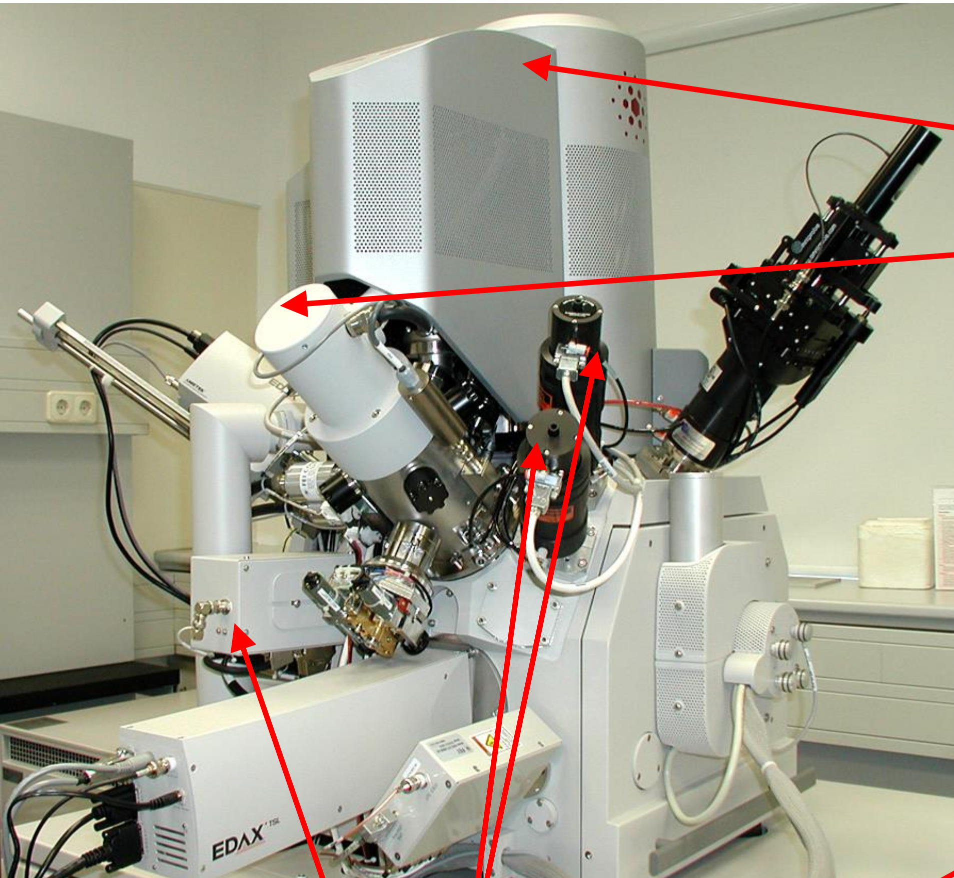
Focused ion beam machining

FEI Quanta 3D SEM/FIB

Zoltán Dankházi

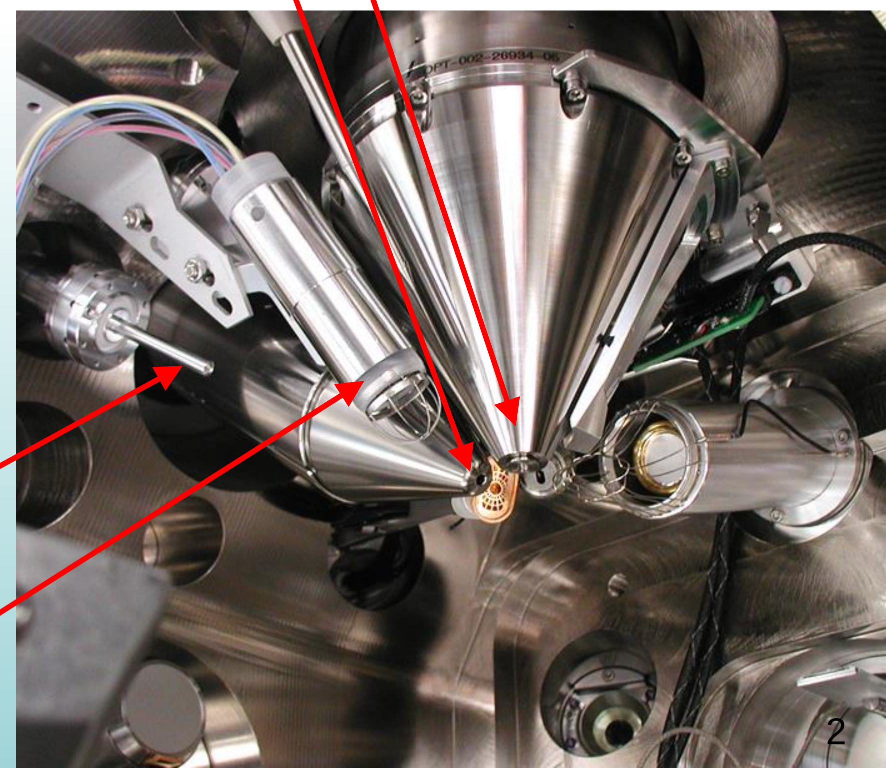
FIB = Focused Ion Beam (Fókuszált ionnyaláb)



What does an SEM/FIB consist of??

electron column

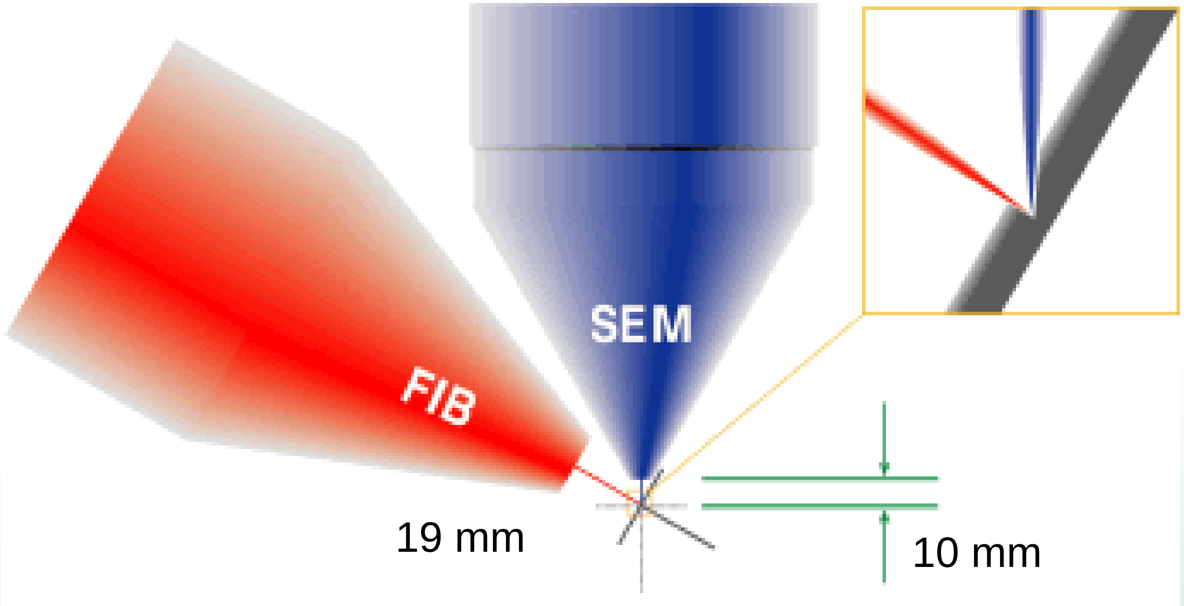
ion column



gas injectors

detector – CDEM (SE, SI)

Dual-Beam System (Kétsugaras mikroszkóp)



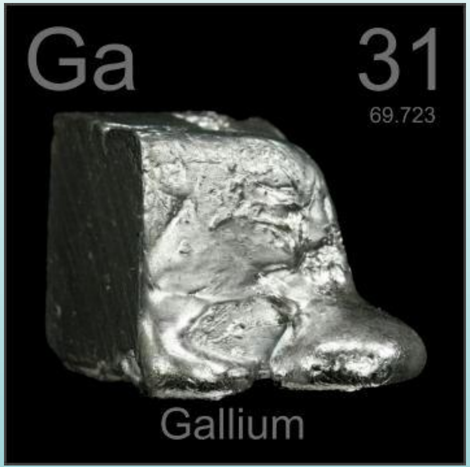
Electron beam – vertically
Ion beam – closes 52° with the vertical → To see the sample perpendicularly by the FIB, the sample must be tilted by 52° → Coincidence of two beams

LMIS = Liquid Metal Ion Source (Folyékony fémion forrás)

Most commonly used metal ion in FIB devices: Ga^+

<u>Why Ga^+?</u>

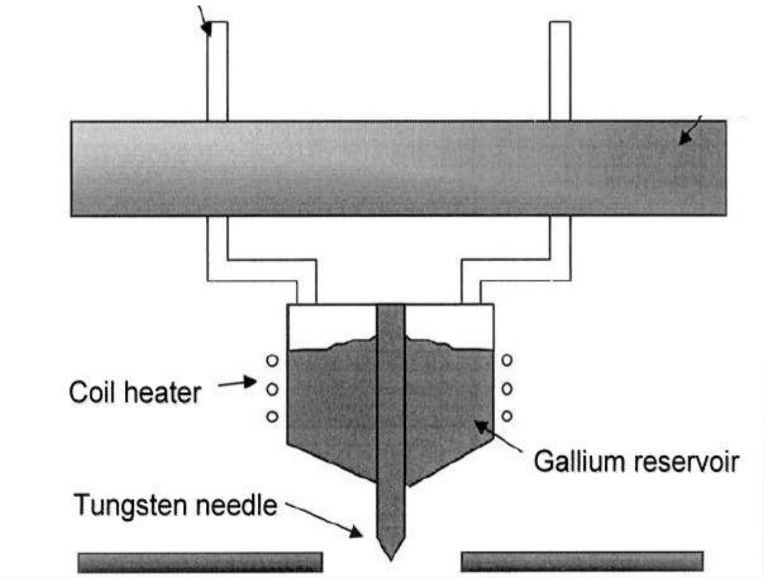
- Low melting point (T_{melt} = 29.8 °C)
- Minimal interaction with the tungsten needle
- Non-volatile, low vapor pressure
- Low surface tension
- Viscous enough
- Easy to supercool (Ga stays liquid for weeks)



LMIS = Liquid Metal Ion Source (Folyékony fémion forrás)

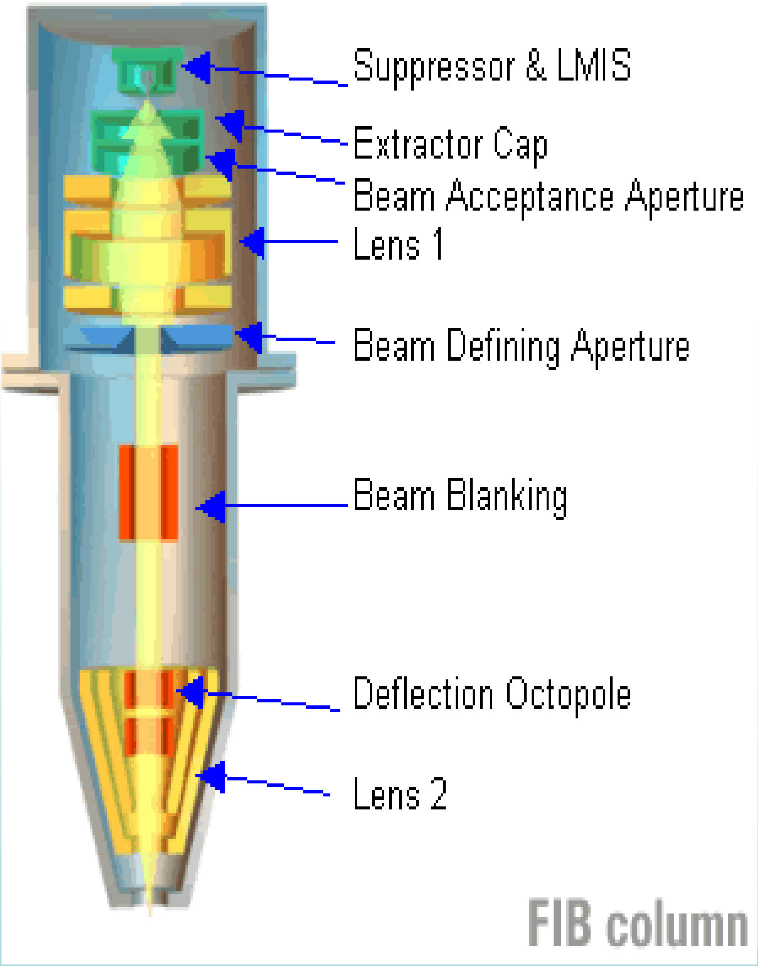
<u>How It Works?</u>

- Ga liquid wets the needle
  needle diameter: 2-5 μm
- A field of 10^8 V/cm forms Ga as a point source
  with a diameter of 2-5 nm
- Extraction voltage ionizes the atoms and
  starts the Ga current (10^8 A/cm^2)
- Low emission: 1-3 μA lower energy scatter,
  more stable beam
- In the beam: ions, neutral atoms, charged 'clusters'
  (the higher the current, the more)
- Ga is running out! If the beam can no longer be maintained, reheat, increase the
  pull-out voltage or replace the Ga tank; average lifespan: 400 hours



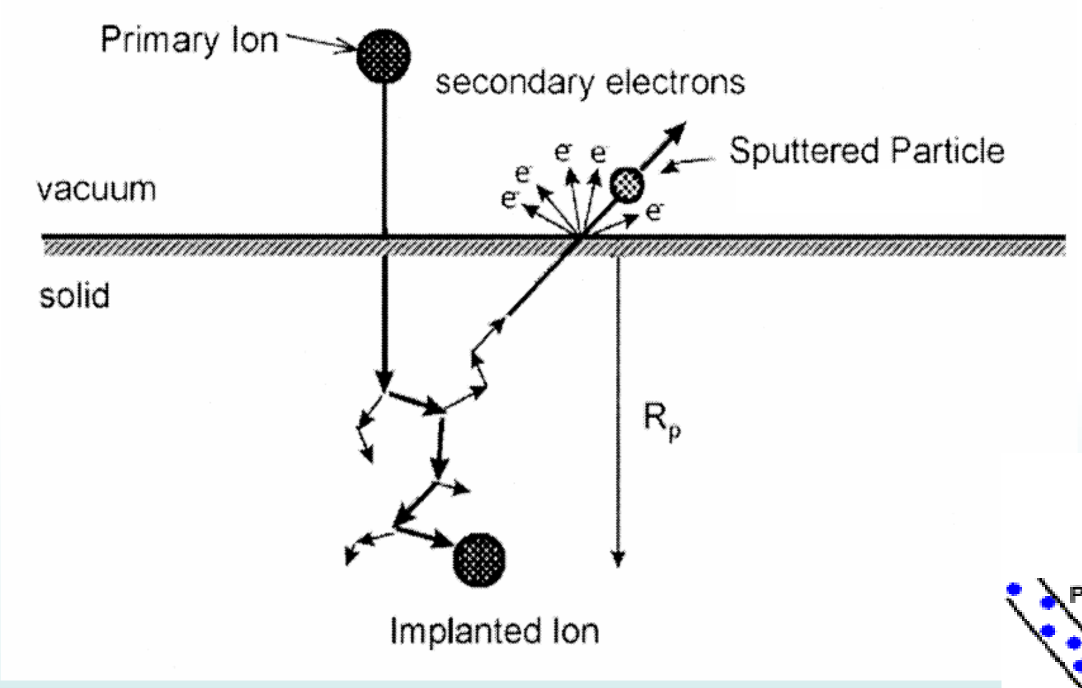
Extraction voltage
electrodes

Ion column



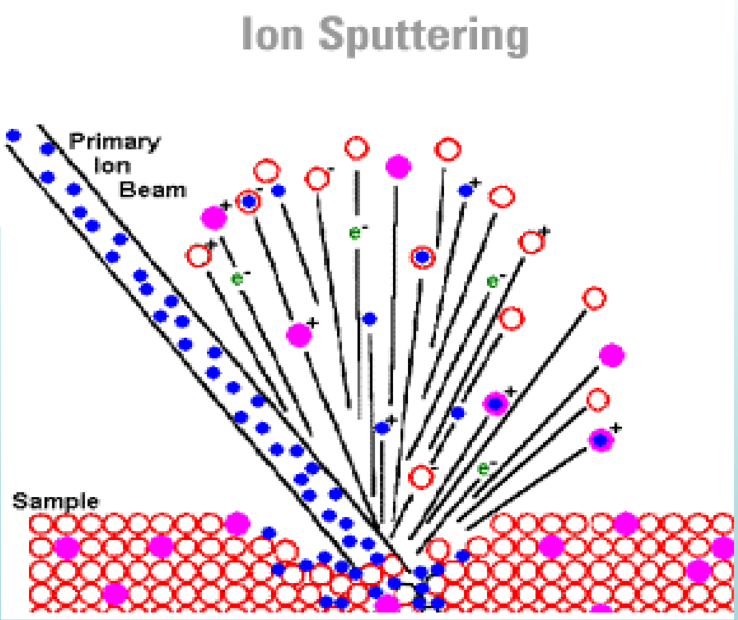
- Accelerating voltage in the column: 2-30 kV
- There are usually two lenses: a condenser and a objective
- Condenser lens shapes the beam
- Objective lens focuses the beam on the sample
- The ion current can be adjusted with apertures from 1.5 pA to 65 nA
- Working distance large: 19 mm (10 mm for electron beam)

