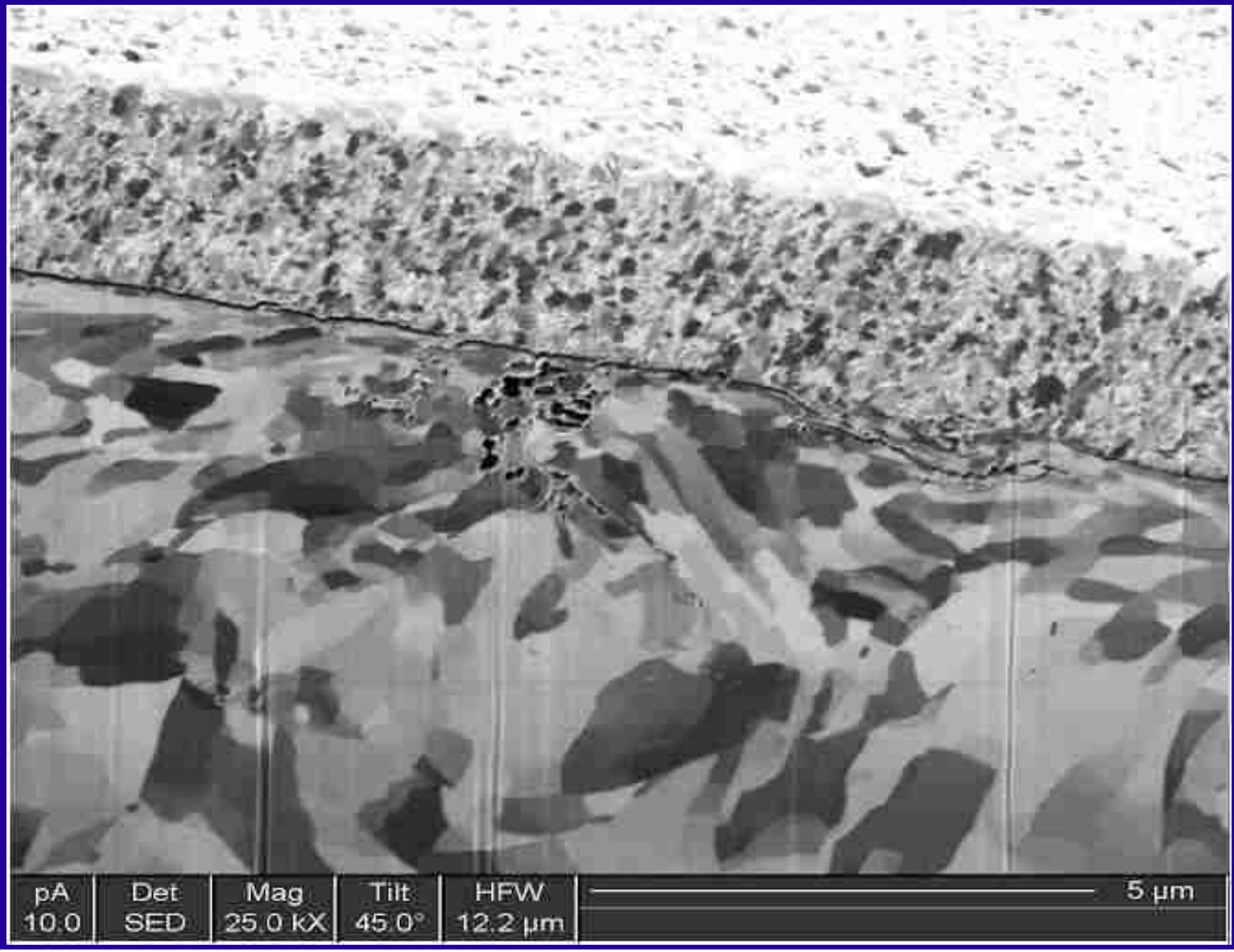
Channeling image contrast



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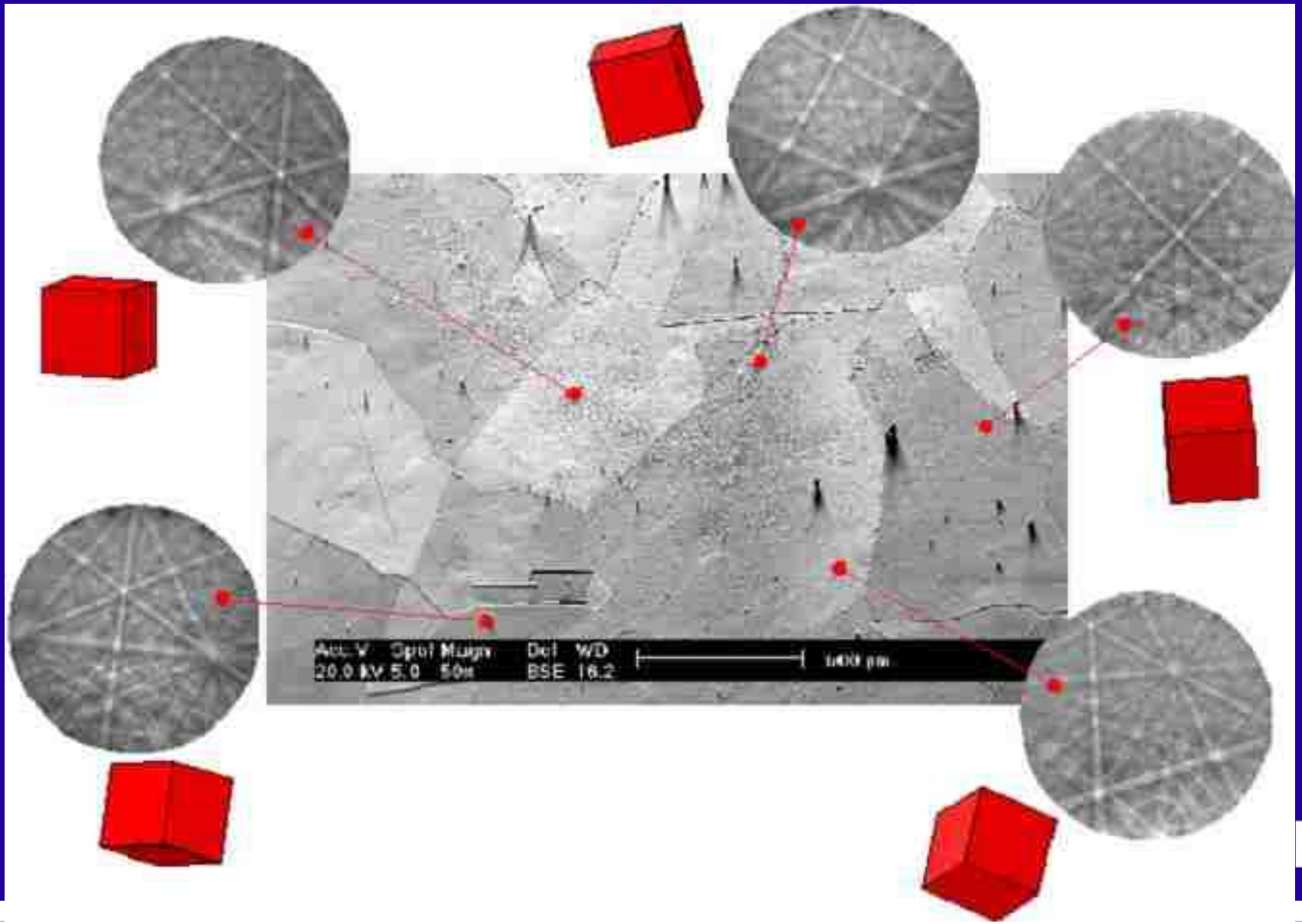
Quantitative micro crystallography - OIM



