

FIB-TEM sample preparation by in-situ lift-out technique

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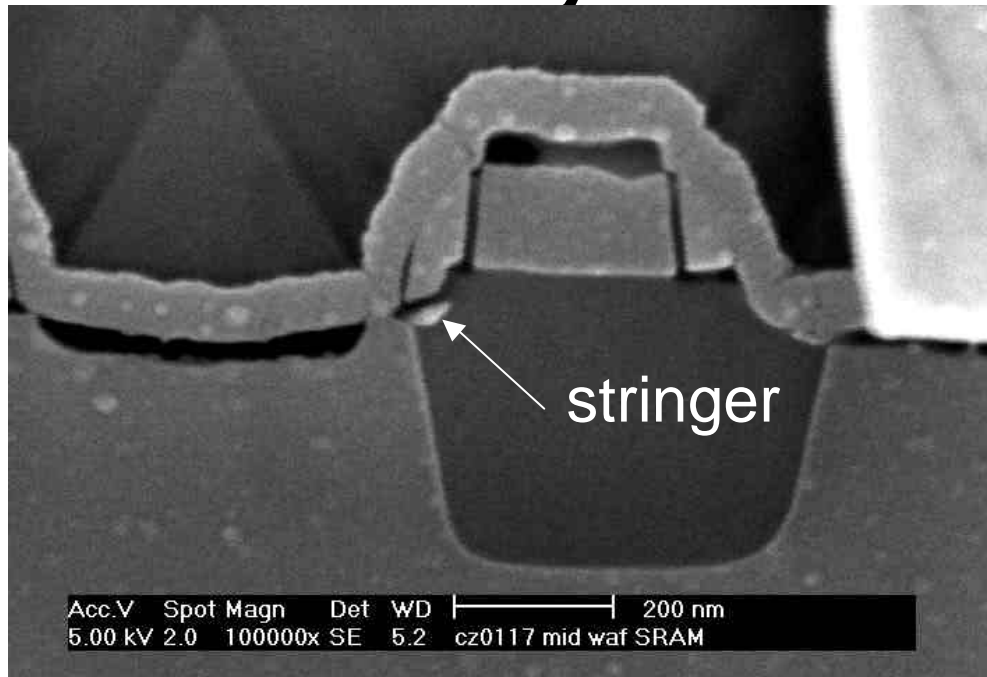


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Contents

- **Why do we need fast and flexible sample thinning?**
- **Traditional FIB TEM sample preparation.**
- **In-situ TEM sample lift-out technique.**
- **Examples.**
- **Summary.**

Why we need thin samples



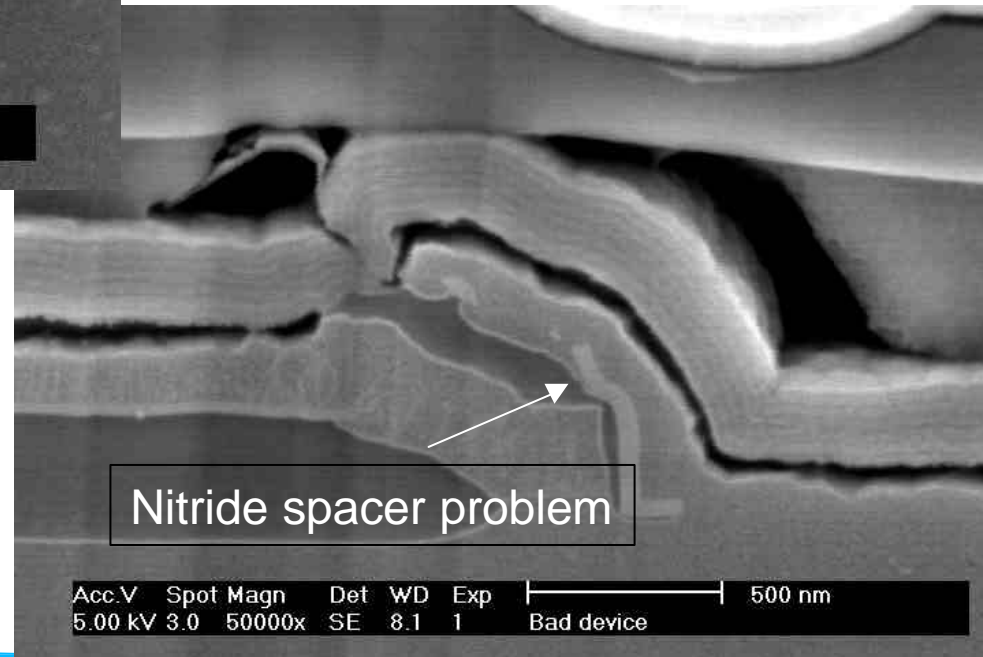
Failure in deep sub mm process

- No localised hot spot, high I_{ddq} .
- Prepared small angle X-section .
- Poly silicon stringers found.

Lateral resolution chem. analysis!

- Localised PEM spot, leaky B-E.
- Prepared localised FIB X-section .
- Spacer problem found.
- P-N poly diode formed.

Lateral resolution chem. analysis!