Ion beam – matter interaction (ion-atom collision)



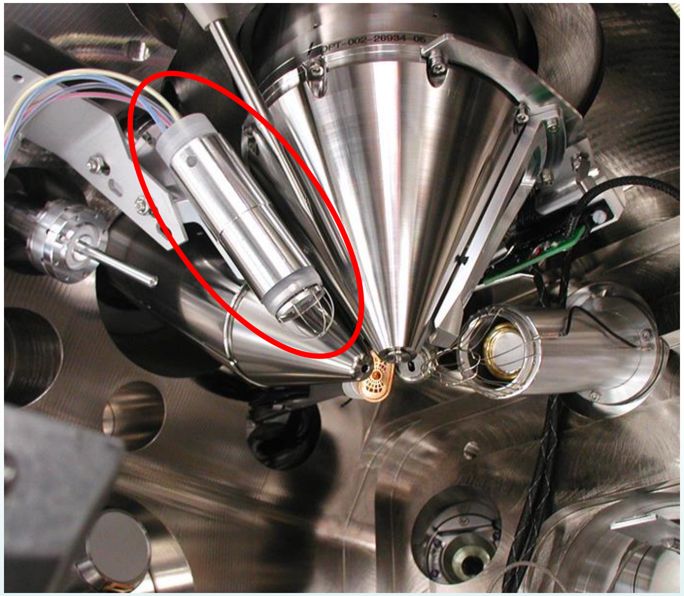
and charged or neutral atomized particles, 'clusters', X-ray photons.

Depth: 10-20 nm (30 keV)

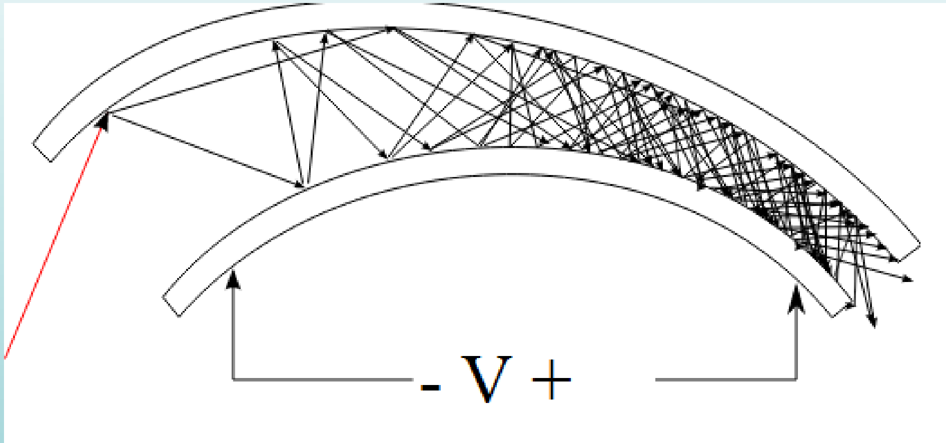


With a sufficiently high current ion beam, the sample material can be effectively removed.

What can be done with ion beams?



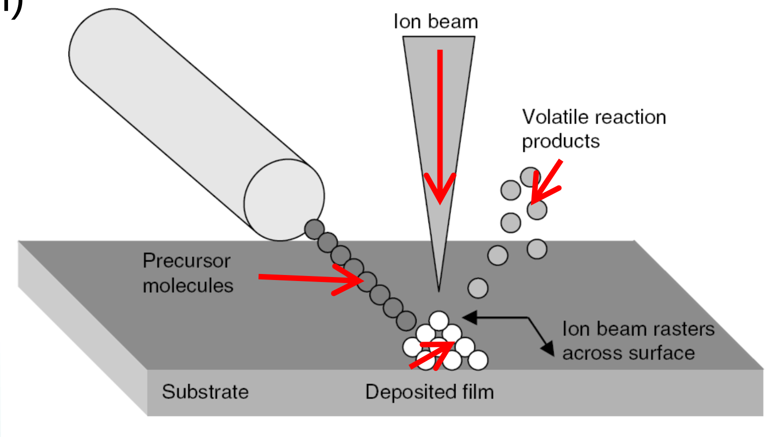
- Imaging
  - CDEM (Continuous Dynode Electron Multiplier): SE, SI (secondary electrons, secondary ions)
  - ETD (Everhart-Thornley Detector): (secondary electrons)



- Gas chemistry
- Preparing cross-section
- TEM sample preparation
- Tomography (3D visualization)
- Etching with bitmap mask

CVD – Chemical Vapour Deposition (Gázkémia)

Different materials (carbon, insulating compound, platinum) can be deposited on the surface of the sample in the nanometer size range.

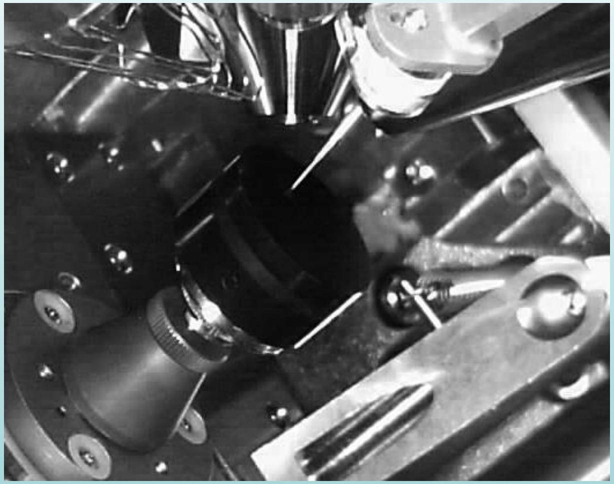


What is it good for?

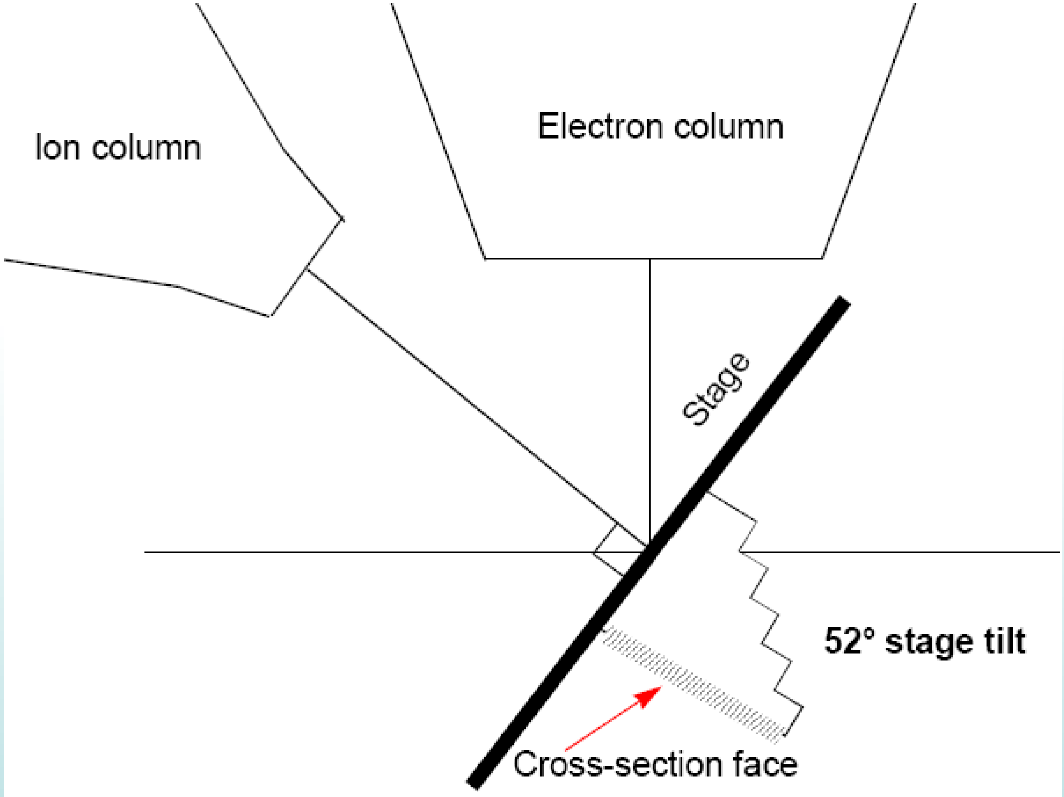
- Nanolithography
- Protects the sample during ion beam machining (more precise lines)

How does it work?

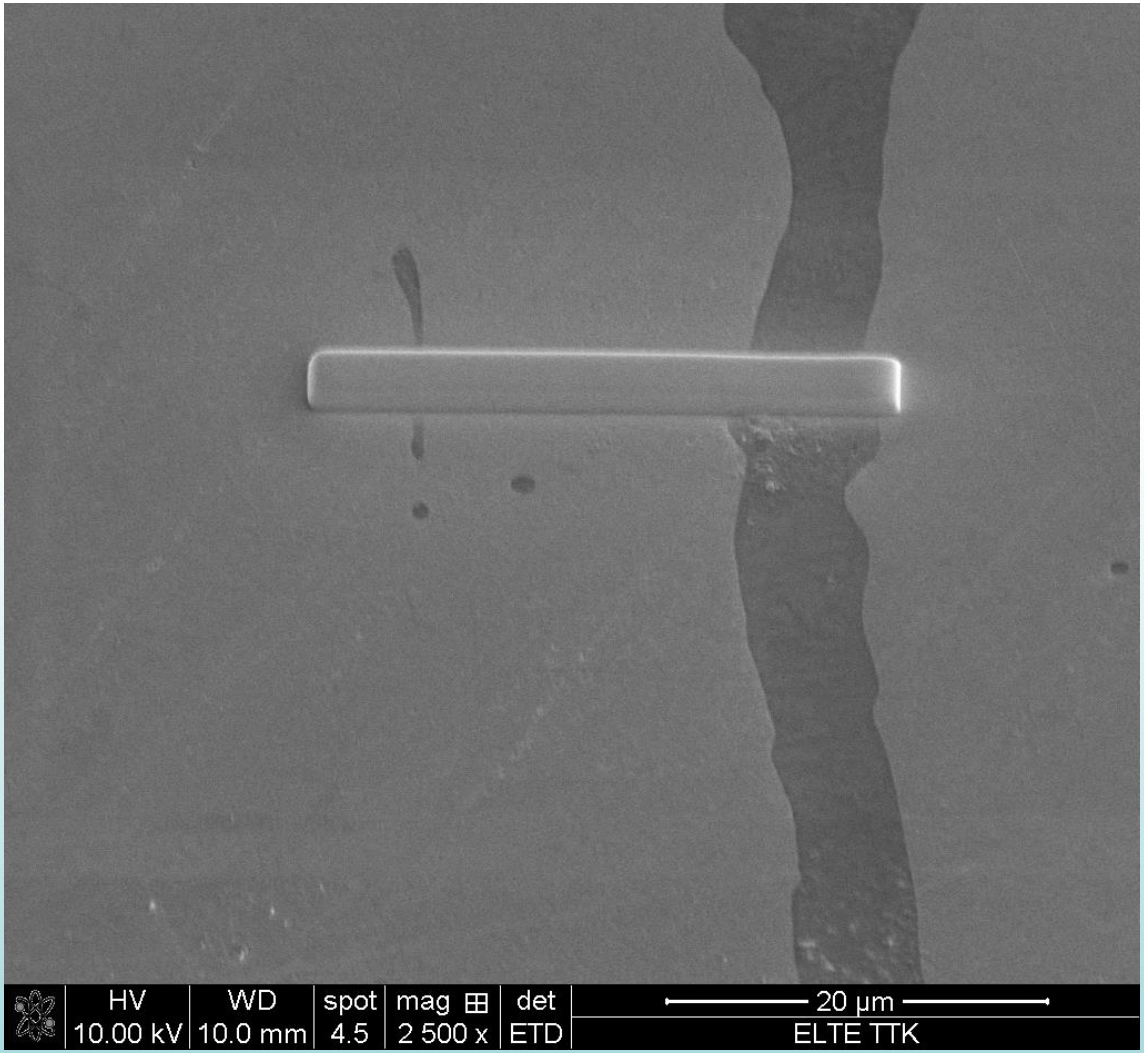
- The needle approaches the sample (50-200 μm)
- Precursor gas delivers to the surface
- The ion beam scans the surface, causing the precursor to decompose into volatile molecules and material destined for the surface
- The deposited material remains on the surface