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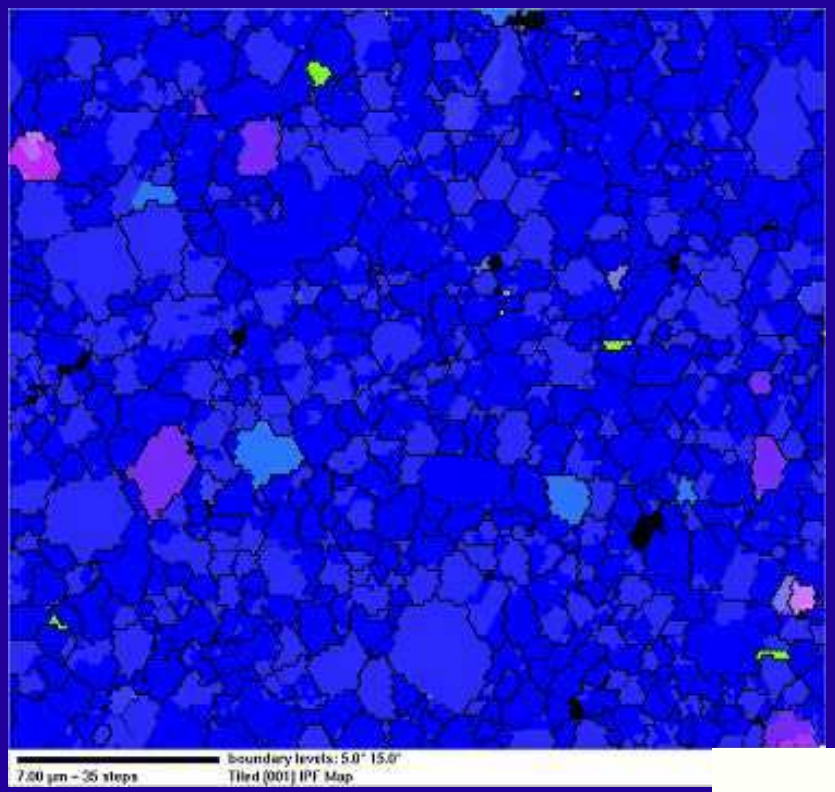
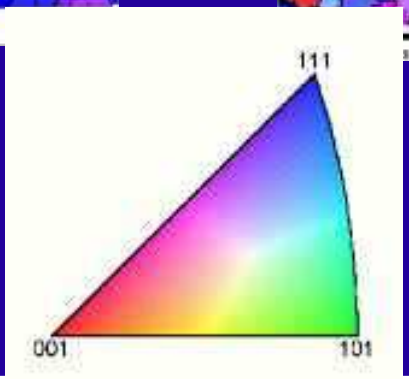
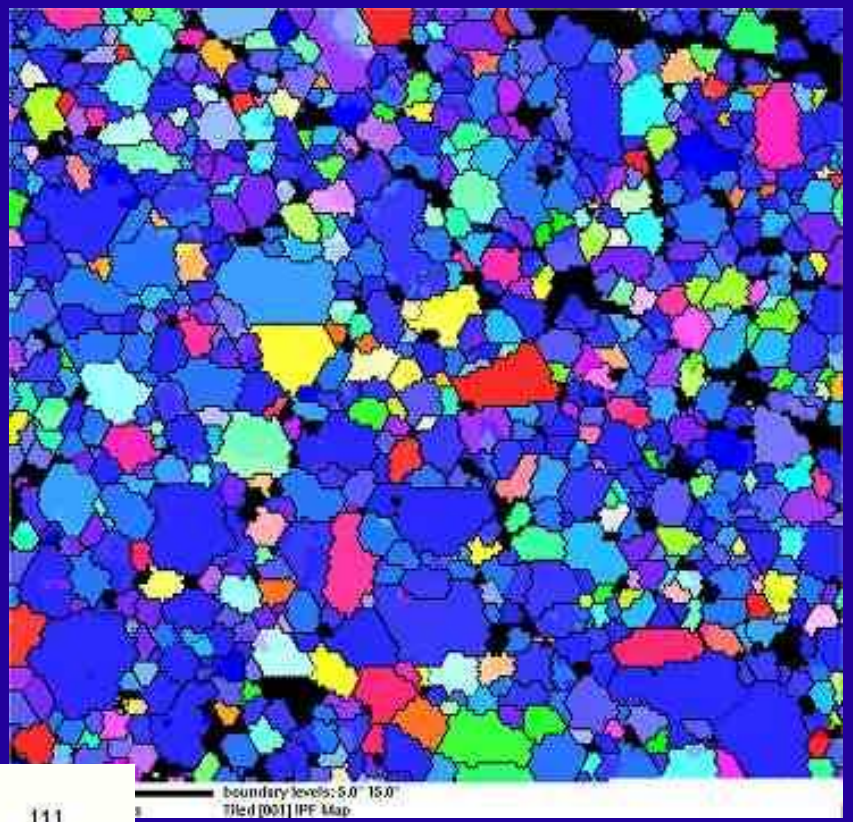
Semi-conductor: Al film for SC