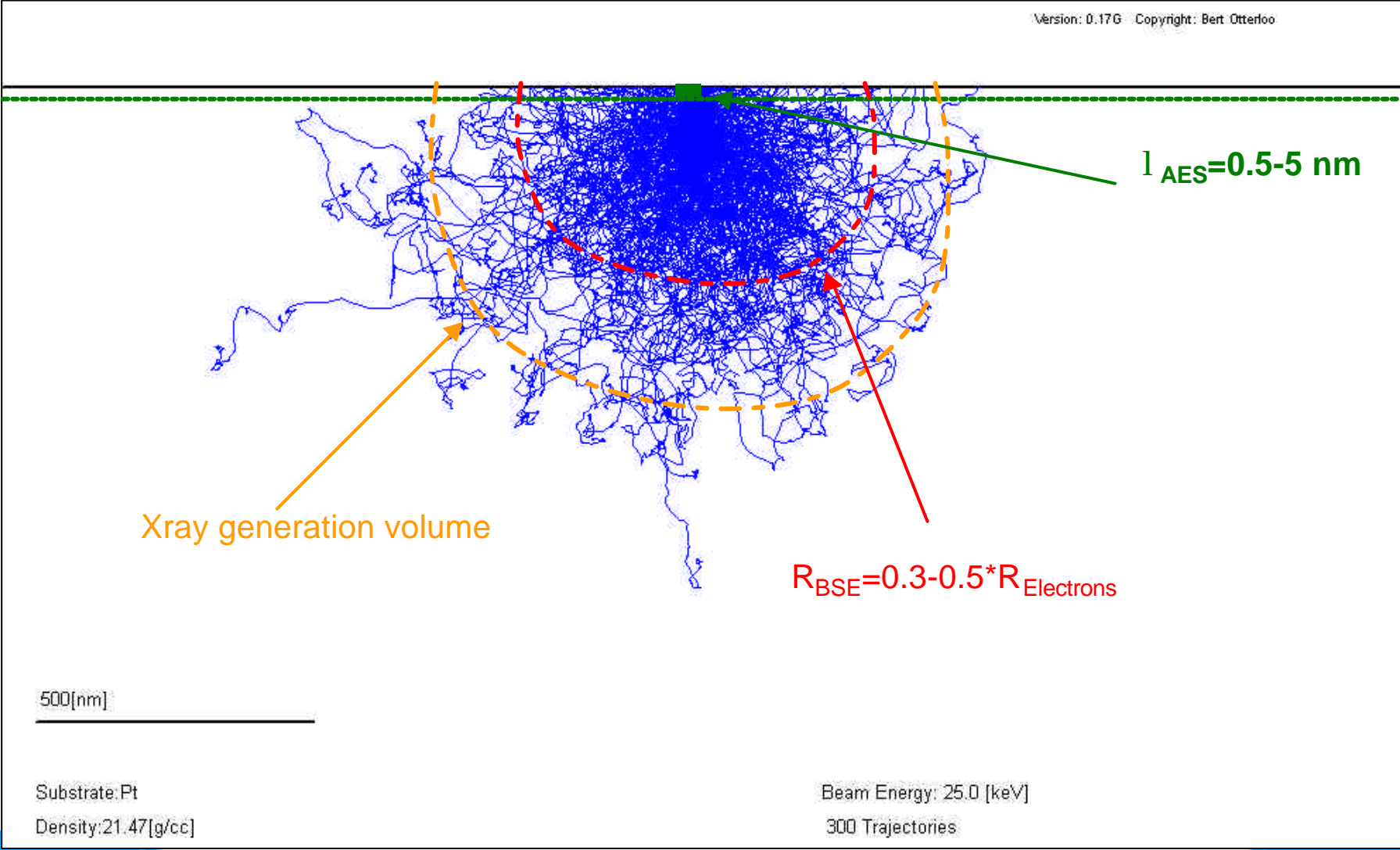


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Information volume



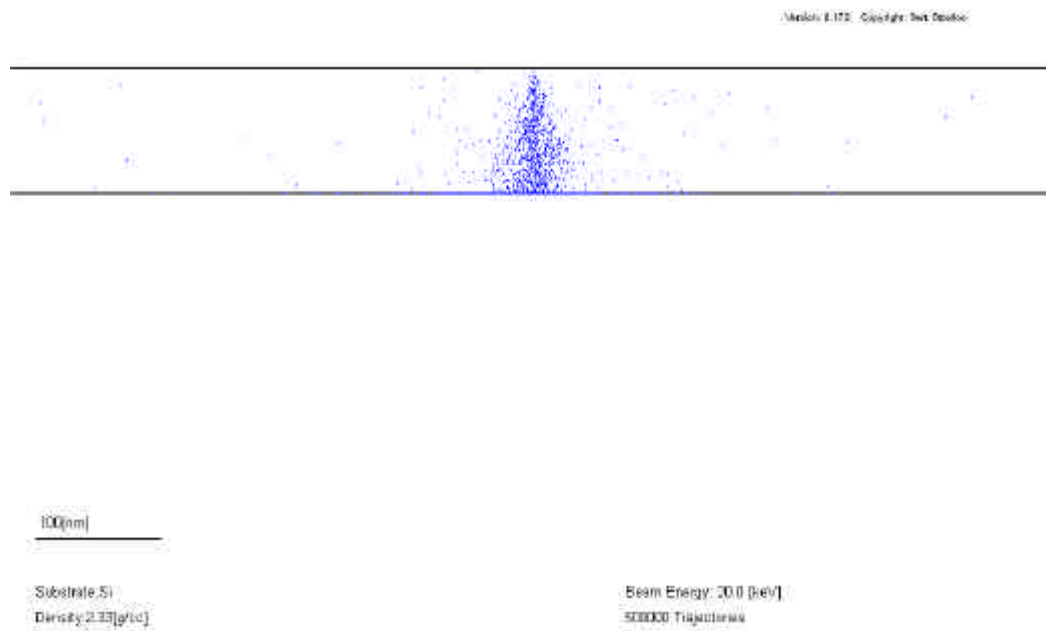
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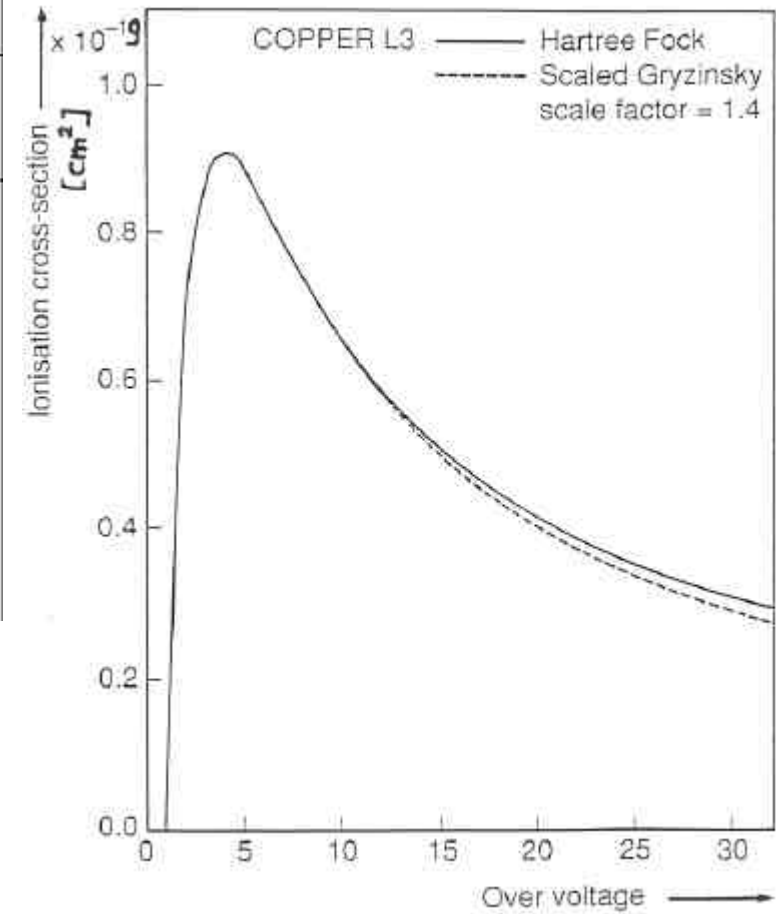
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X-ray generation in thin film (STEM/EDX)