Preparing a cross section



Platinum layer evaporated on the surface



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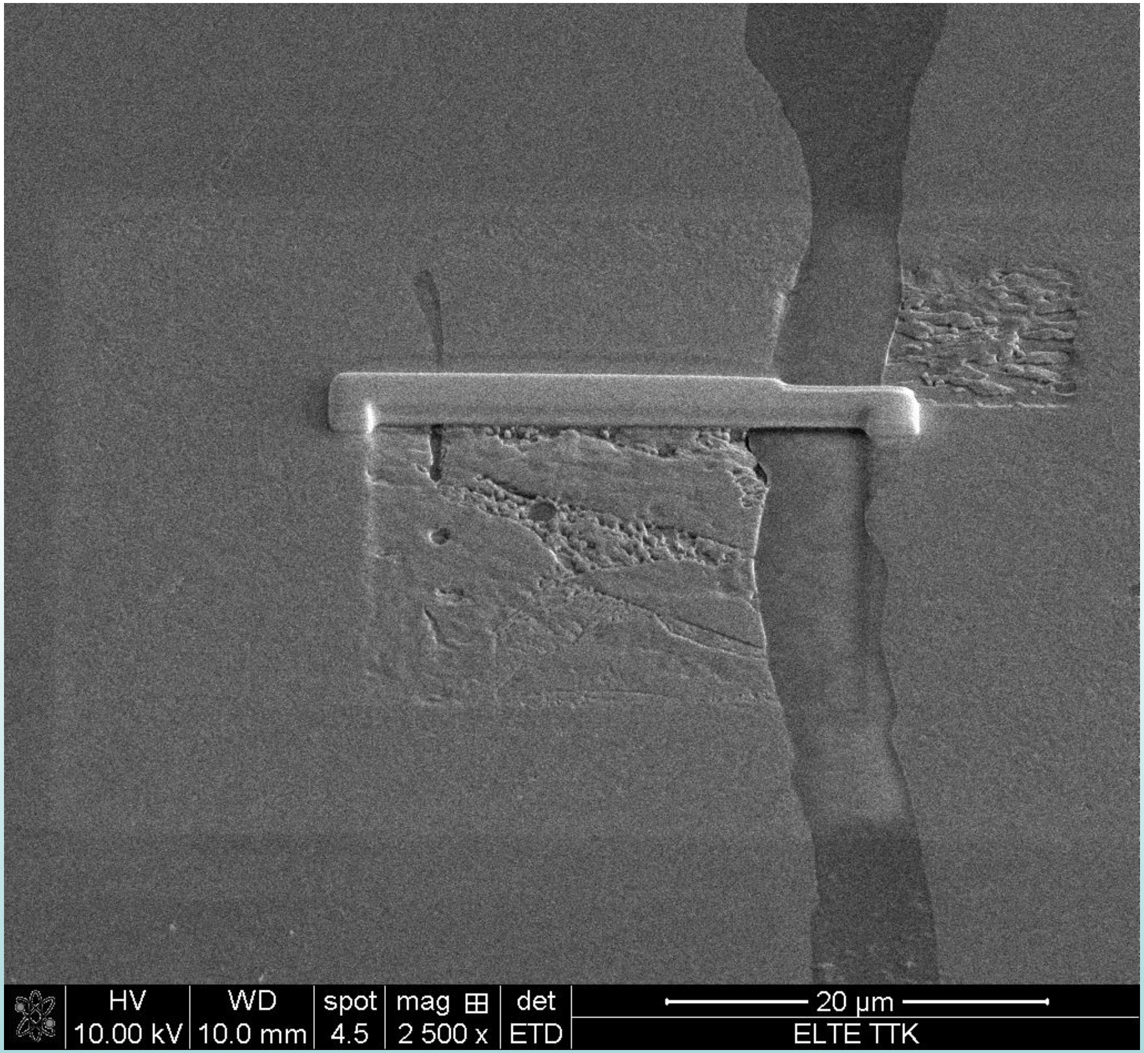

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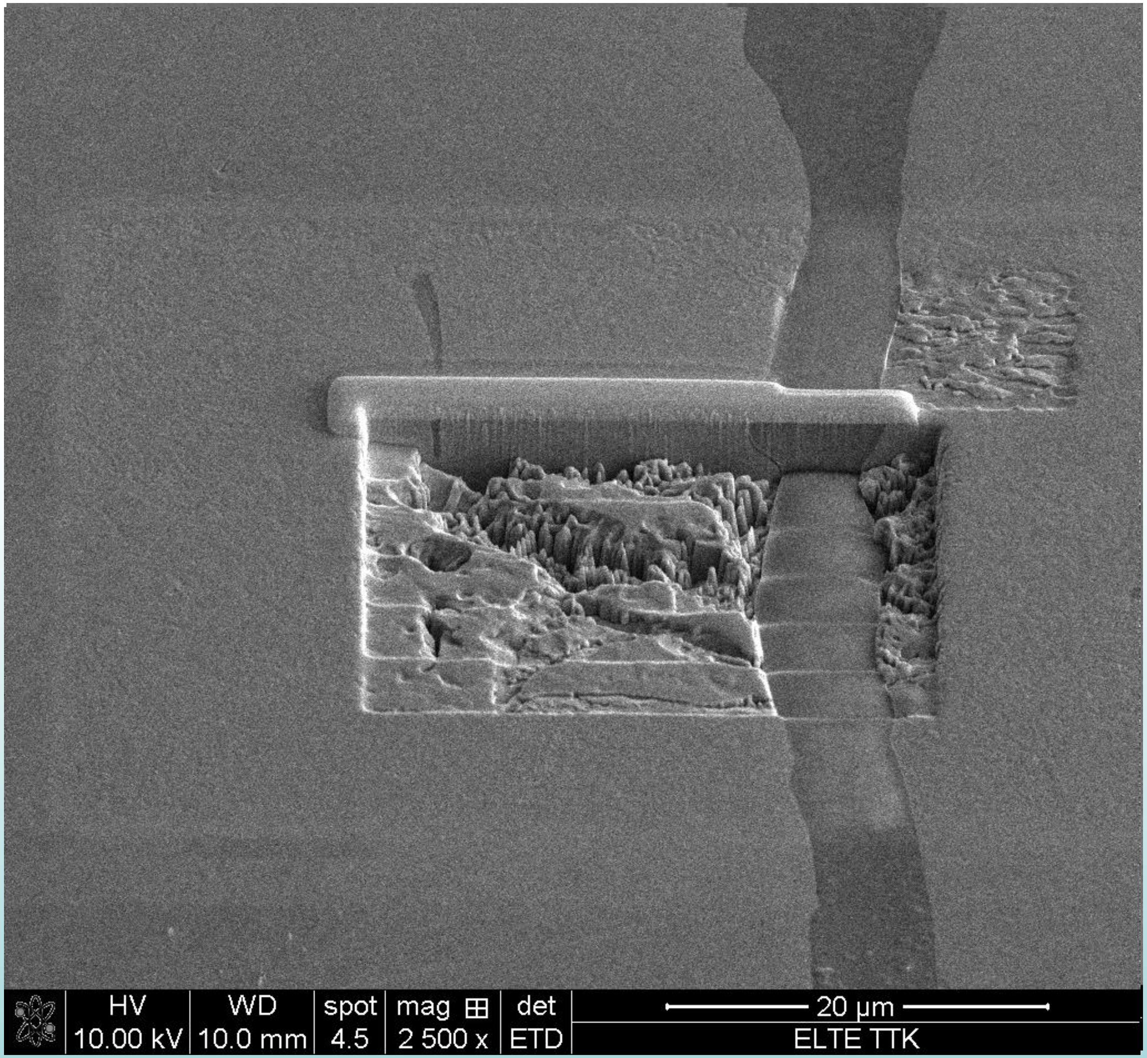

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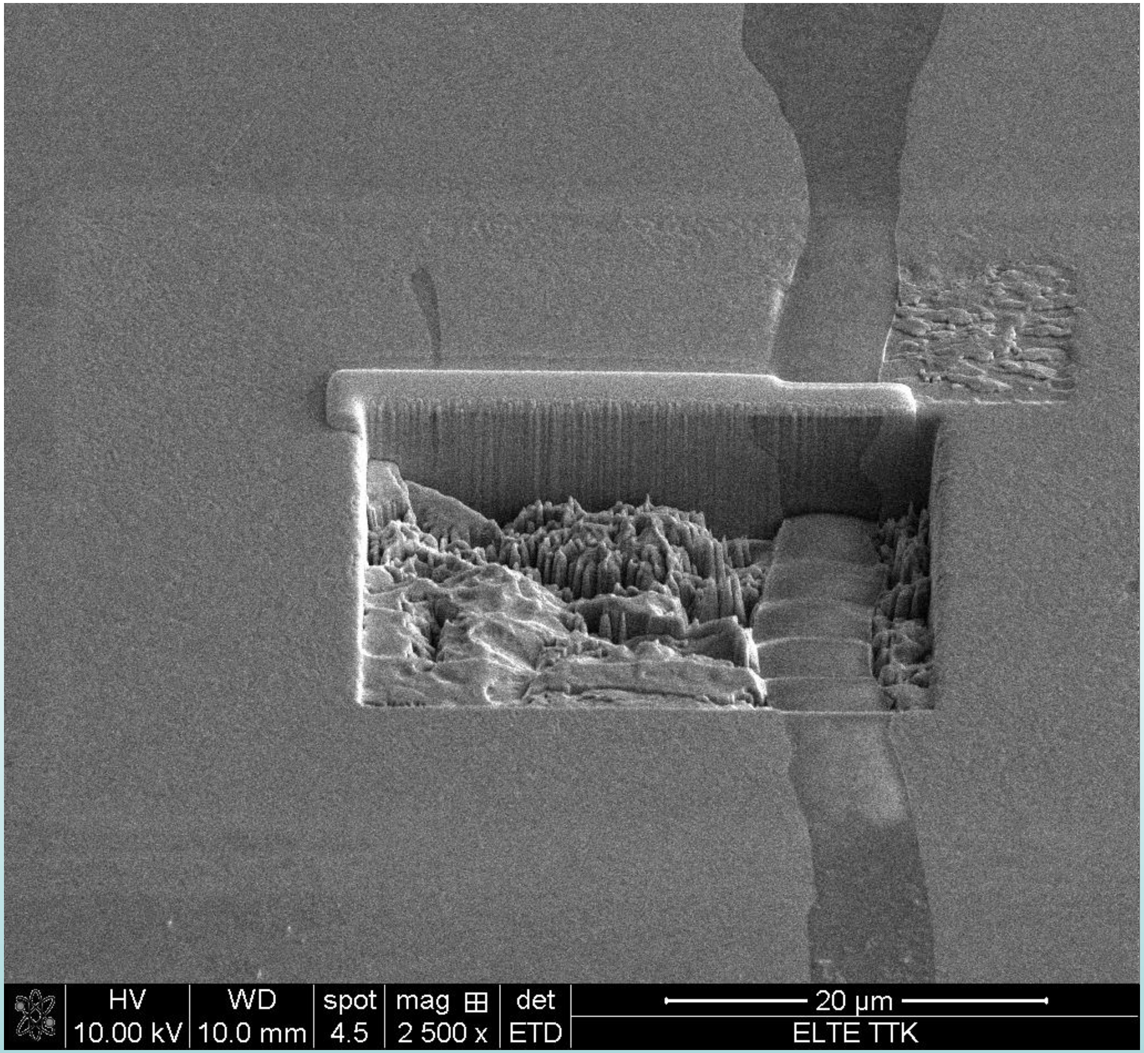

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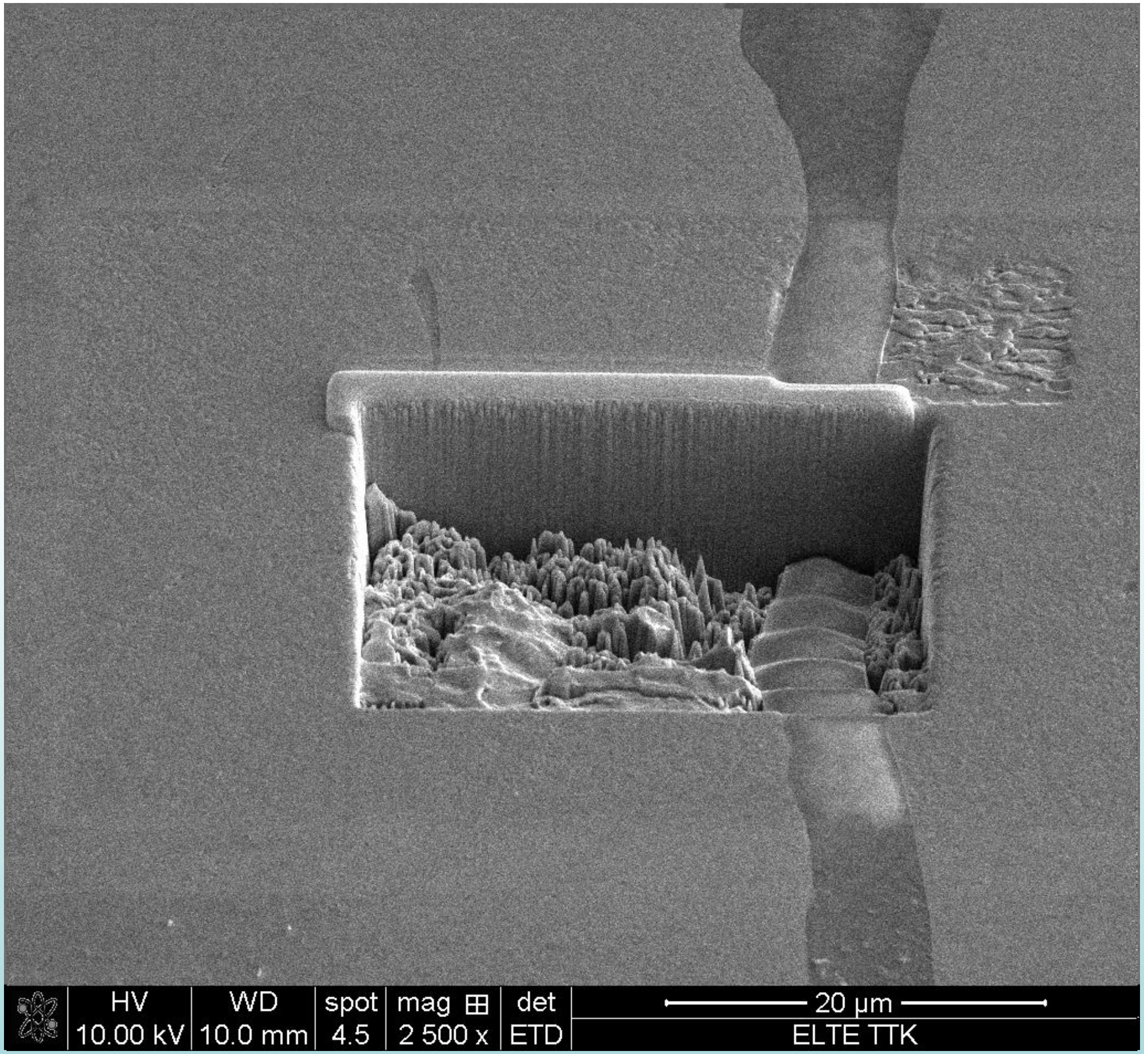
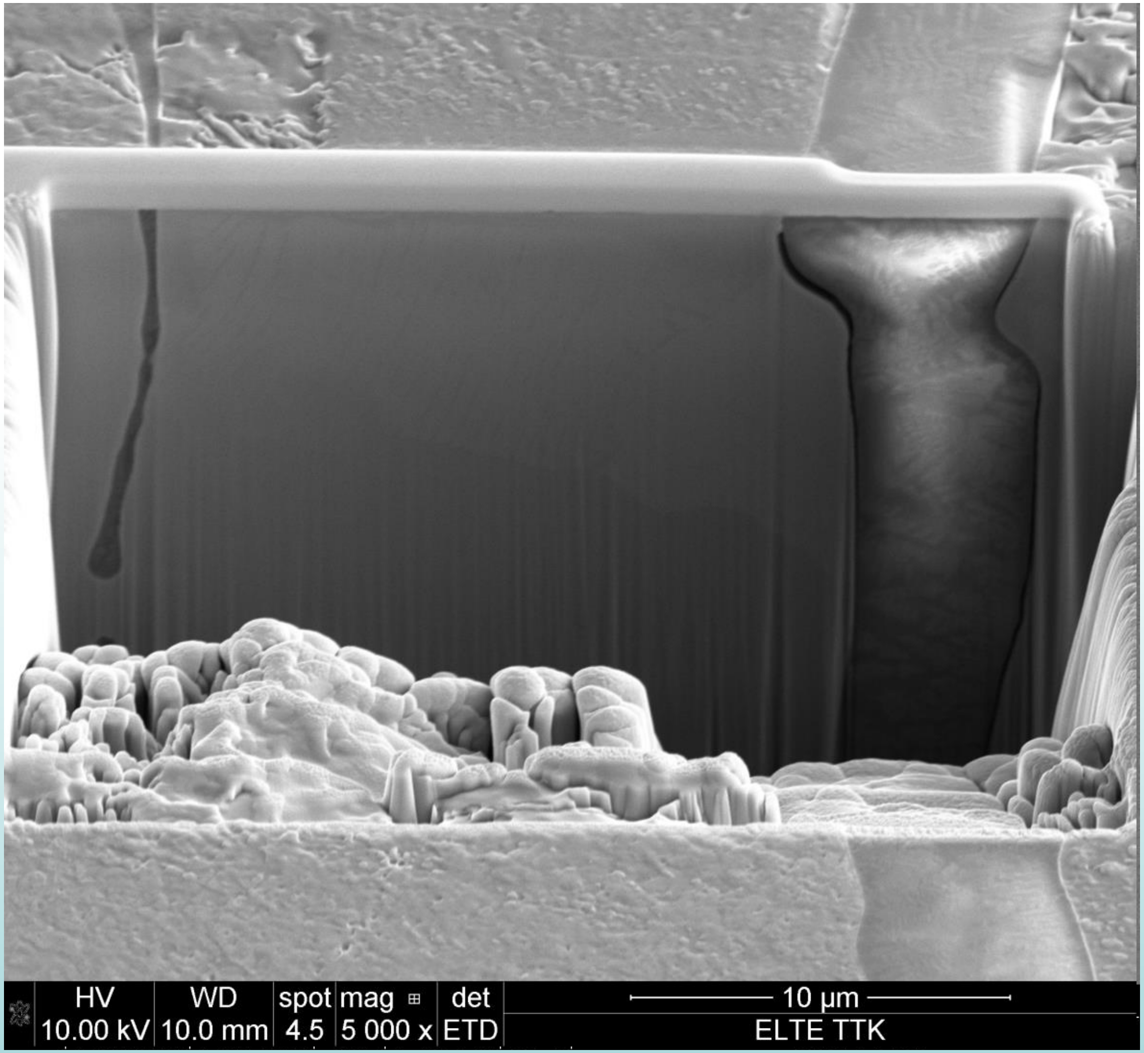
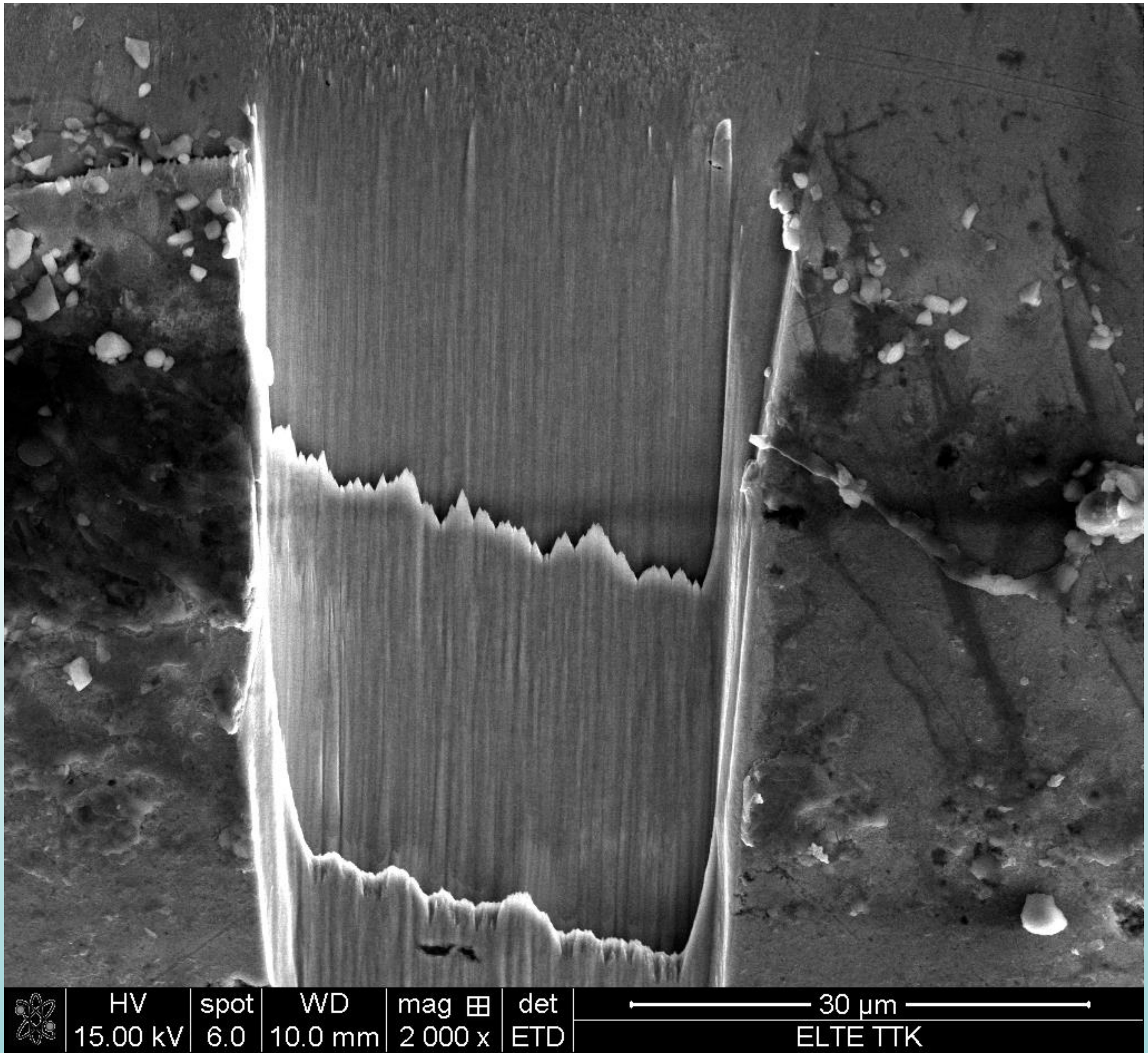