High Mean Time to Failure





Low Mean Time to Failure

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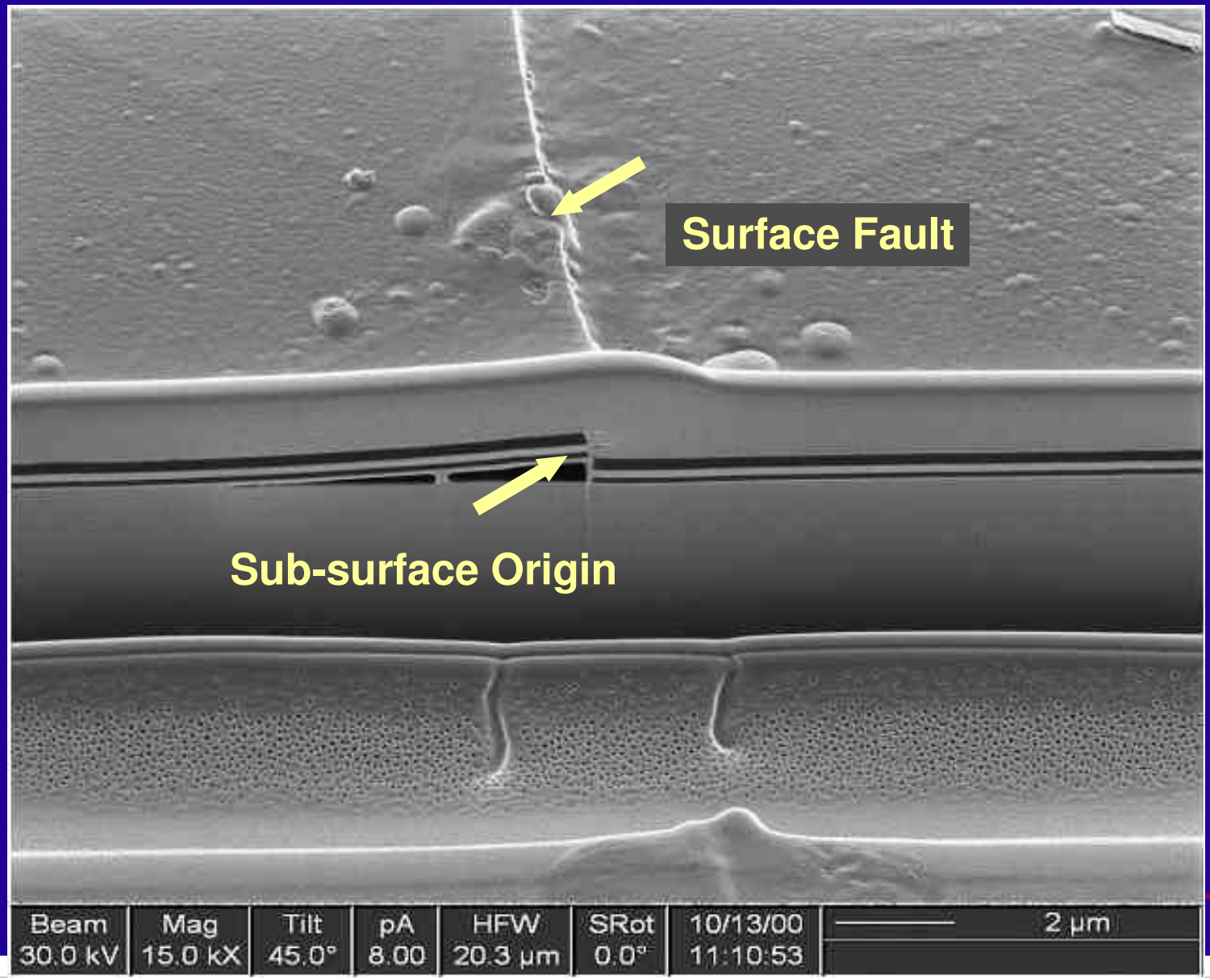
Expose 3rd dimension



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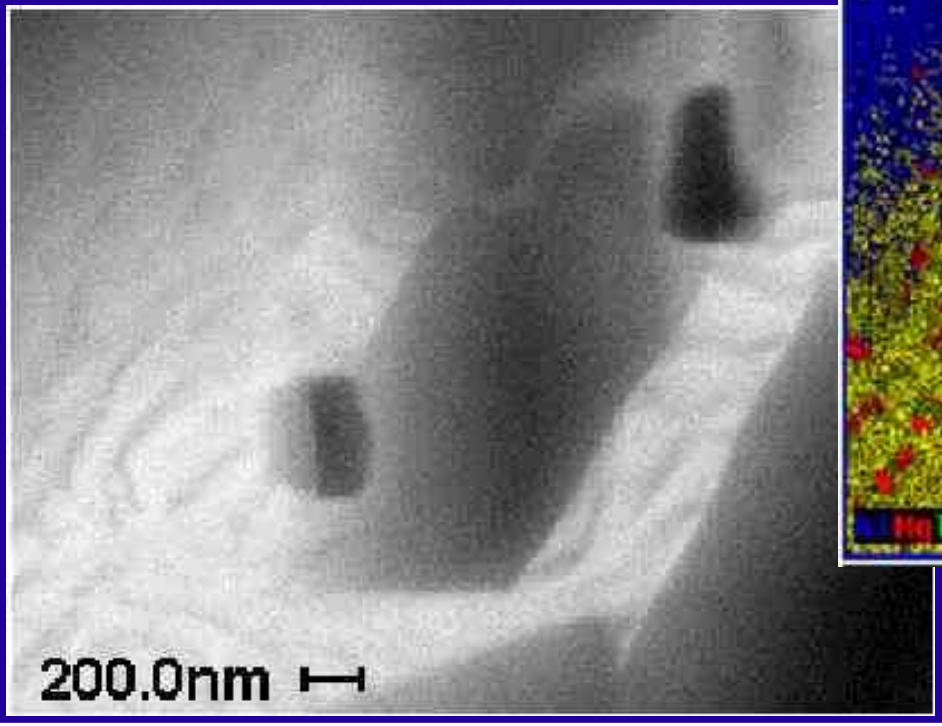
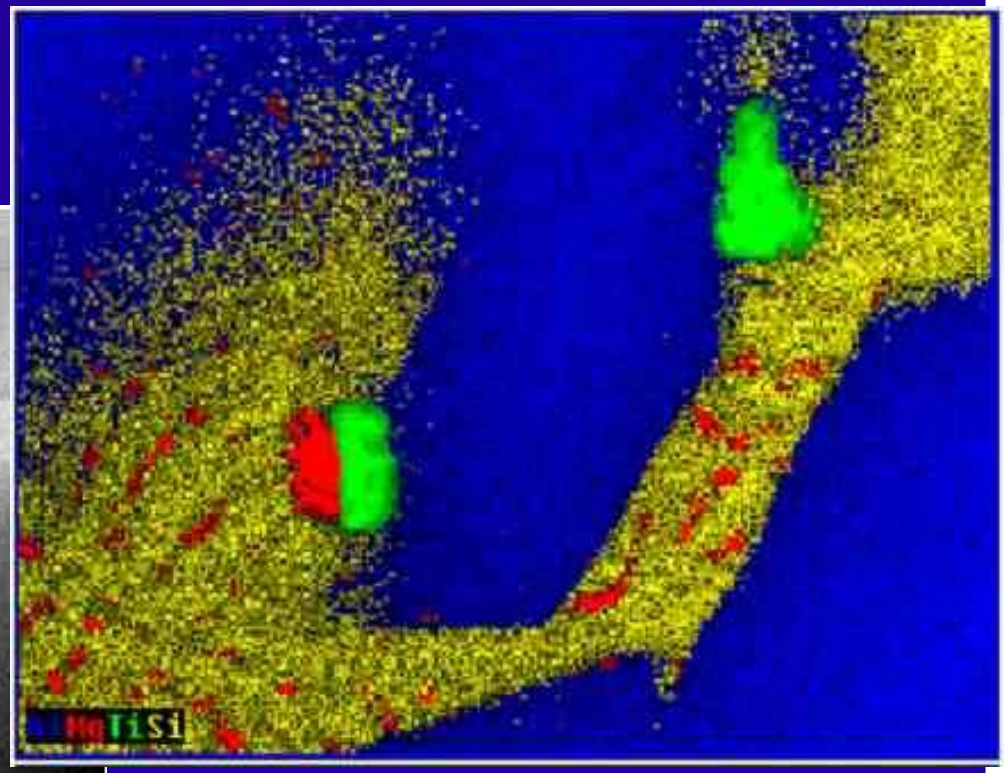
Foil preparation - STEM