Small analysis volume (example Si K α)



10-30 kV: Optimum X-ray excitation (example Cu L)

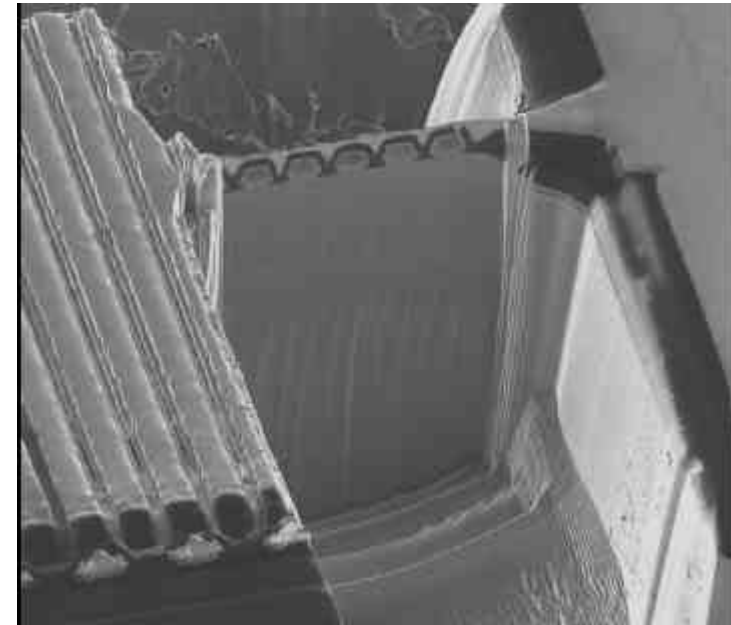
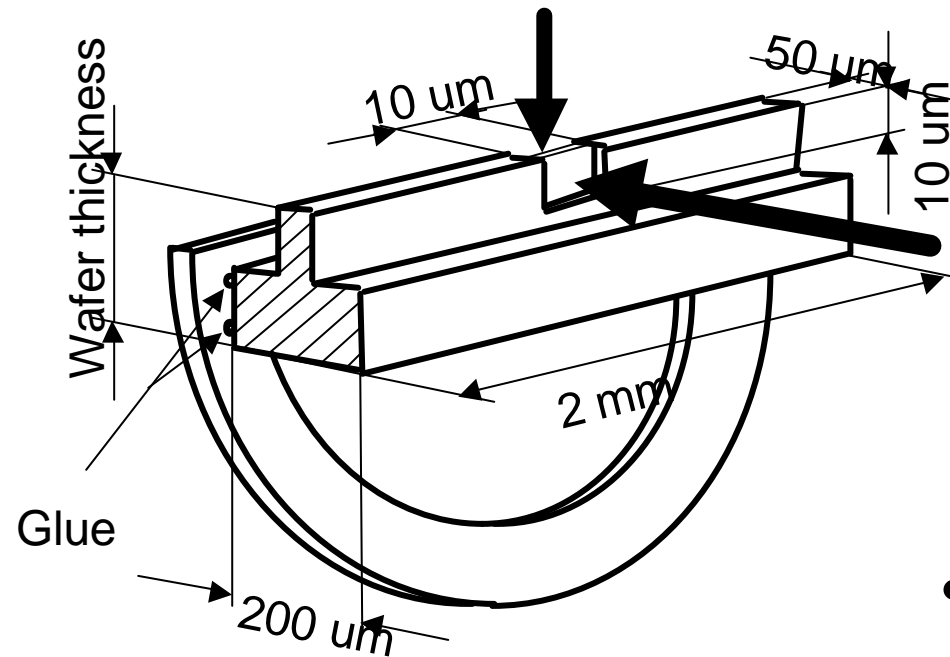


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FIB TEM sample preparation by bar sawing.



- Re-thinning possible
- High succes rate
- 2 mm bar needed
- Shadowing of X-ray detector

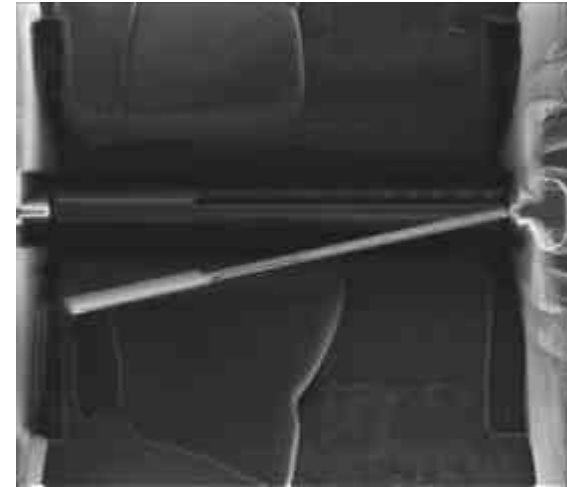
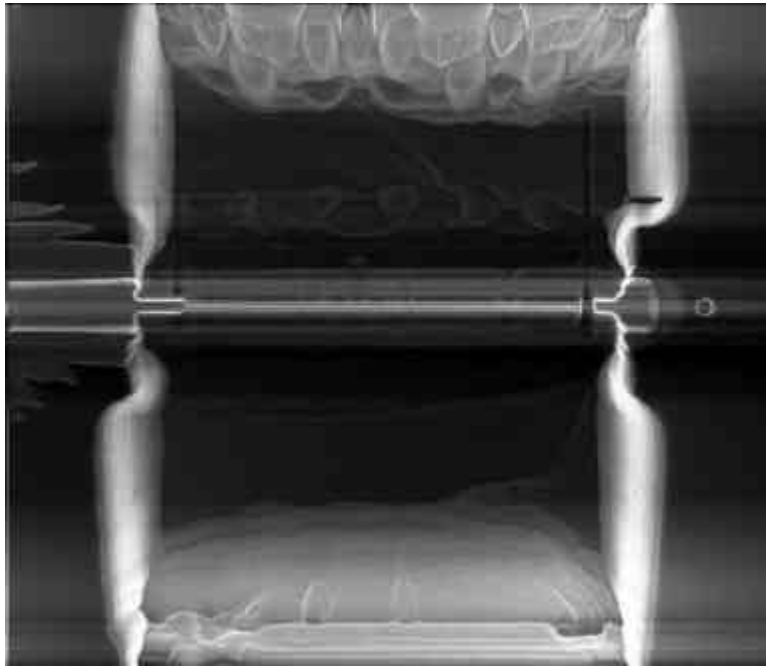
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External Plucker tool

- Transfer to TEM support grid by glass rod (electrostatic forces).
- No re-thinning possible.
- Varying success rate.