Focused ion beam machining

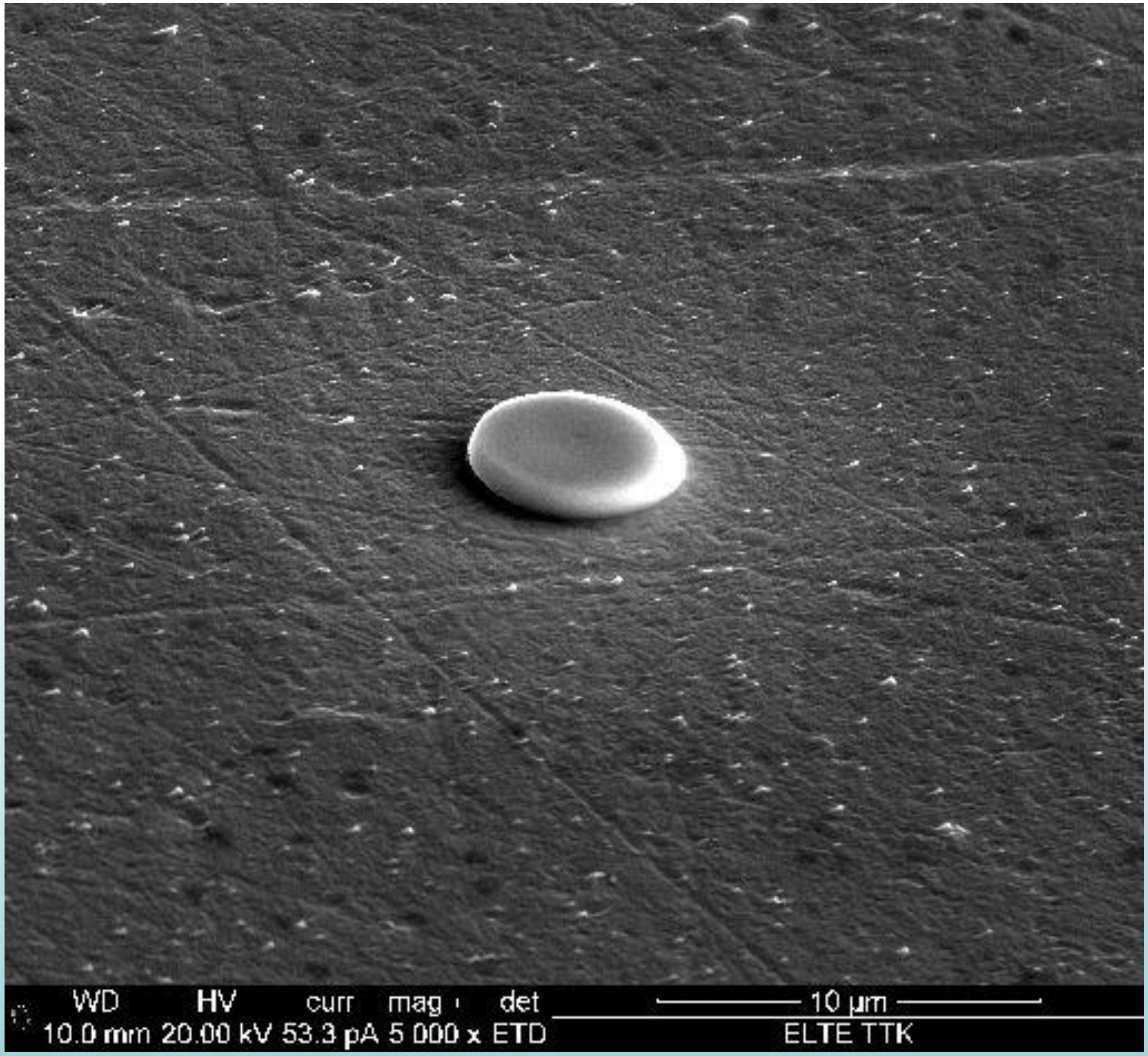
Preparing a cross section



Tangential excision for EBSD test



Preparation of micropillar (Cu)



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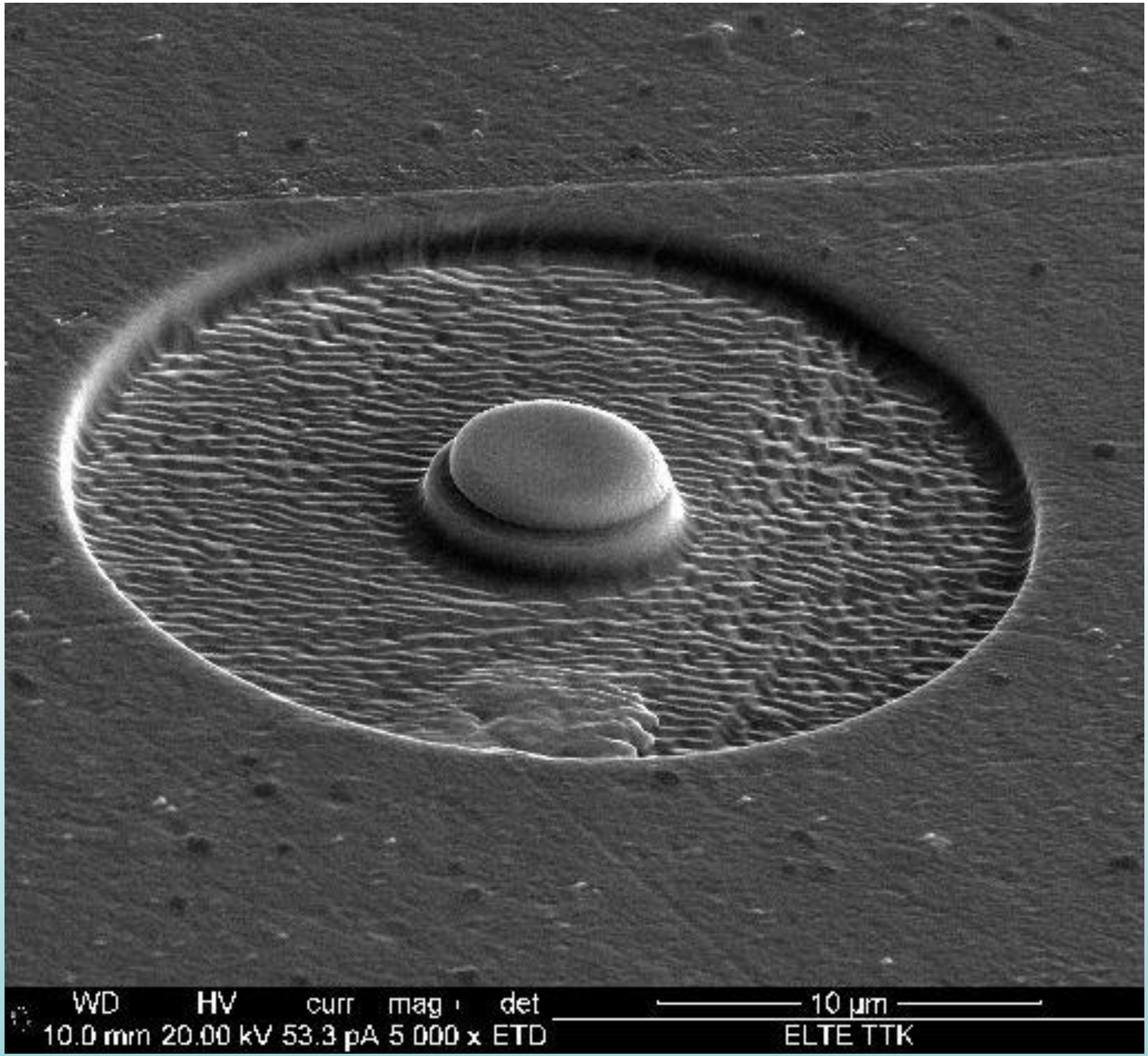

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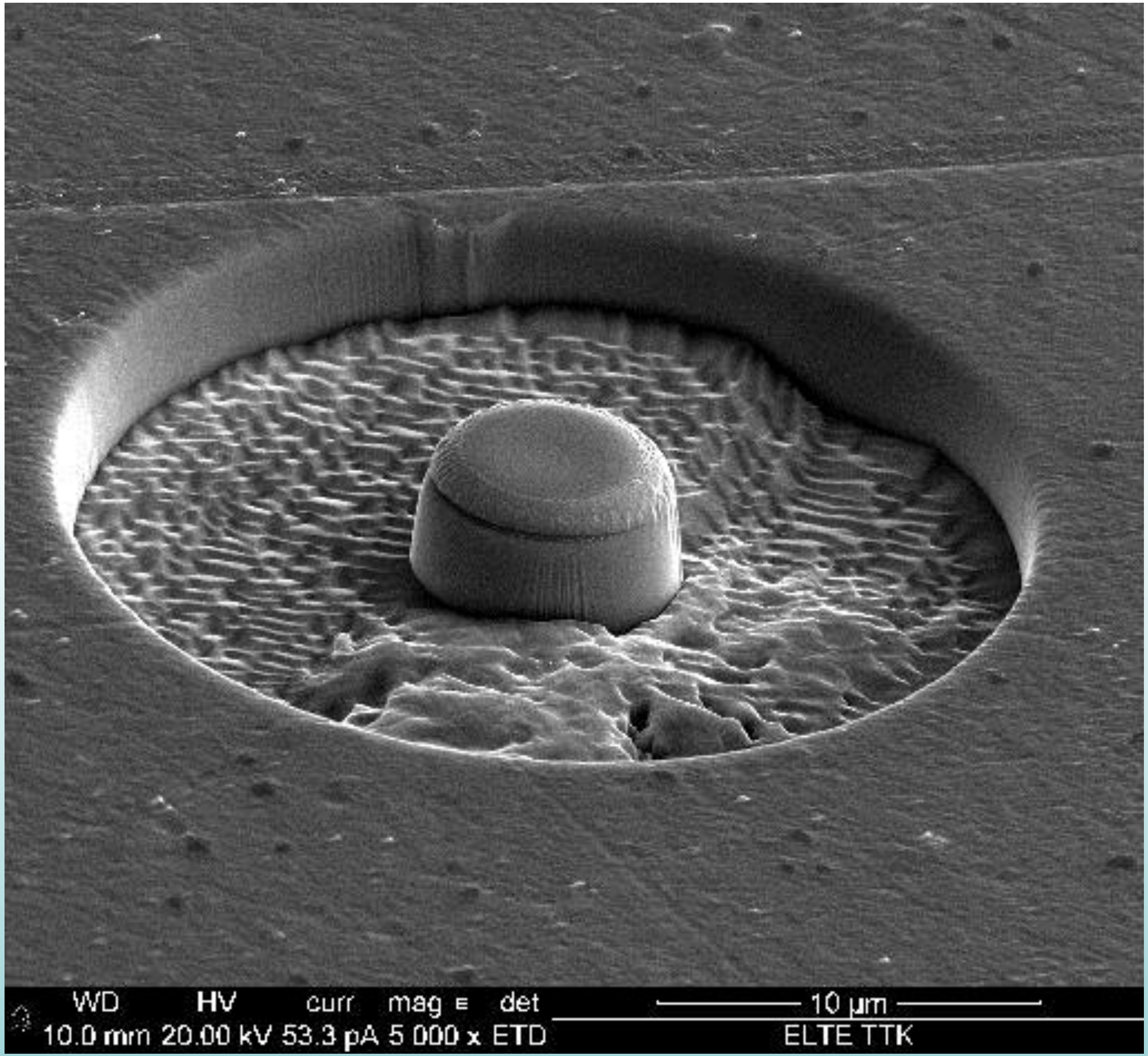