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





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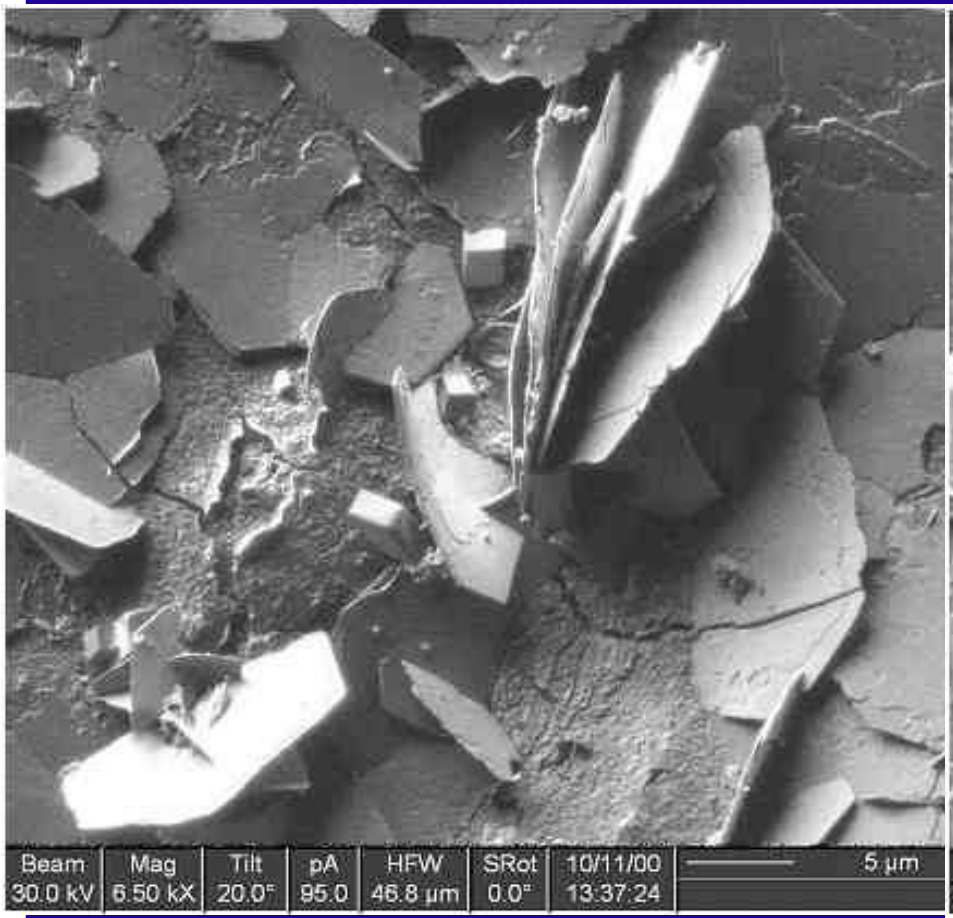
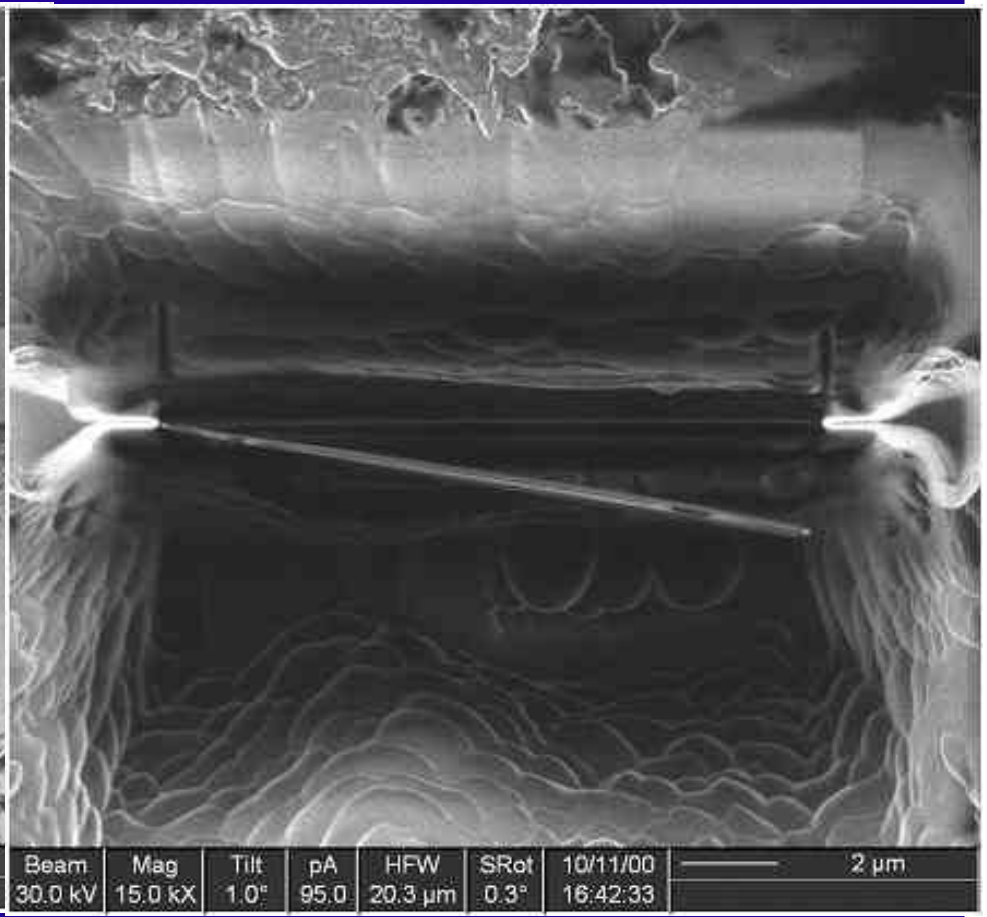
Foil preparation - TEM