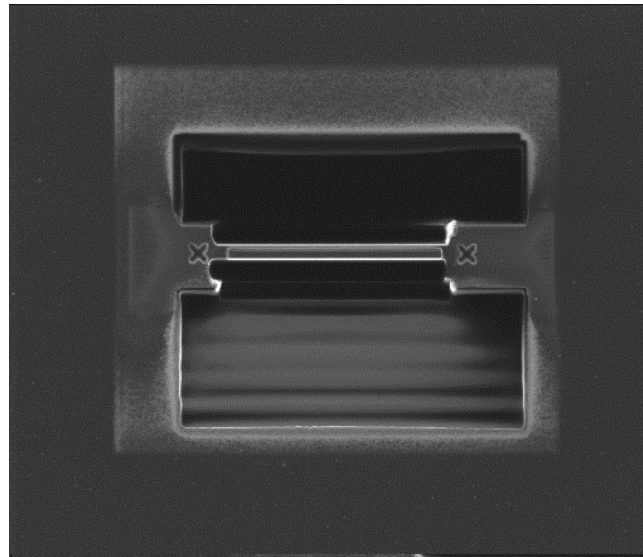
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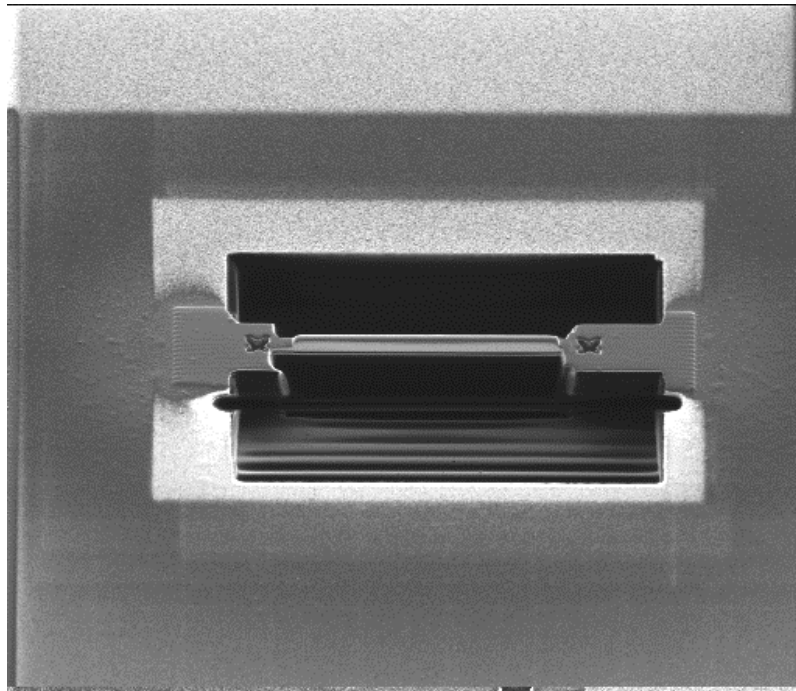
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Milling

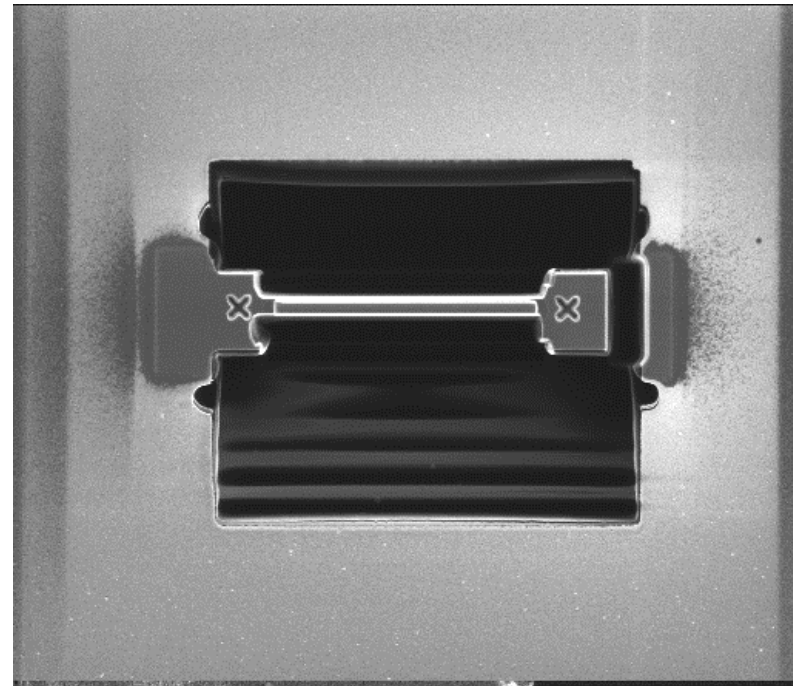
- Depth 5 μm .
- High current till 4 μm from membrane, medium current till 1.5 μm from membrane.
- Can be automated.



In-situ plucker tool



Tilted FIB image of TEM sample cut loose at bottom



Tilted FIB image of TEM sample cut loose at bottom and right side.

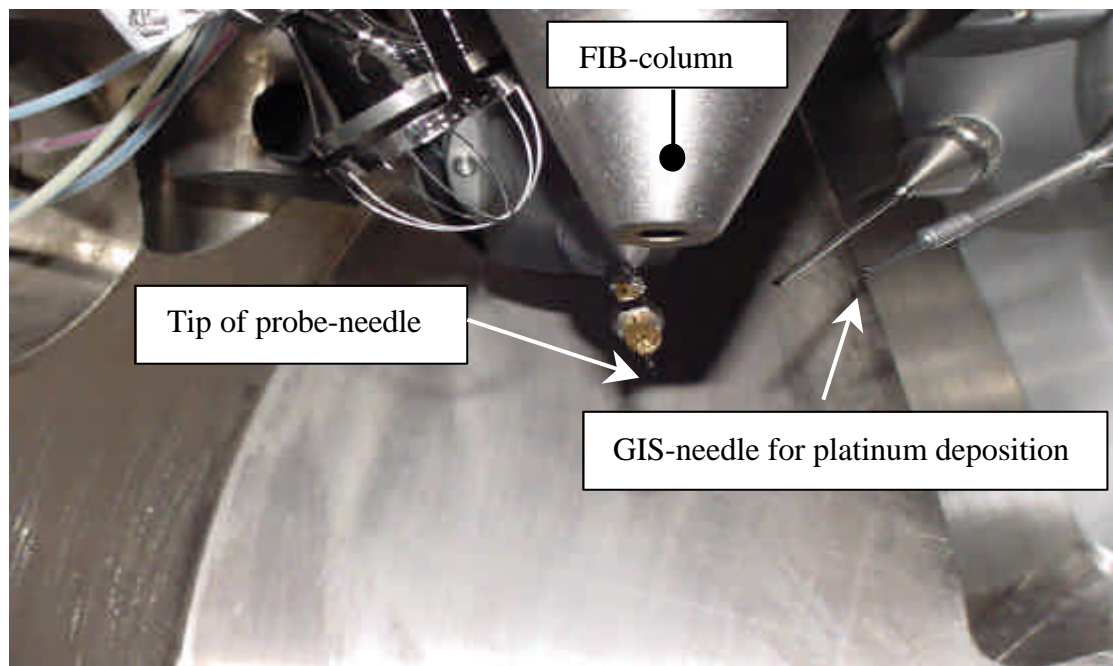
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Modification of the Gas -injector