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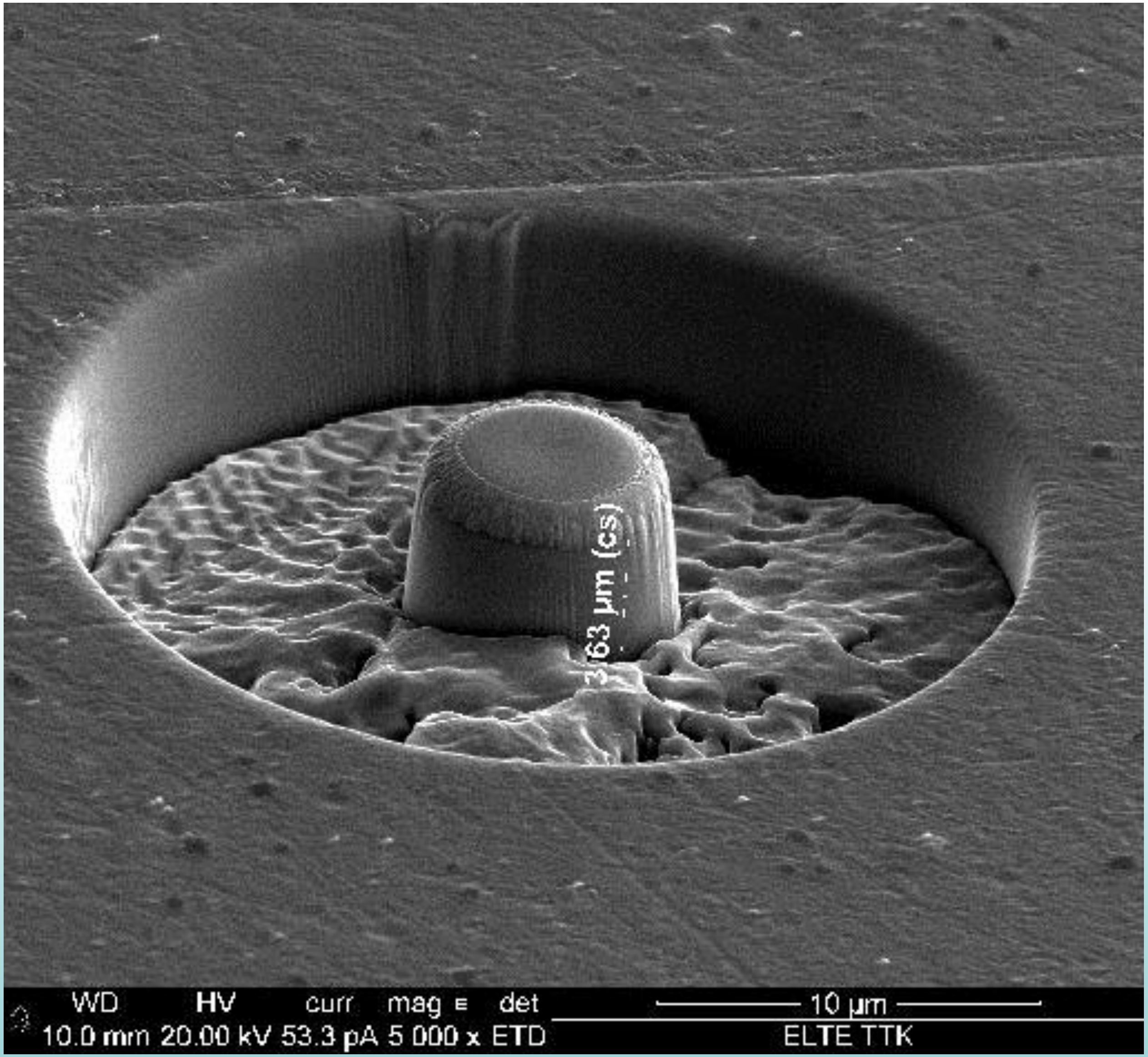

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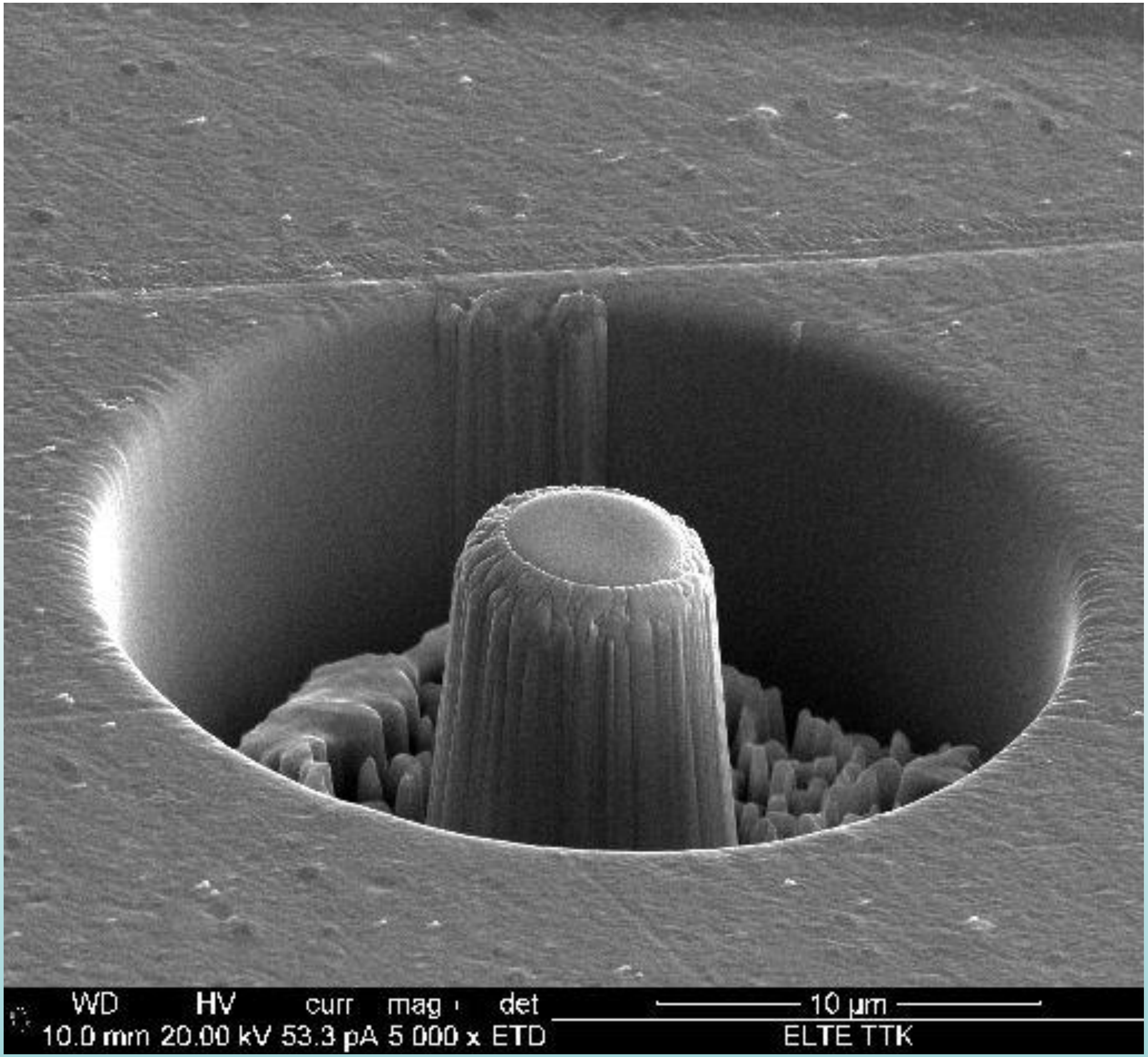

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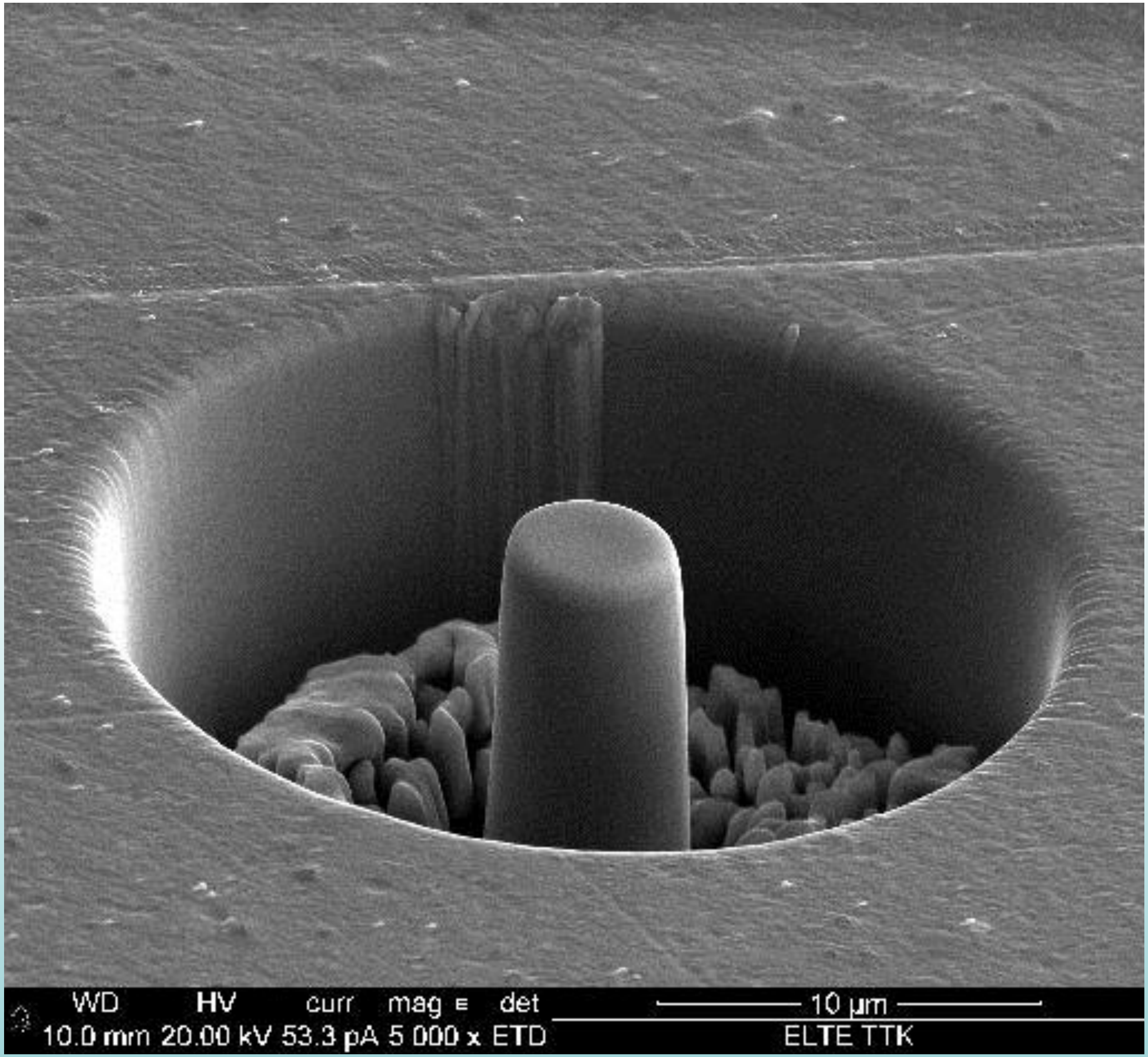

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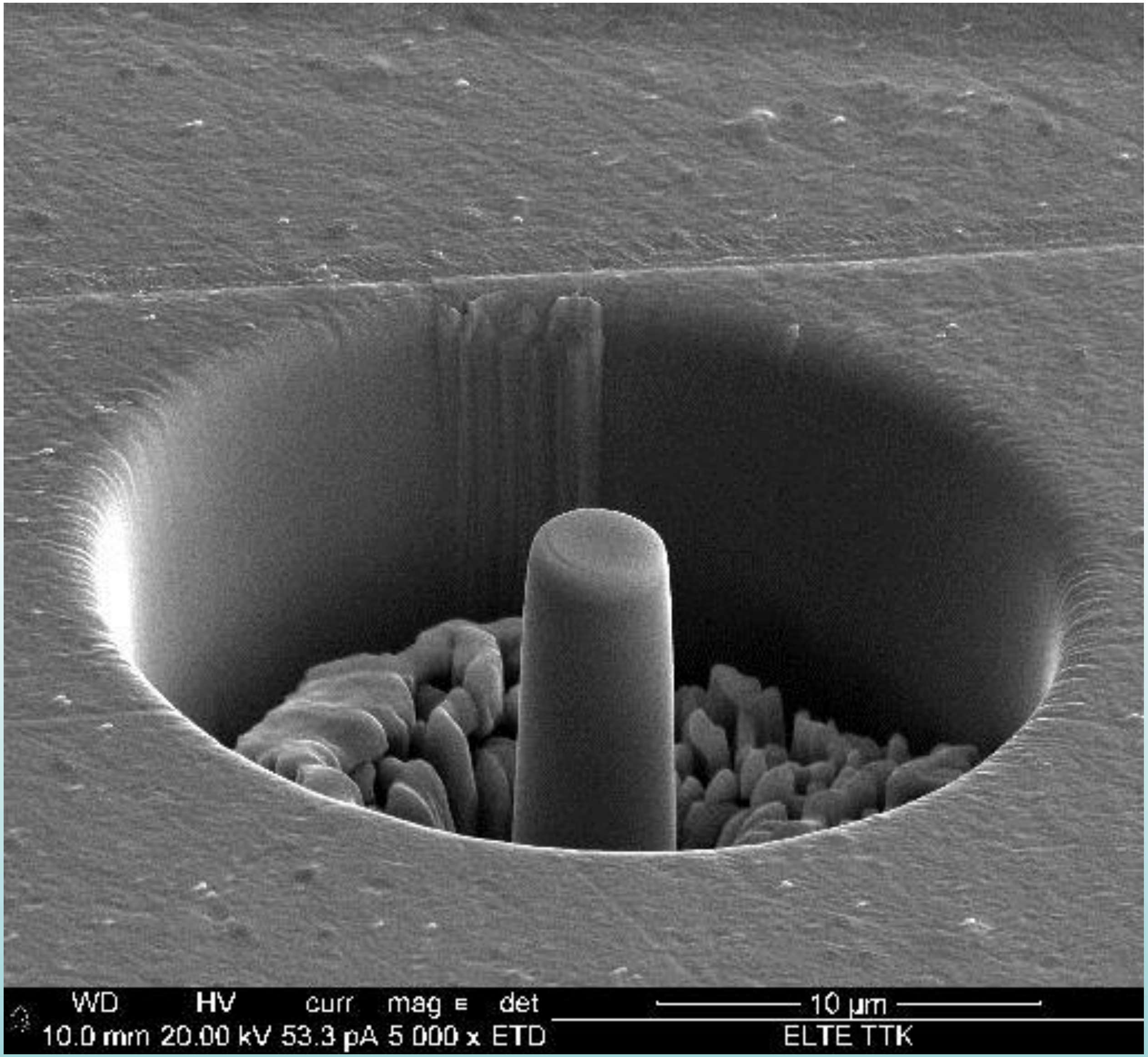