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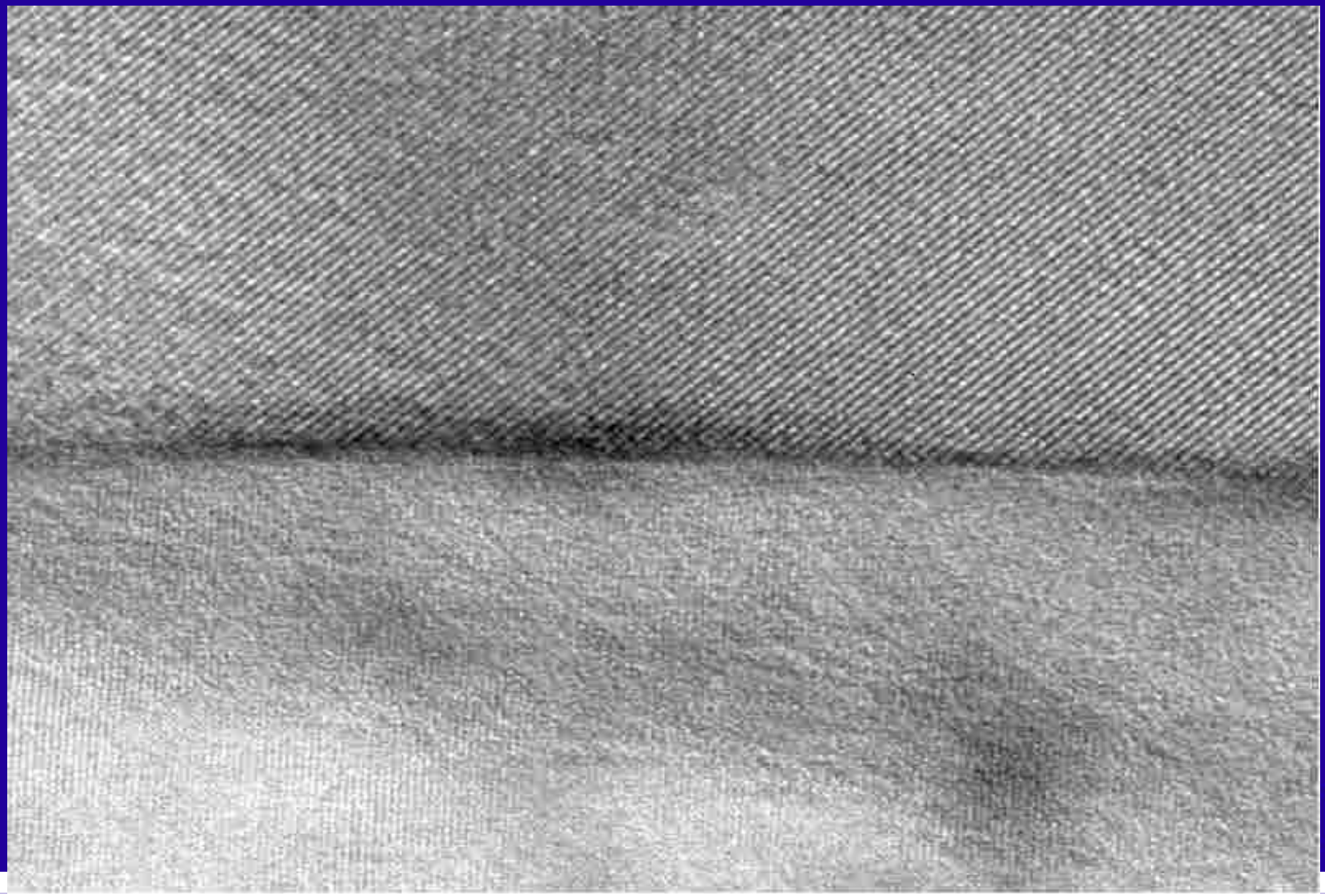
HR TEM image



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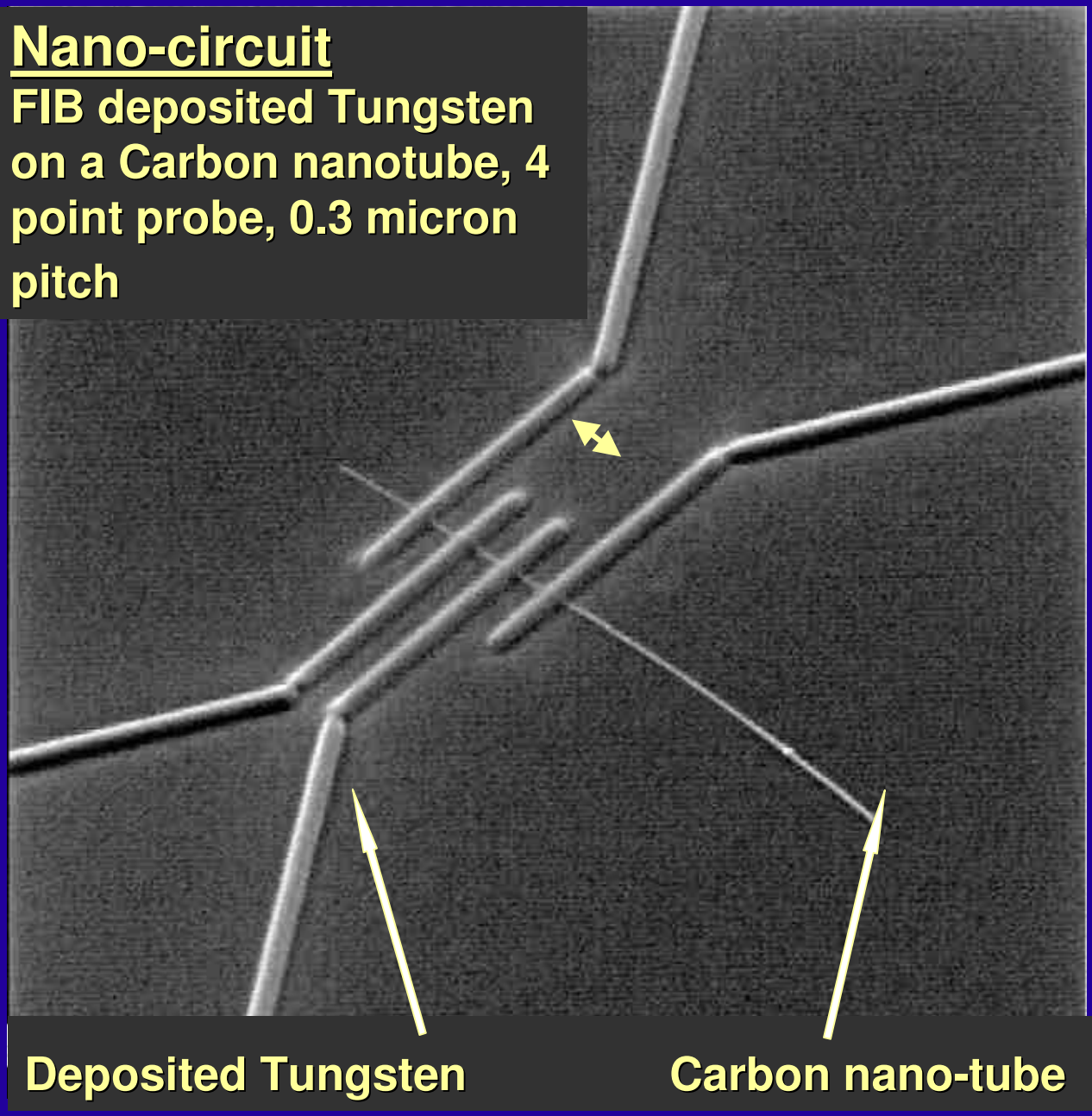
Deposition