- Needle attached to the injector

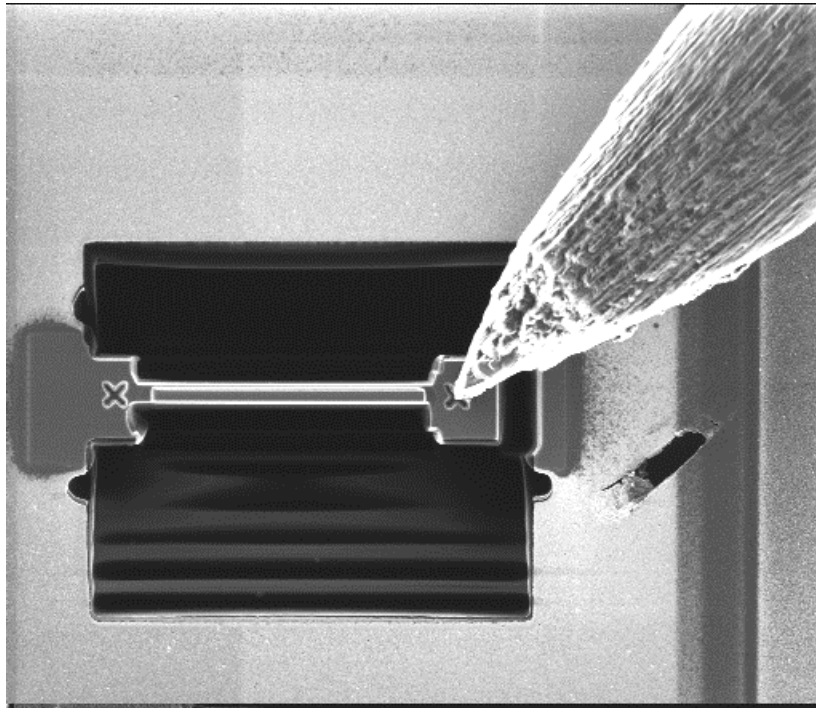


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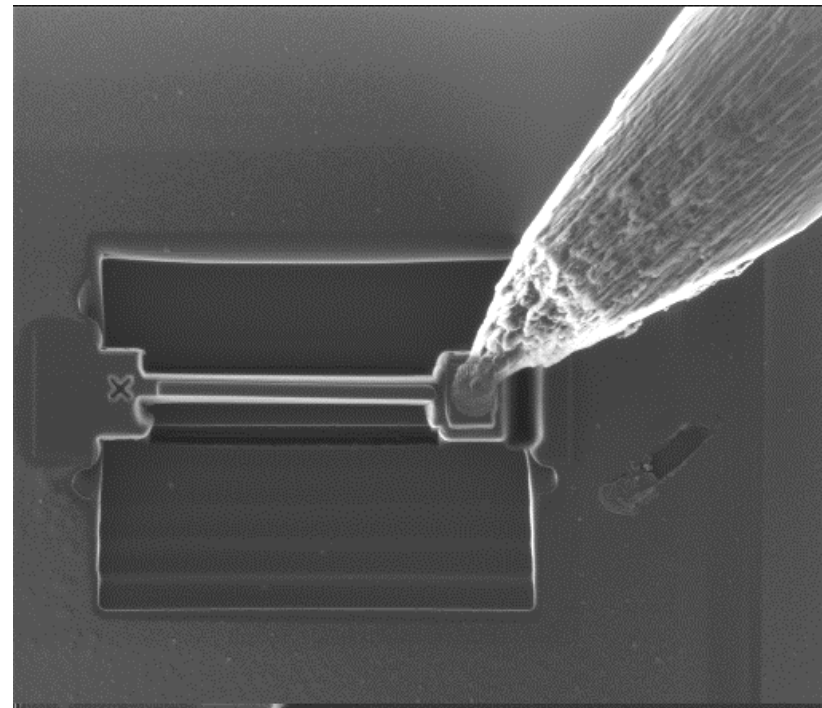


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In-situ plucker tool



FIB image showing probe needle approaching the ear.



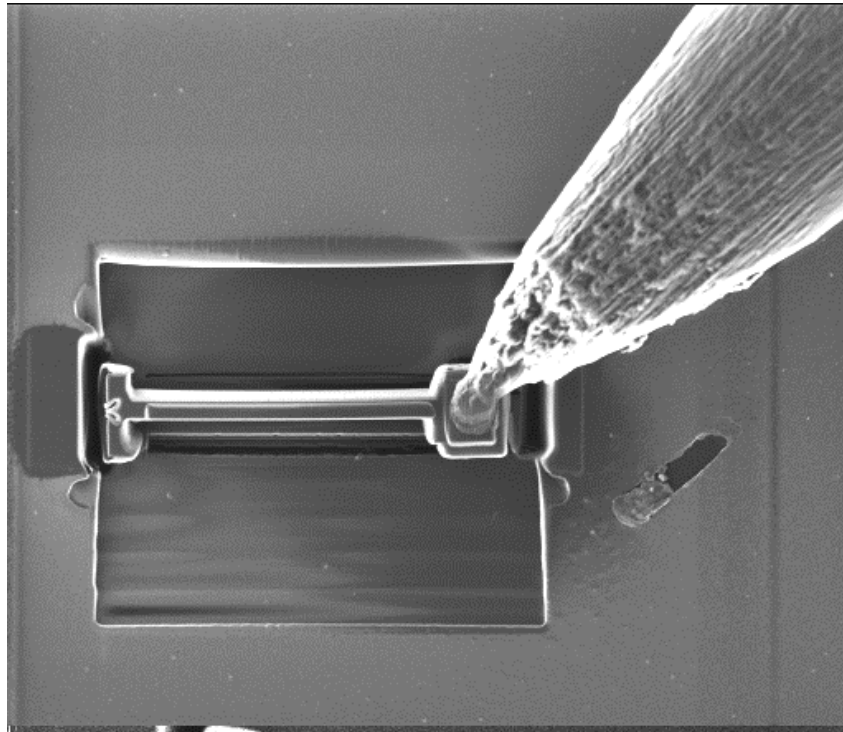
FIB image showing probe needle attached to the ear.