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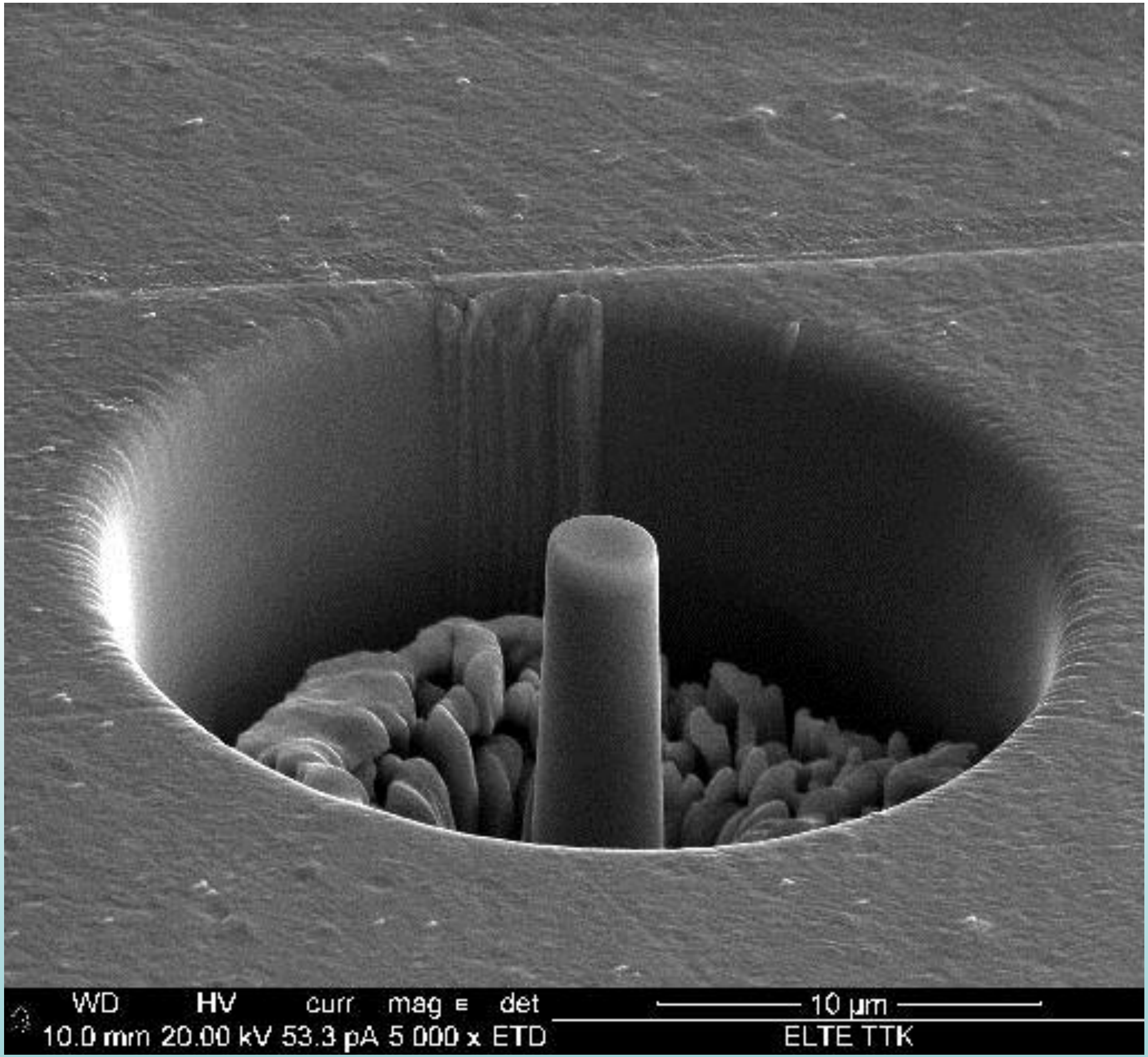
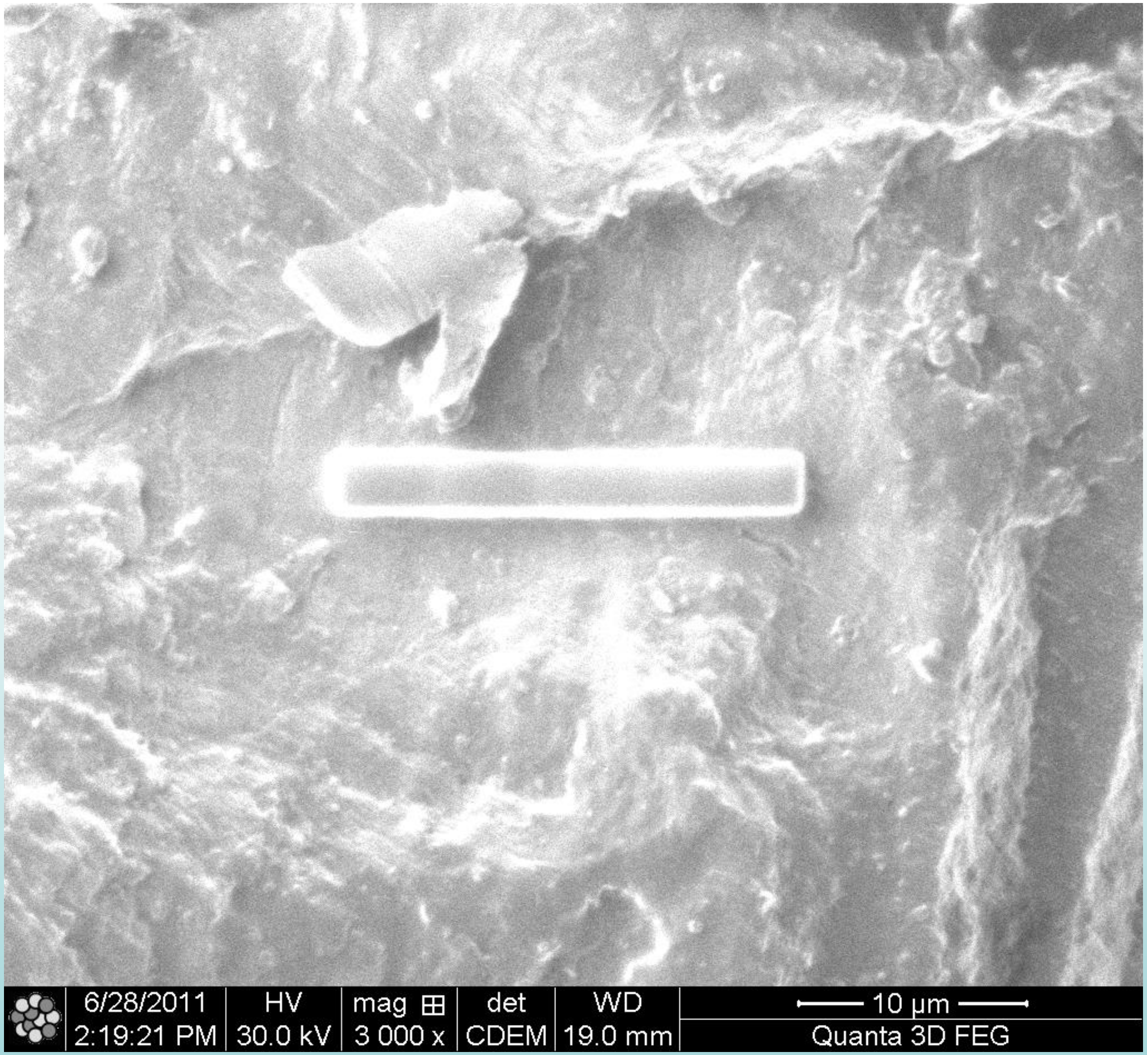


Preparation of a thin sample for TEM measurement



Focused ion beam machining

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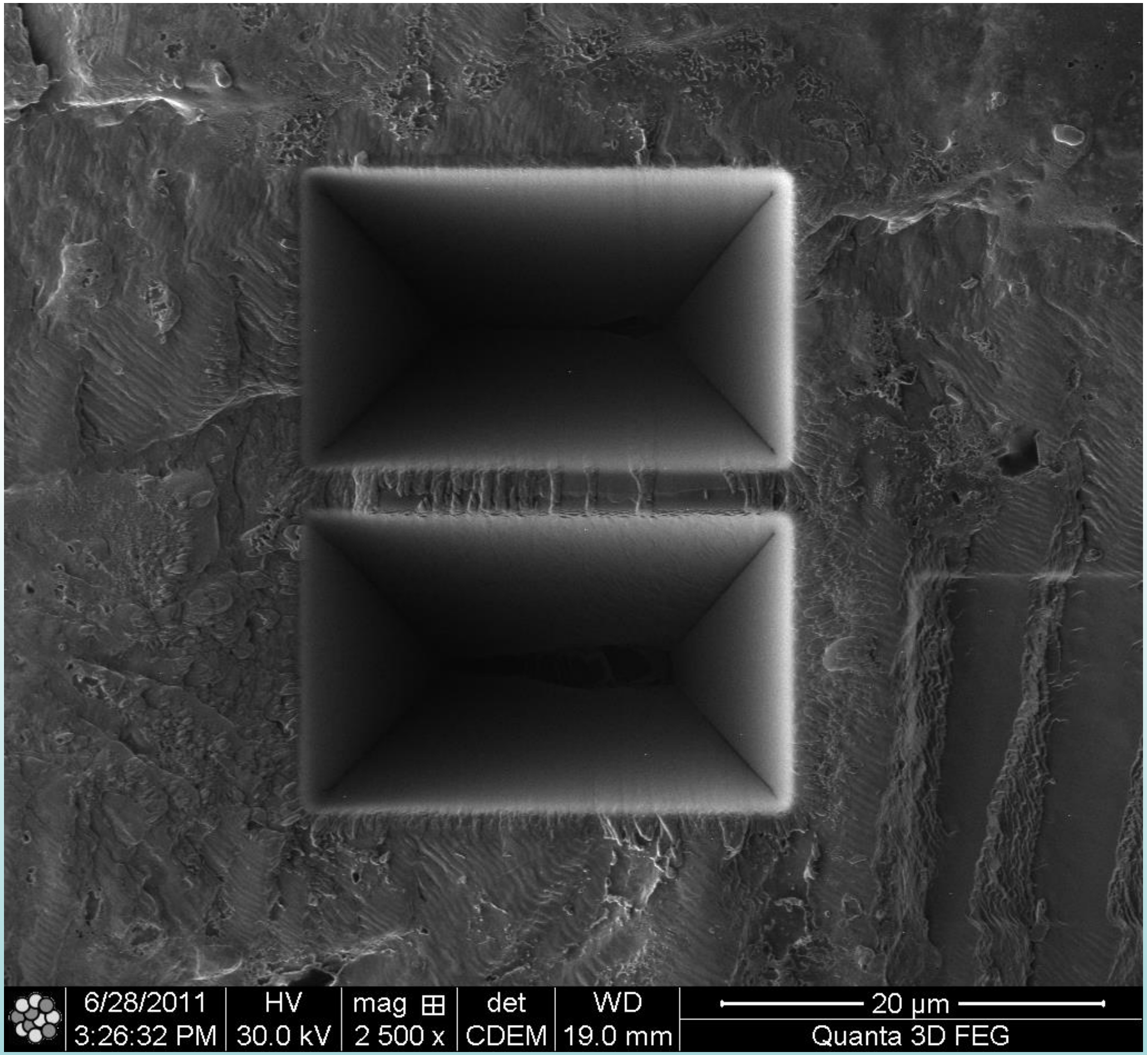

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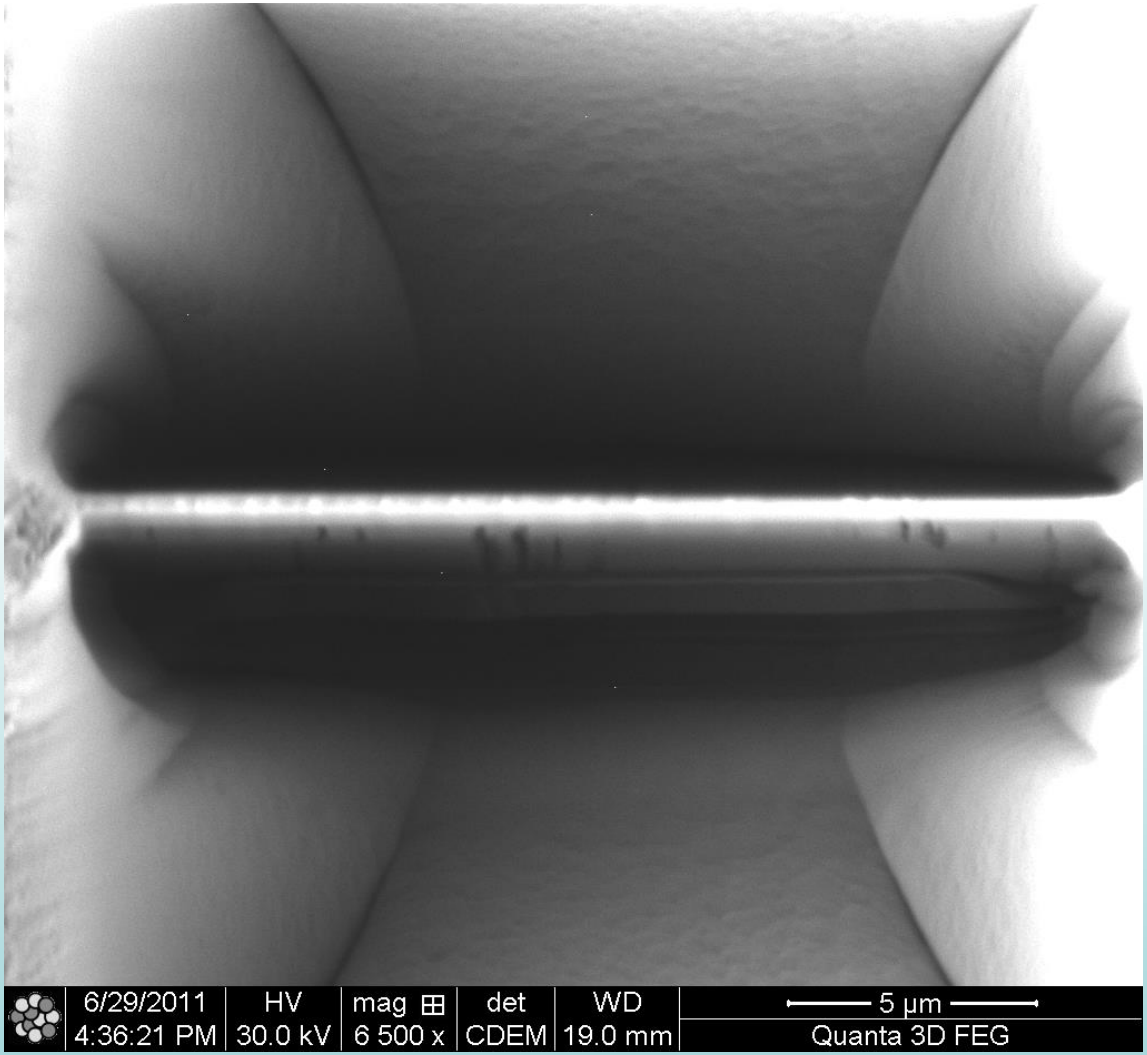