- Nanotube probing

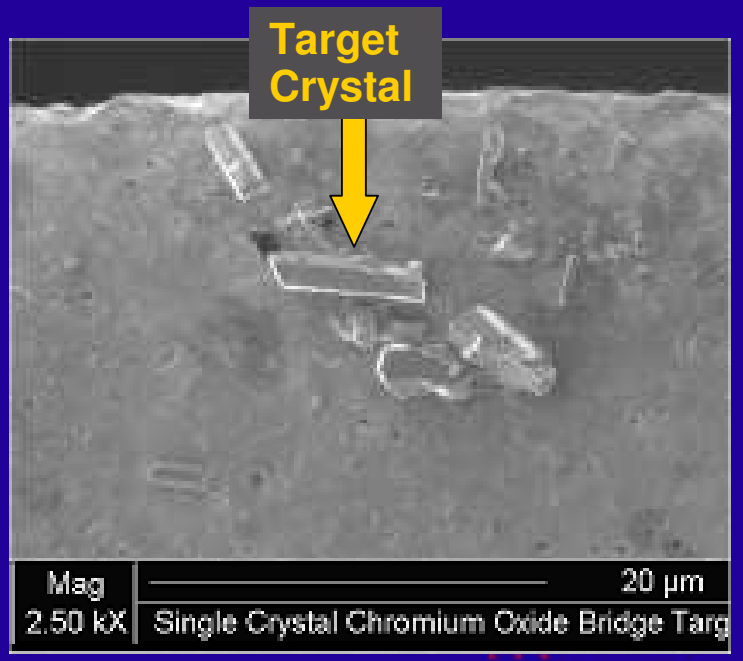
Nano-circuit

FIB deposited Tungsten on a Carbon nanotube, 4 point probe, 0.3 micron pitch



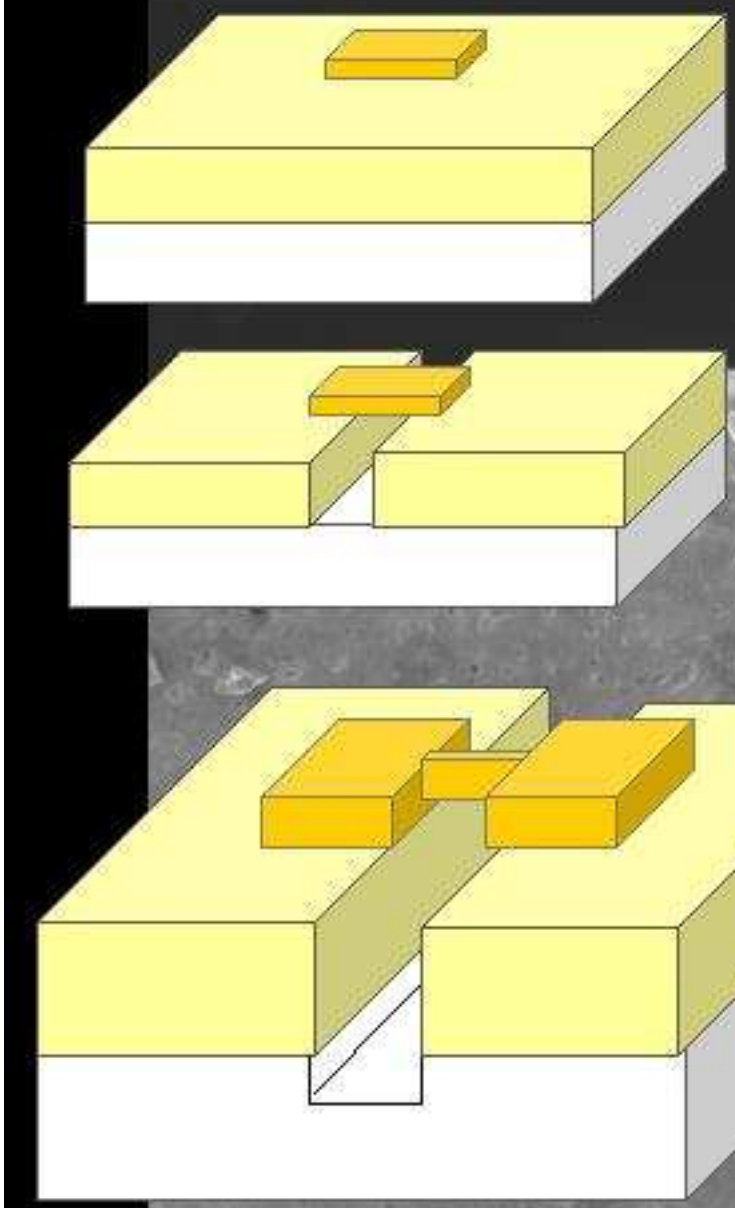
Combined benefits DualBeam - example

- 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

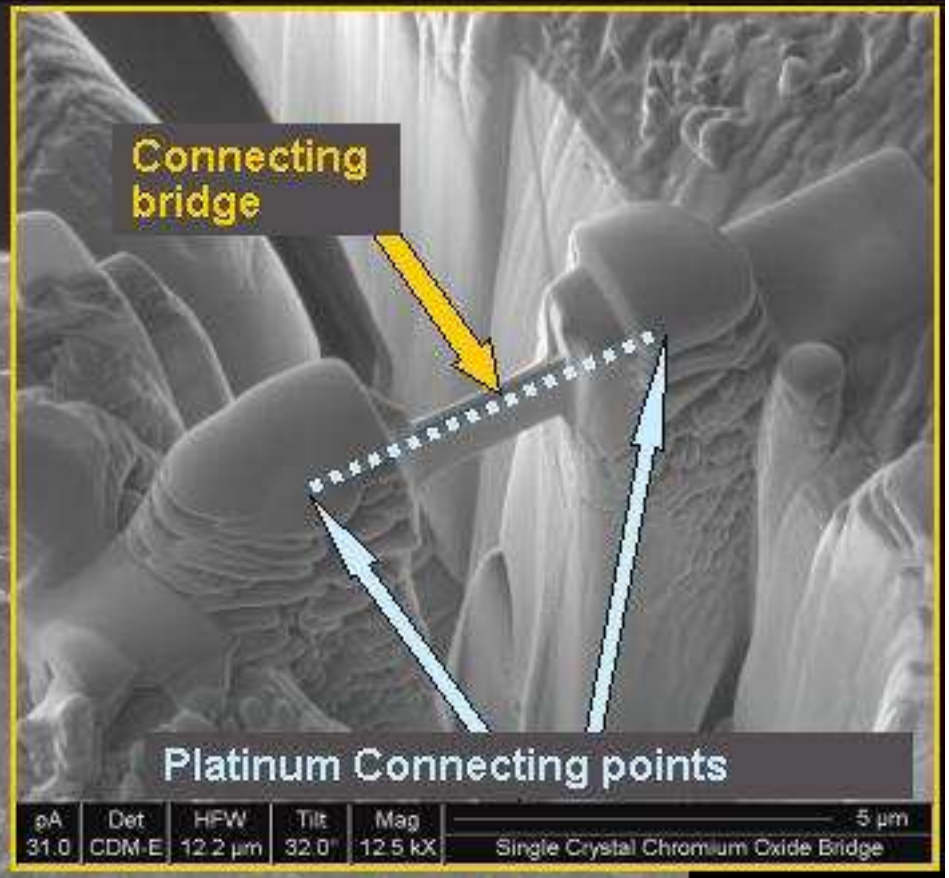


Single crystal measurements:

Electrical properties of Chromium oxide



Target Crystal



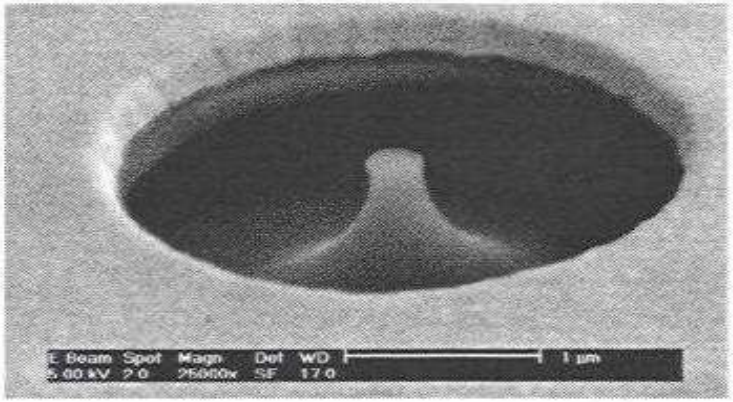
Chromium Oxide Particle
Conducting Substrate
Insulating Substrate

Courtesy of S.Liou, U.Nebraska

20 µm
Single Crystal Chromium Oxide Bridge Target

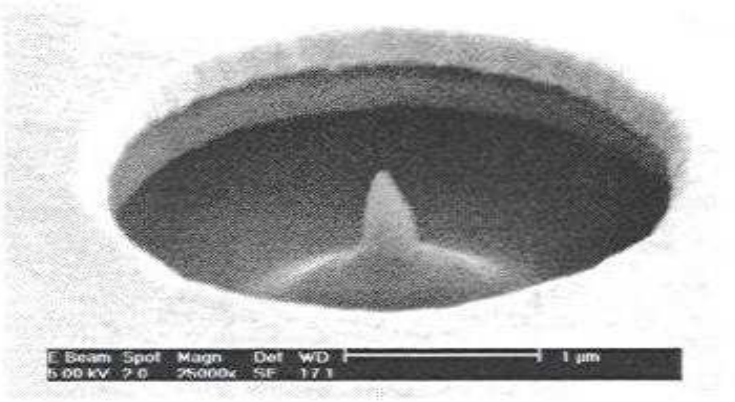
Attempt to sharpen Field emitter array with FIB (Osaka University)