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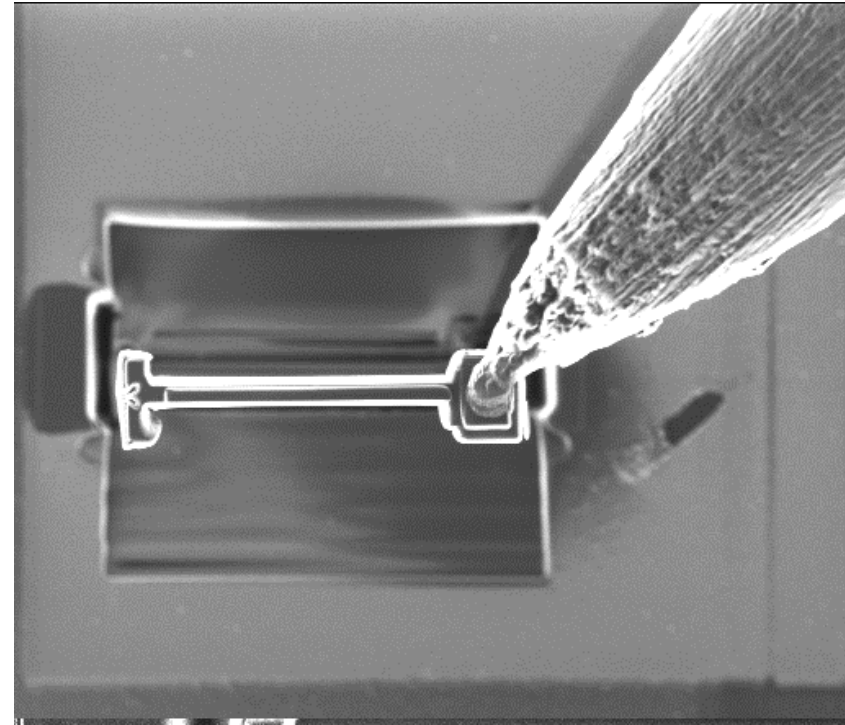


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In-situ plucker tool



FIB image showing free TEM sample



FIB image showing the TEM sample on its way to the support grid

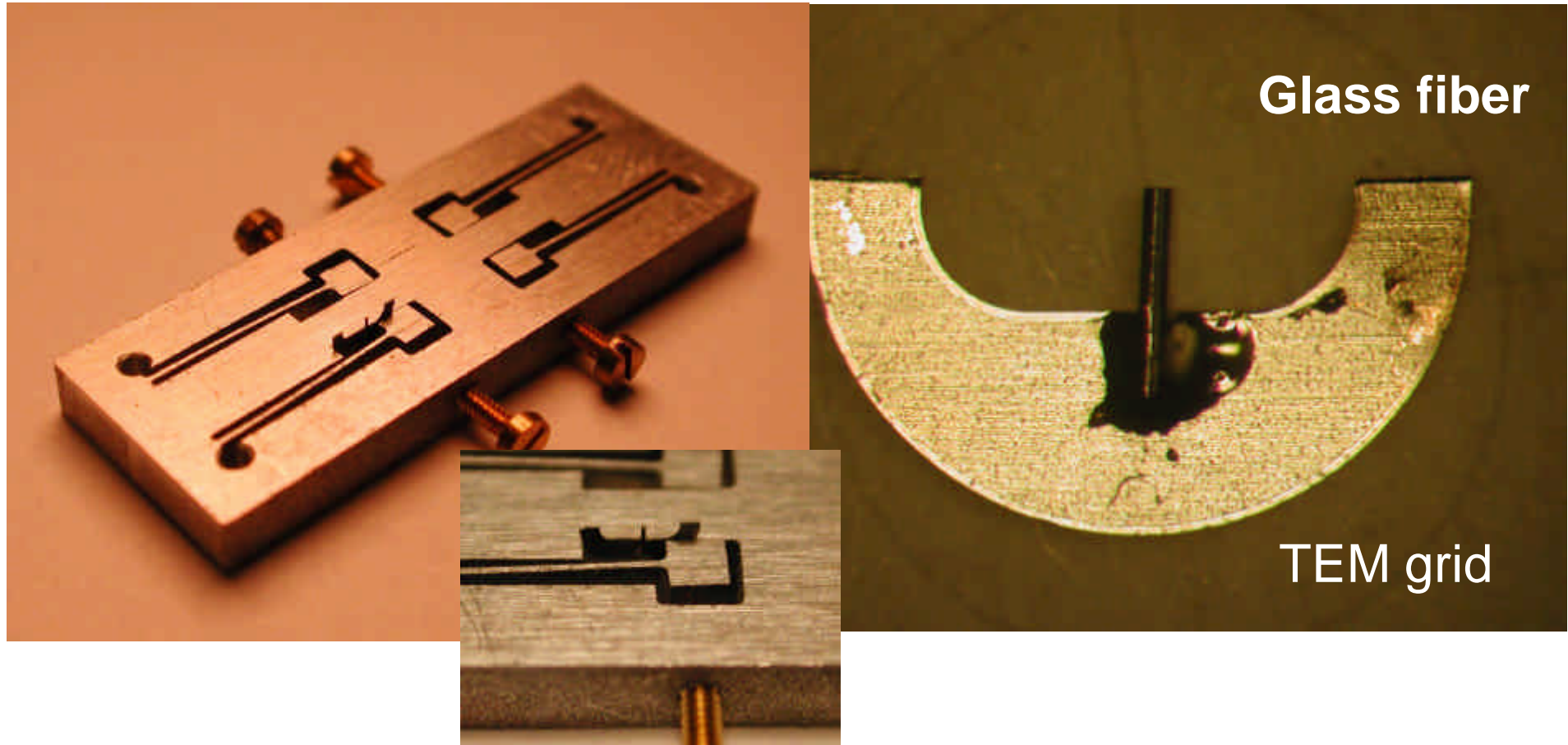
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In-situ plucker tool