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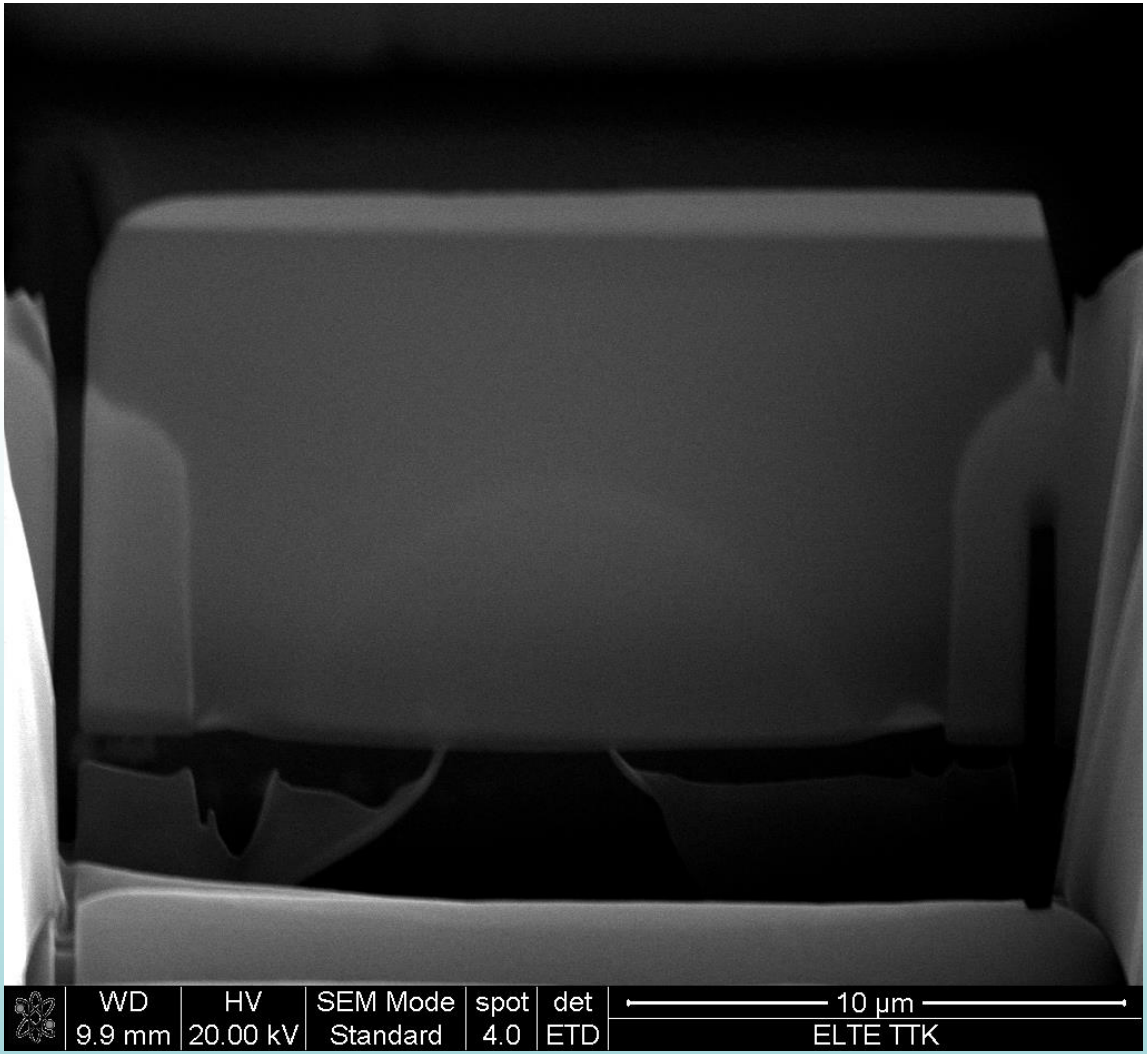

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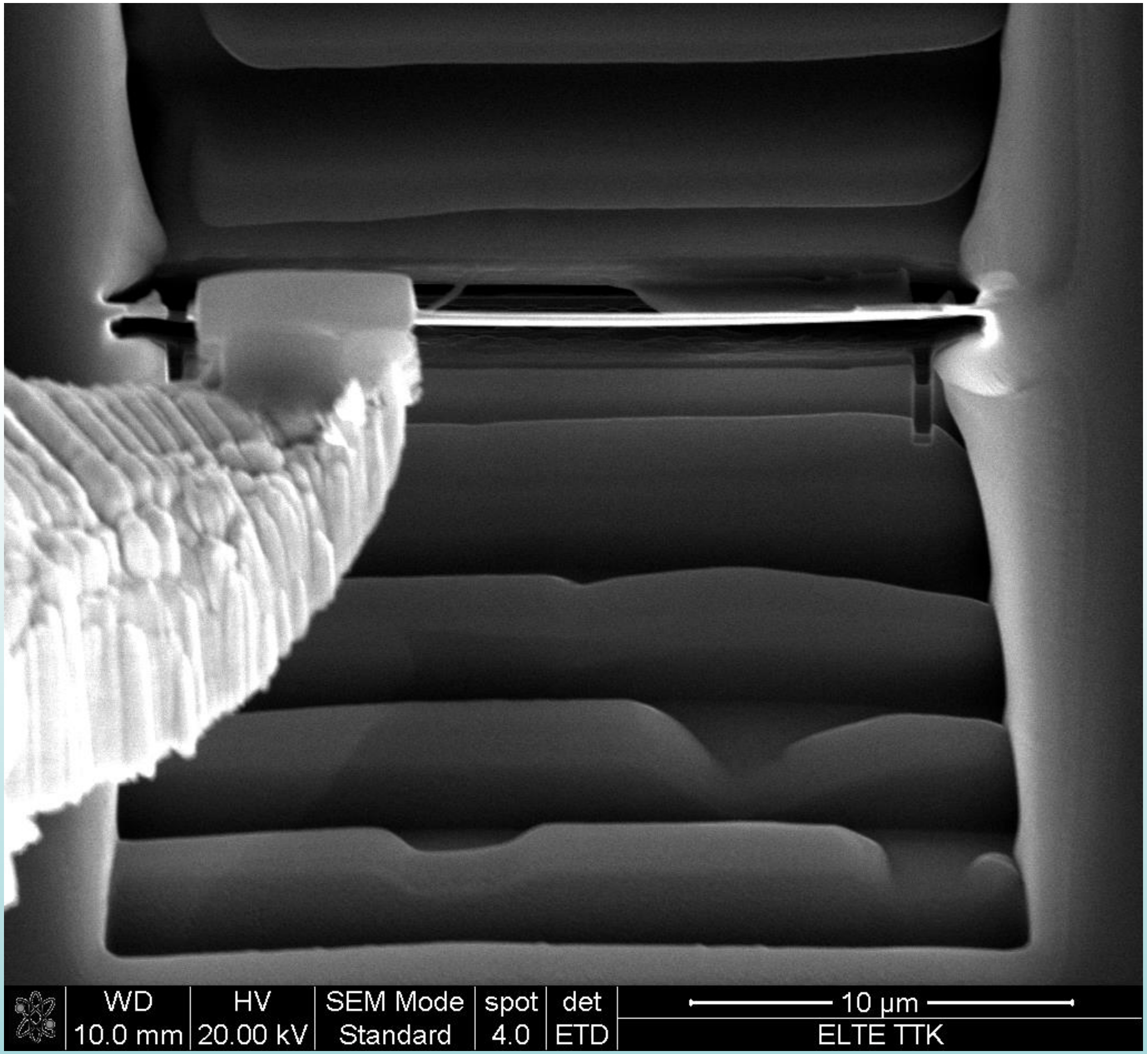

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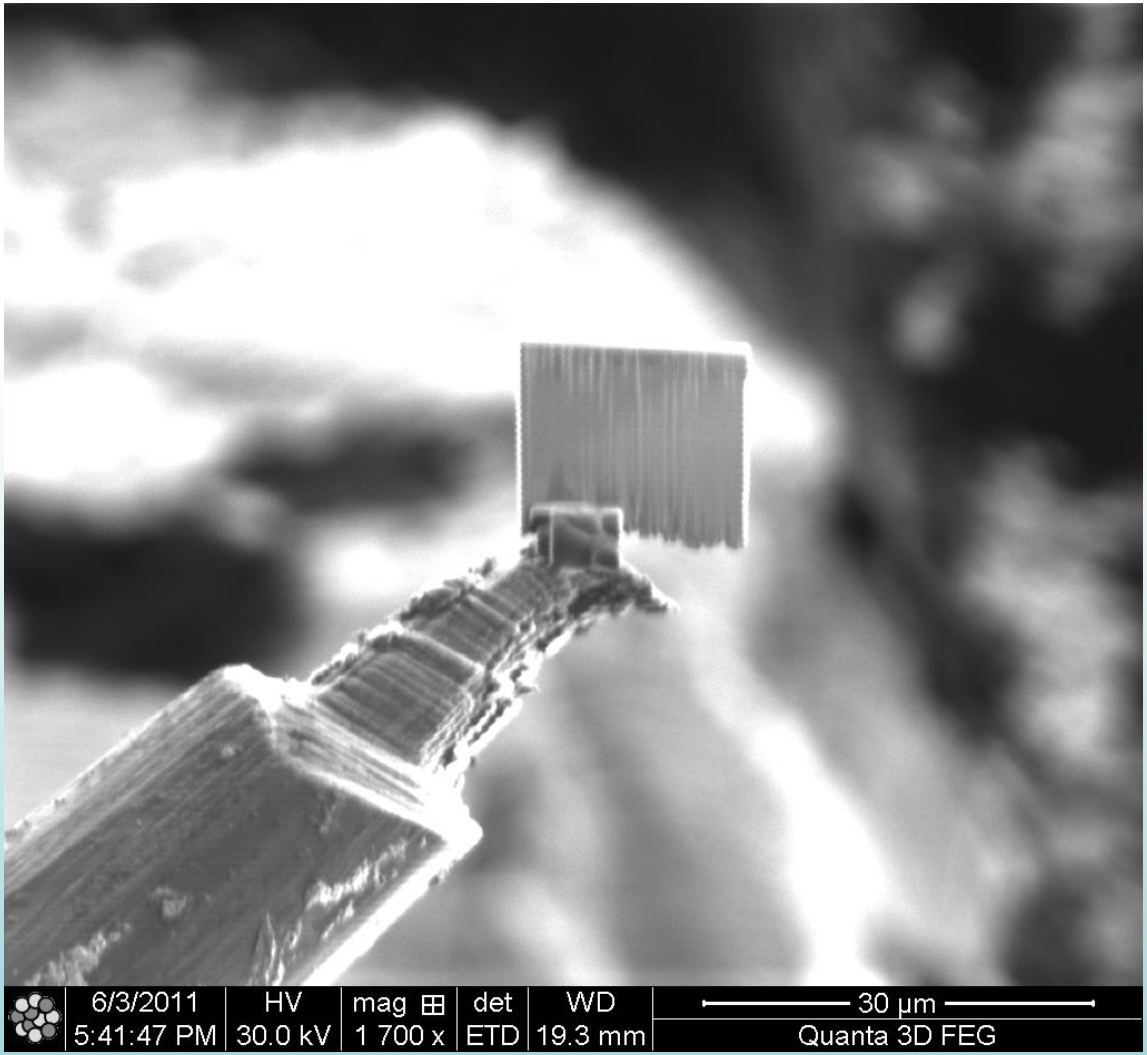

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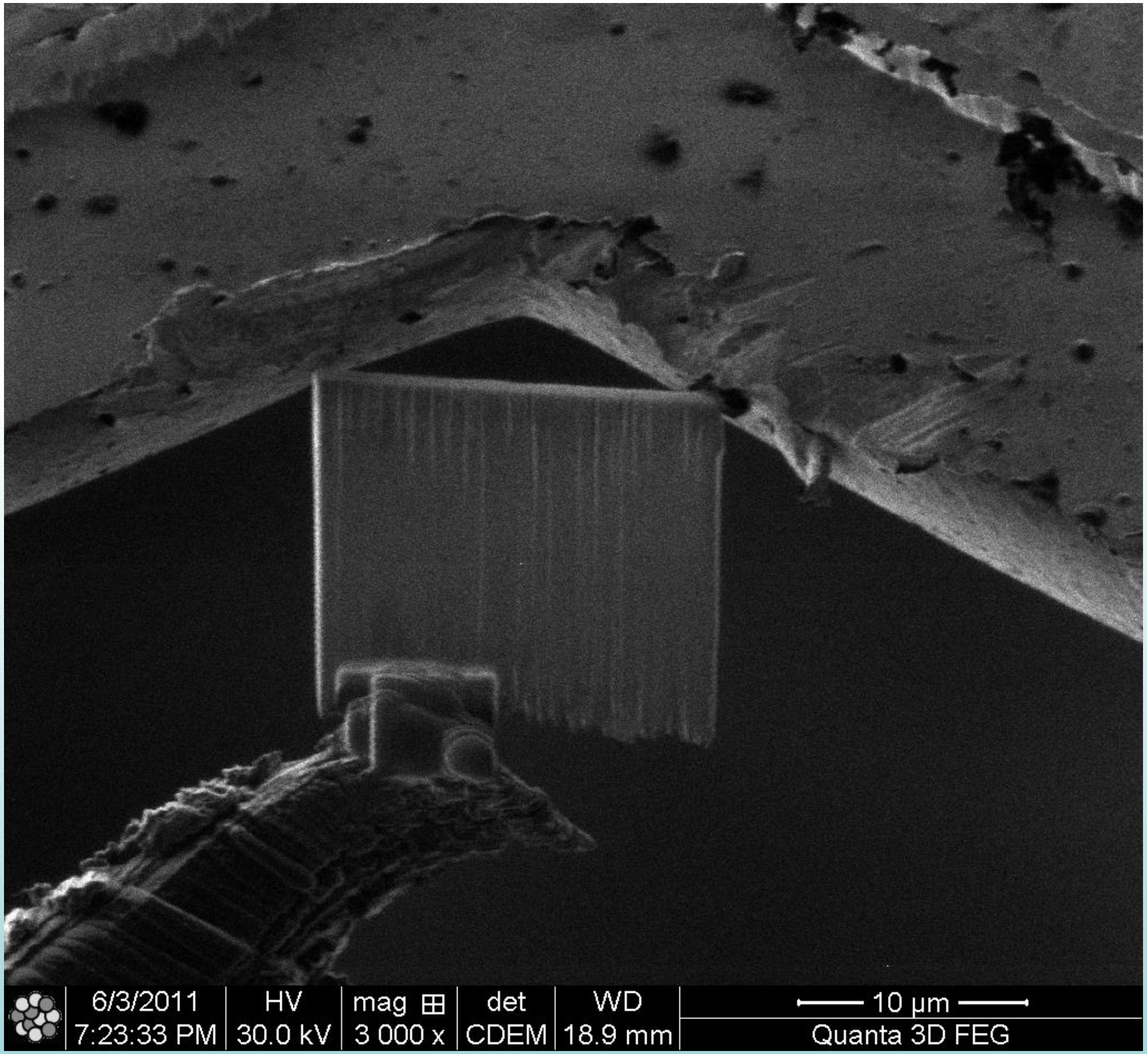