Si FEA after FIB Sharpening

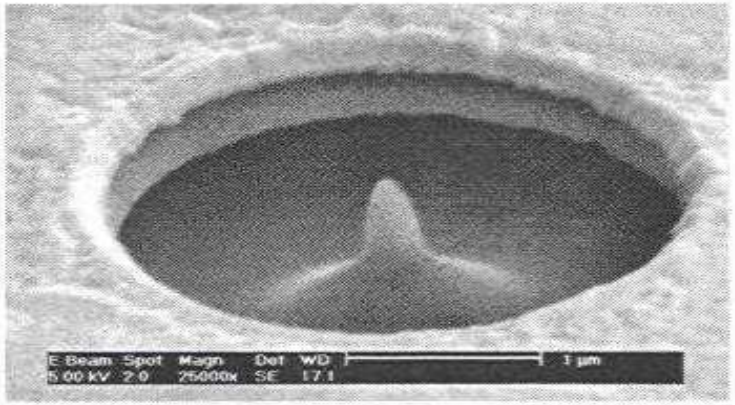


t = 0 s

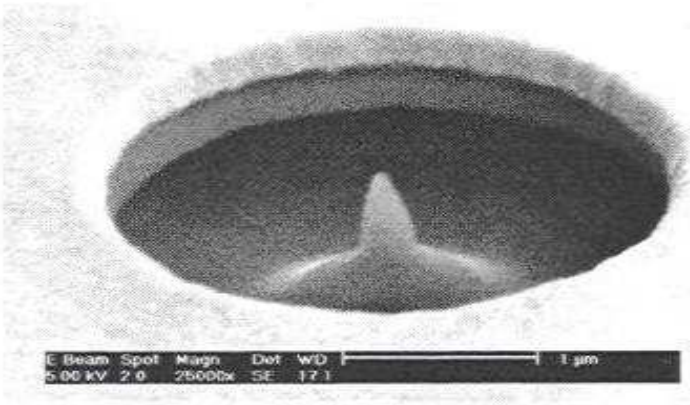
i = 7 pA



t = 10 s



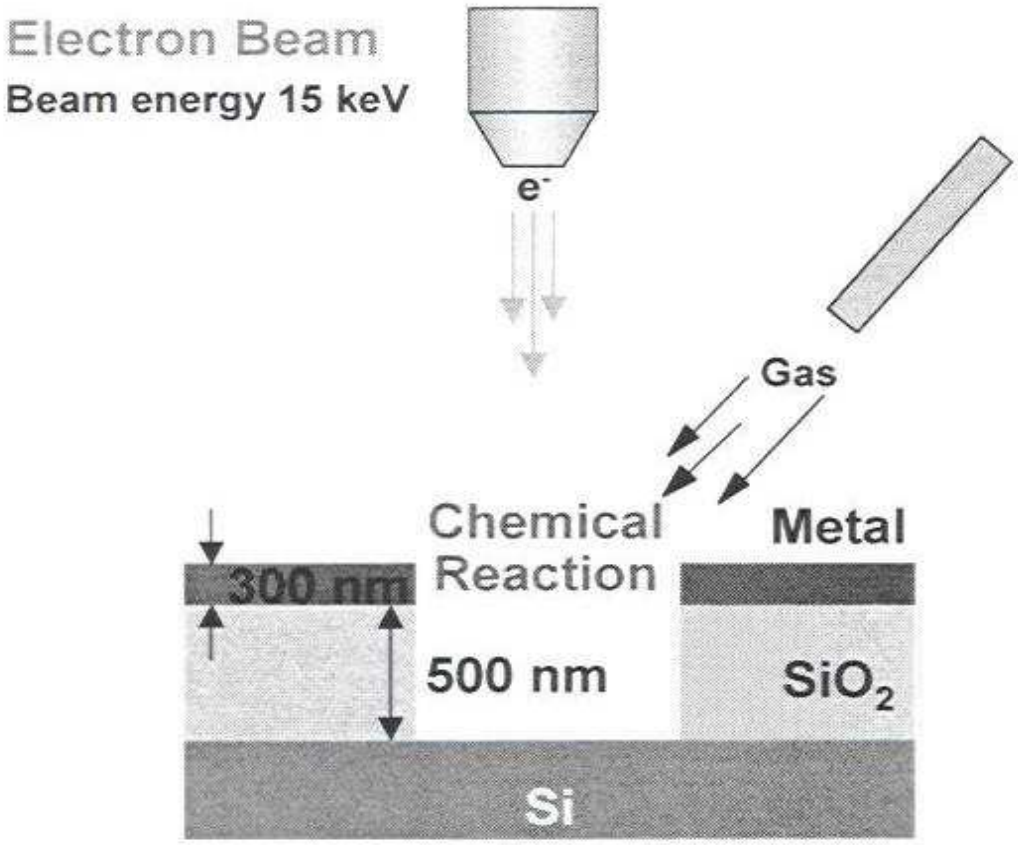
t = 5 s



t = 15 s

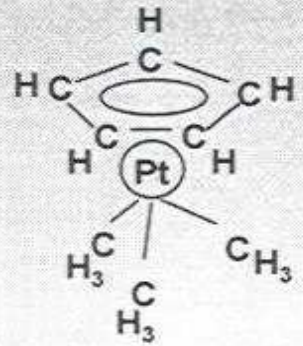
Nano technology: new EDIB

Pt Deposition



Gas Injection System

Gas : $C_5H_5Pt(CH_3)_3$



gas flow

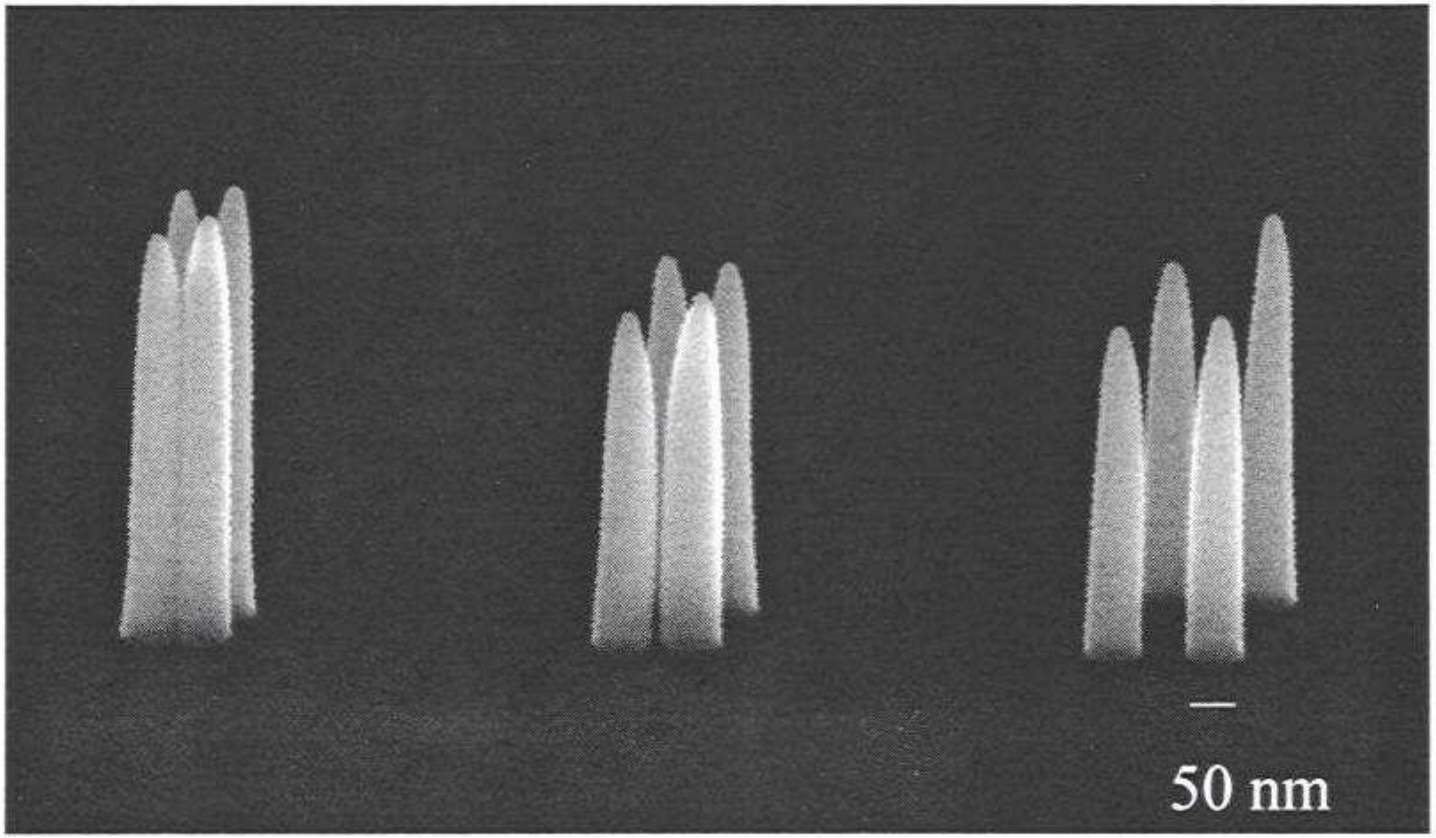
$10^{18} \sim 10^{19}$ molecule / $cm^2 \cdot s$

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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