TEM grid with support fiber



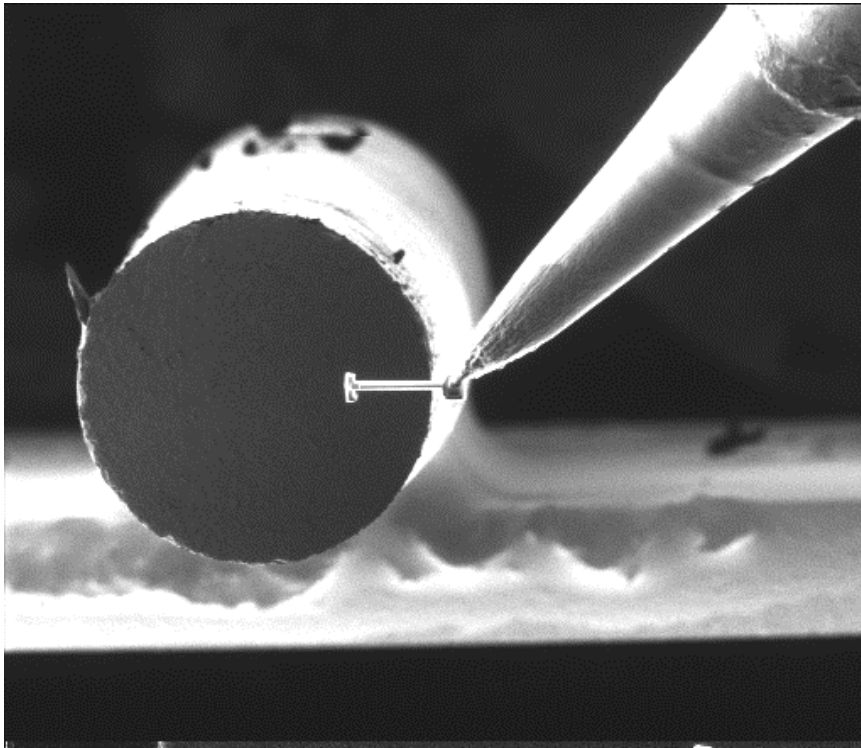
Optical images showing TEM grid with support fiber in special clamping tool.

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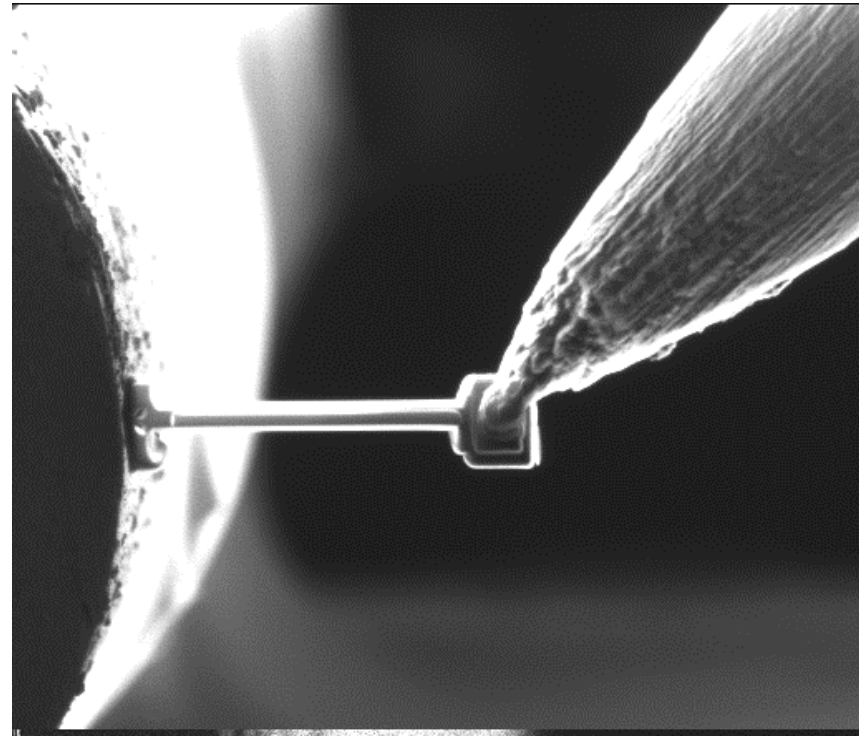


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In-situ plucker tool



FIB image of the TEM sample with the support fiber



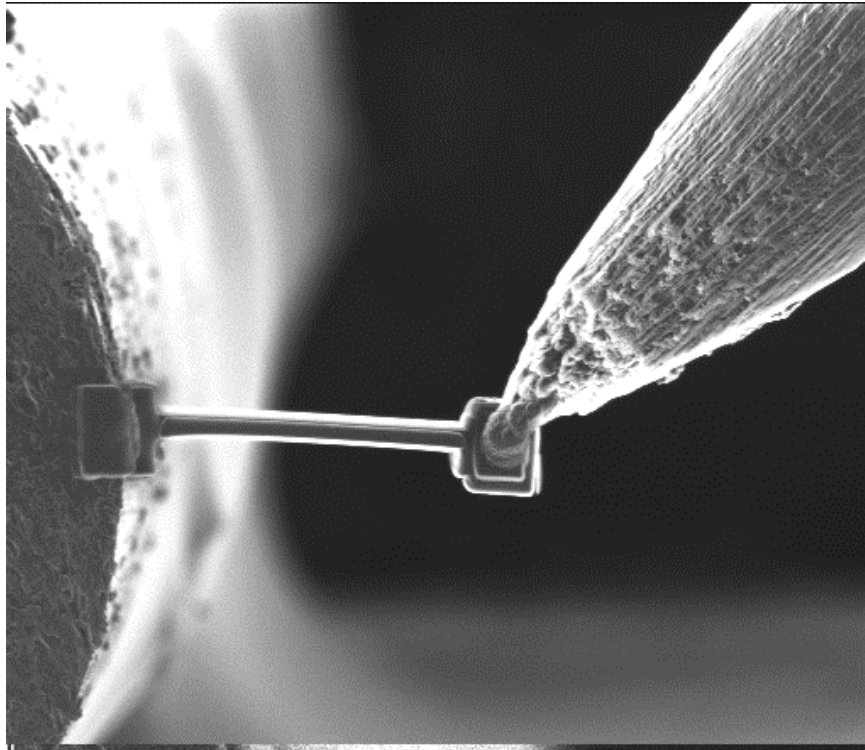
FIB image showing the TEM sample "attached" to the fiber