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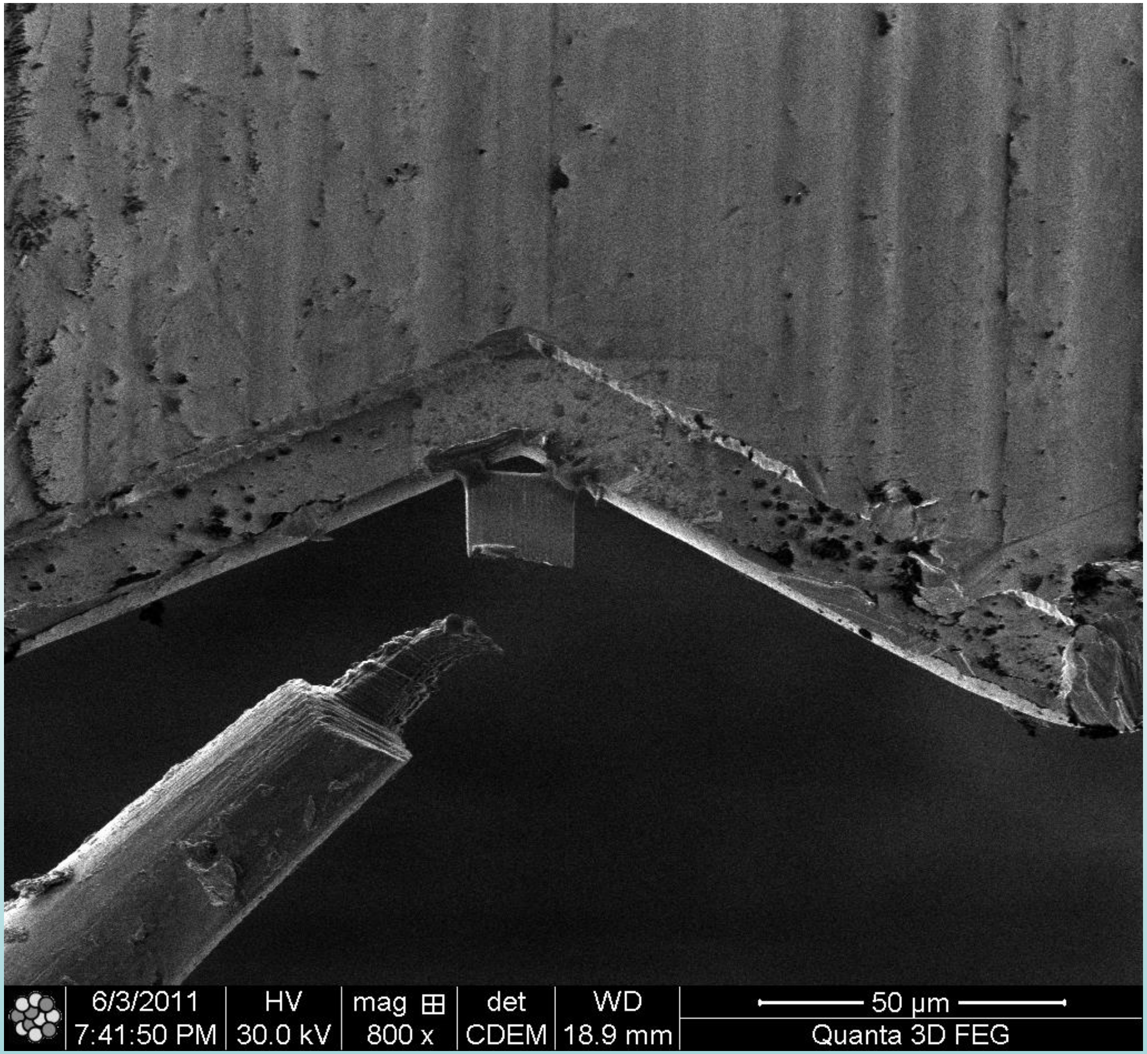
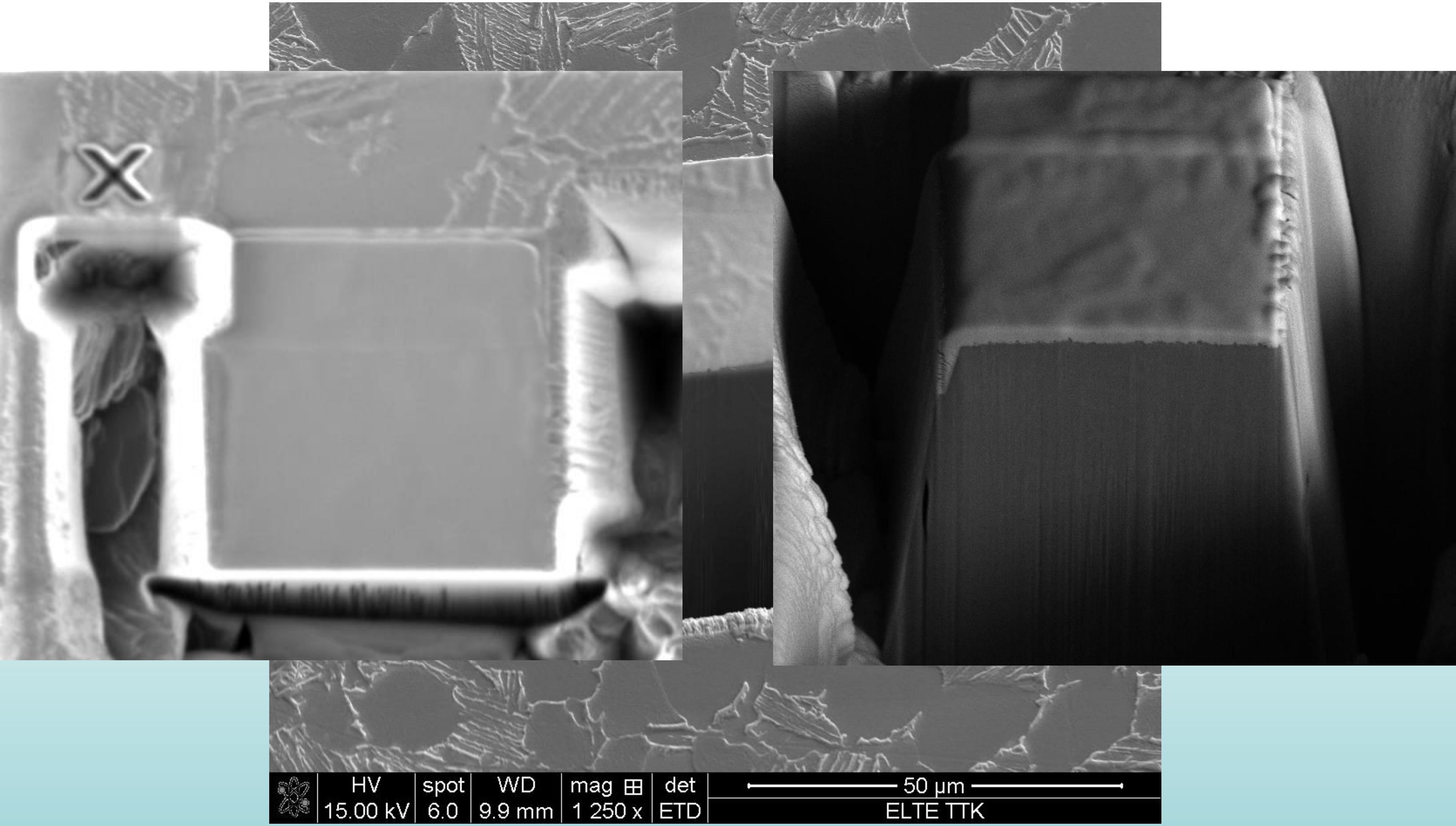
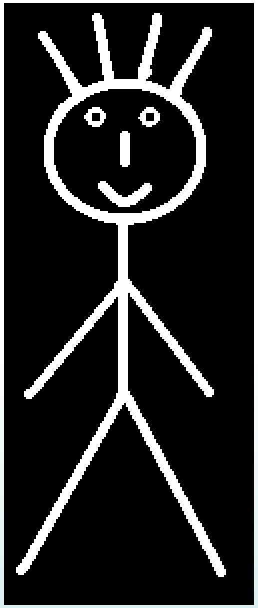
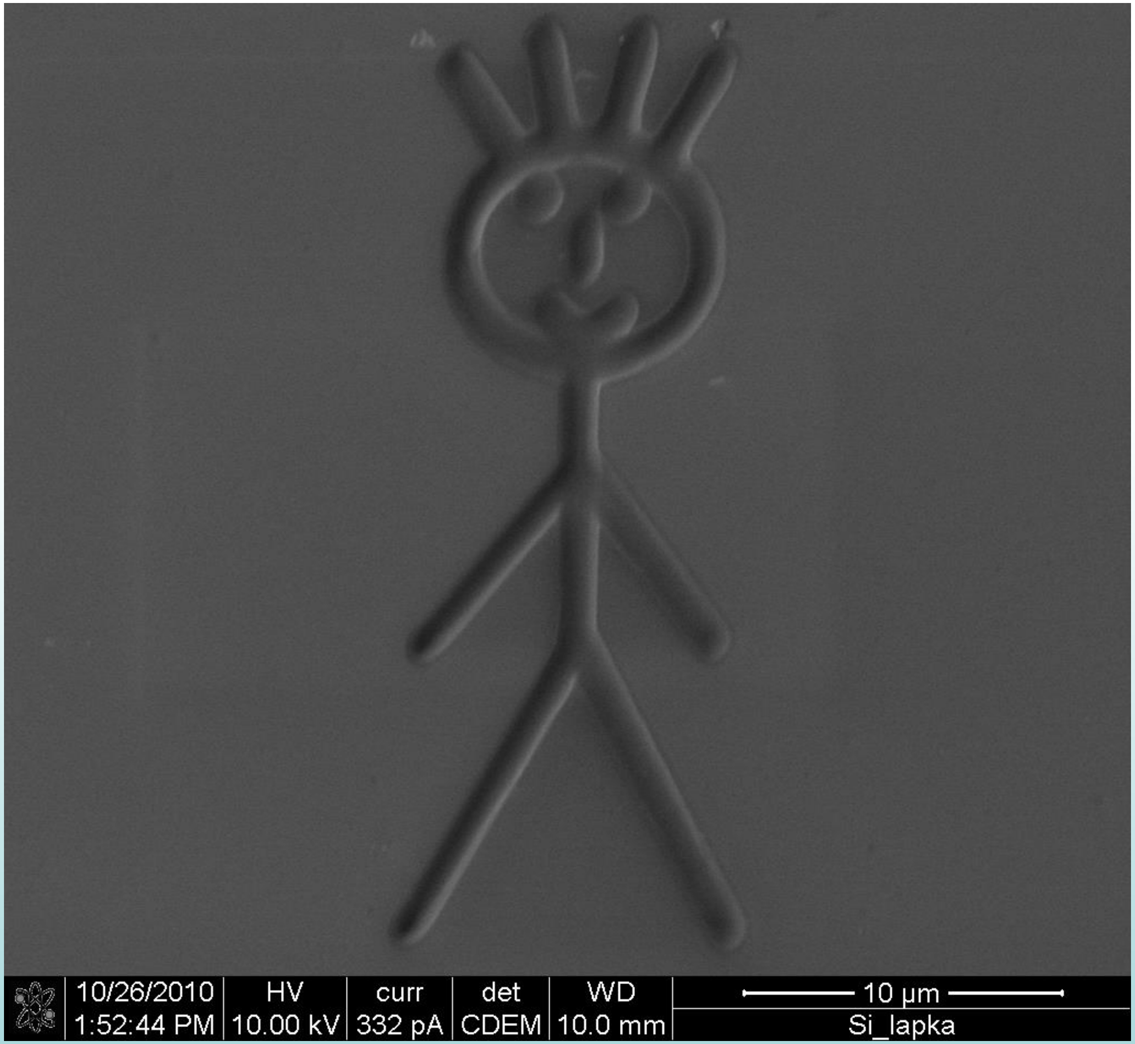


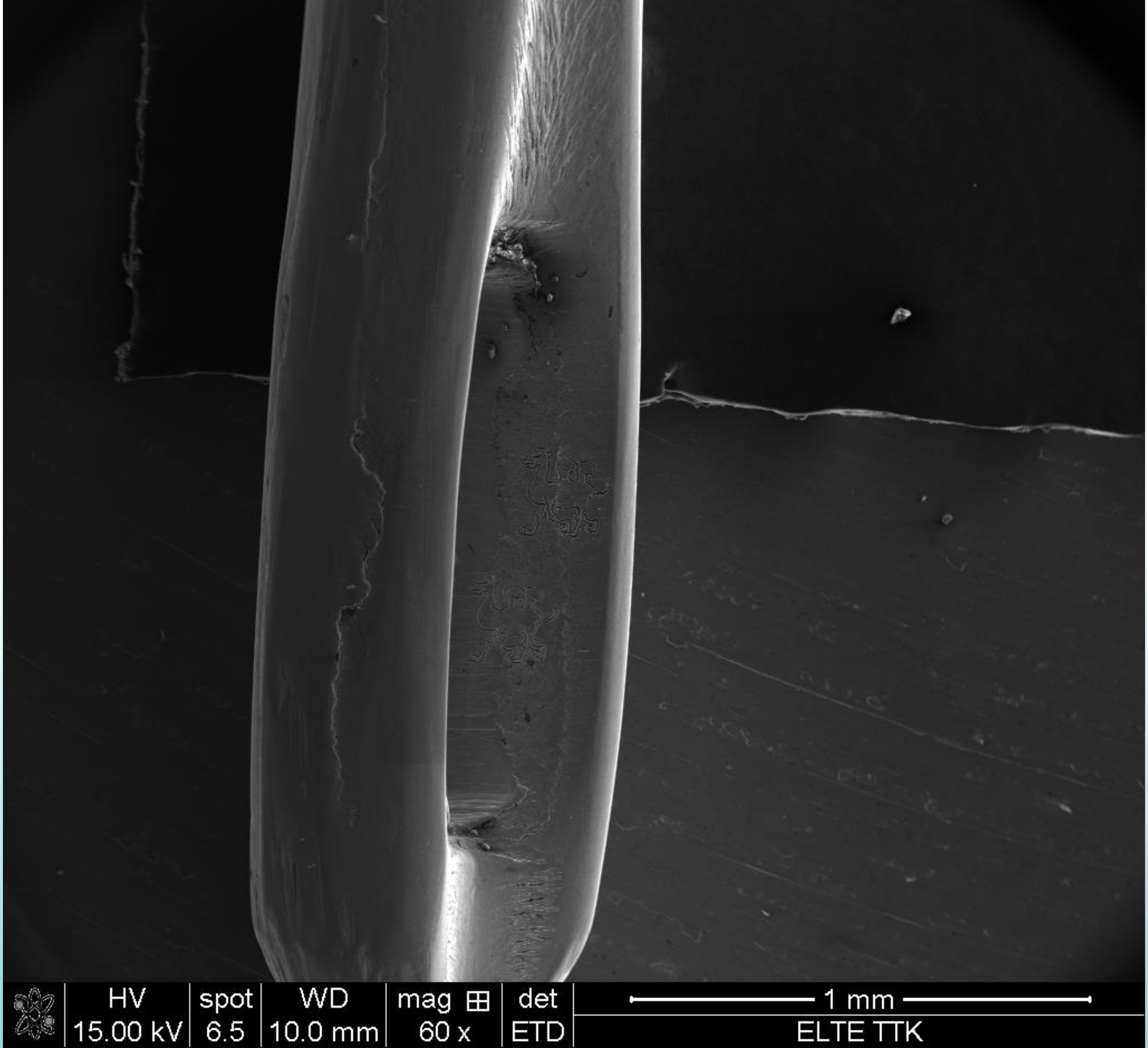
Tomography (Slice And View)



Etching with grayscale bitmap mask (Si)






HV
15.00 kV
spot
6.5
WD
10.0 mm
mag
60 x
det
ETD
1 mm
ELTE TTK


Thank you for
your
attention!
HV 15.00 kV
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mag 500 x
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100 µm
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