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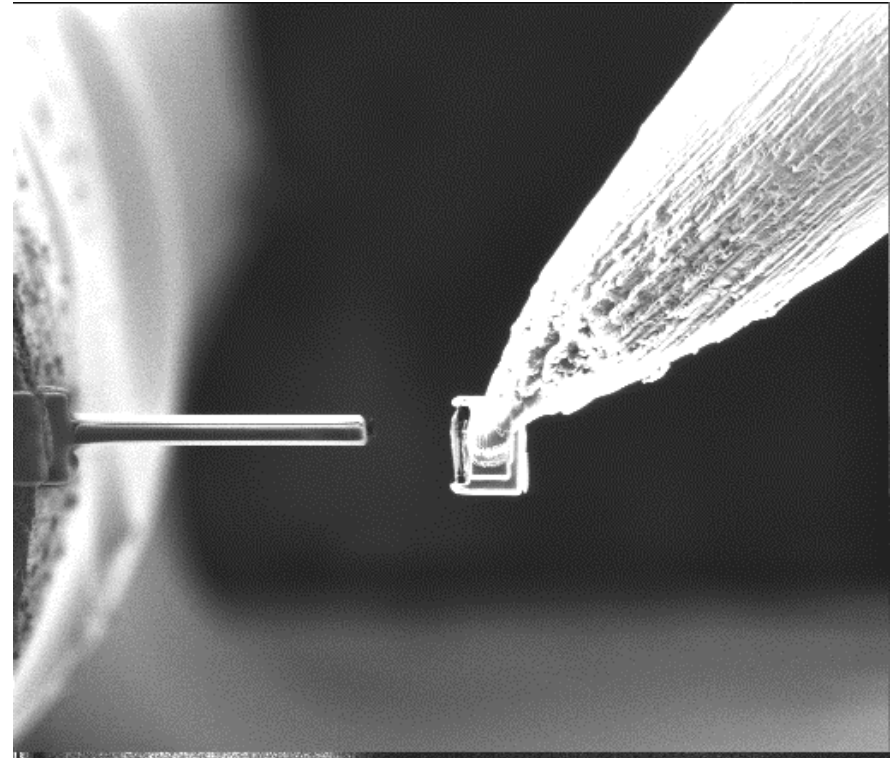


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In-situ plucker tool



FIB image of the sample attached with Platinum on the fiber



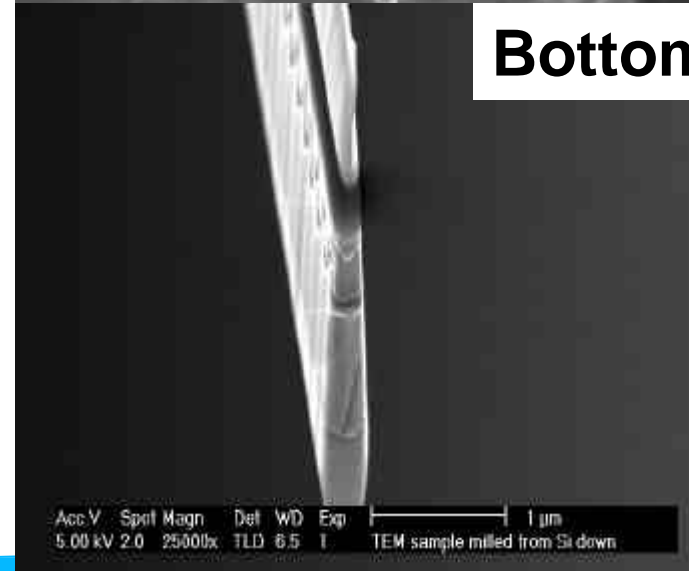
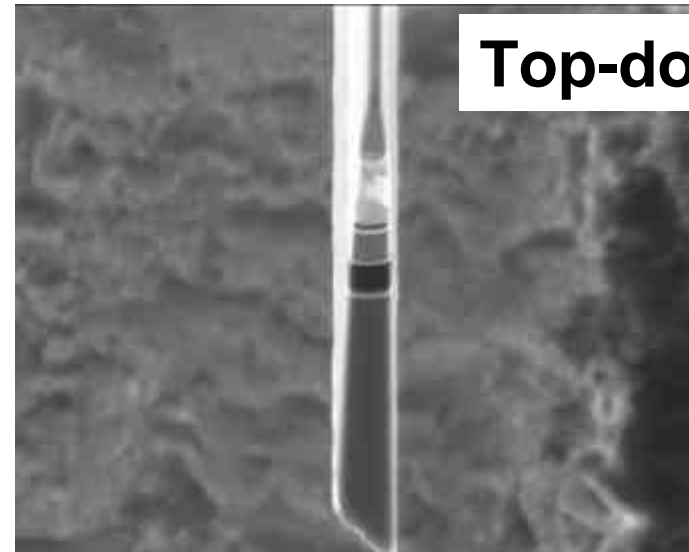
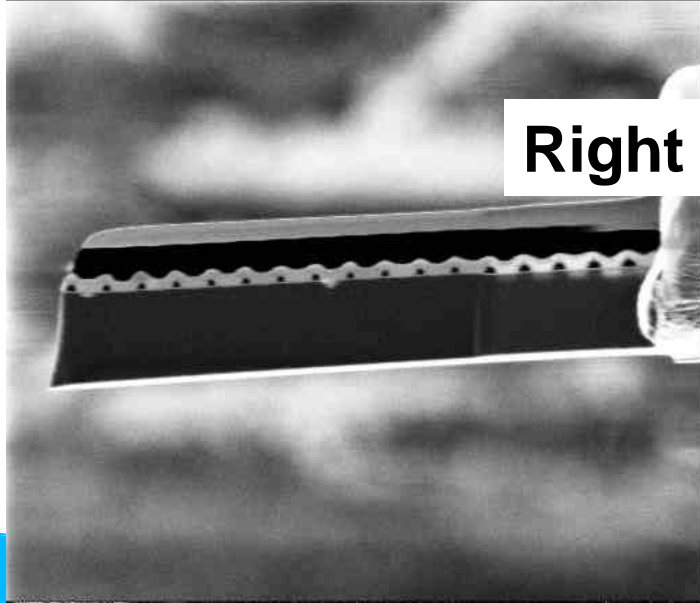
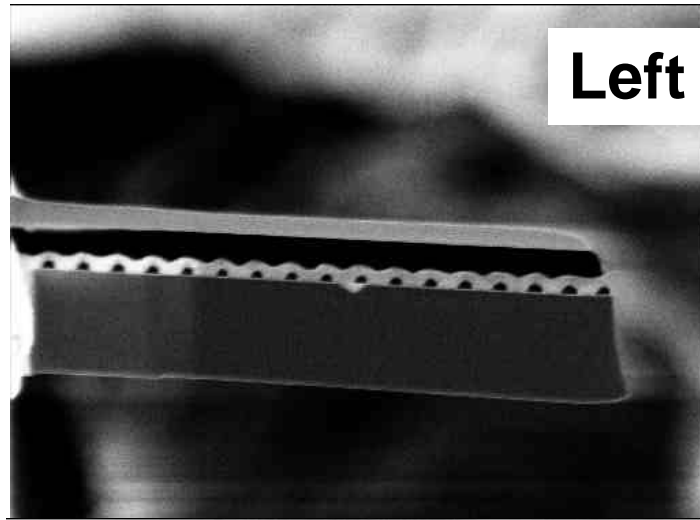
FIB image showing the sample cut from the needle

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Excellent sample access during final milling



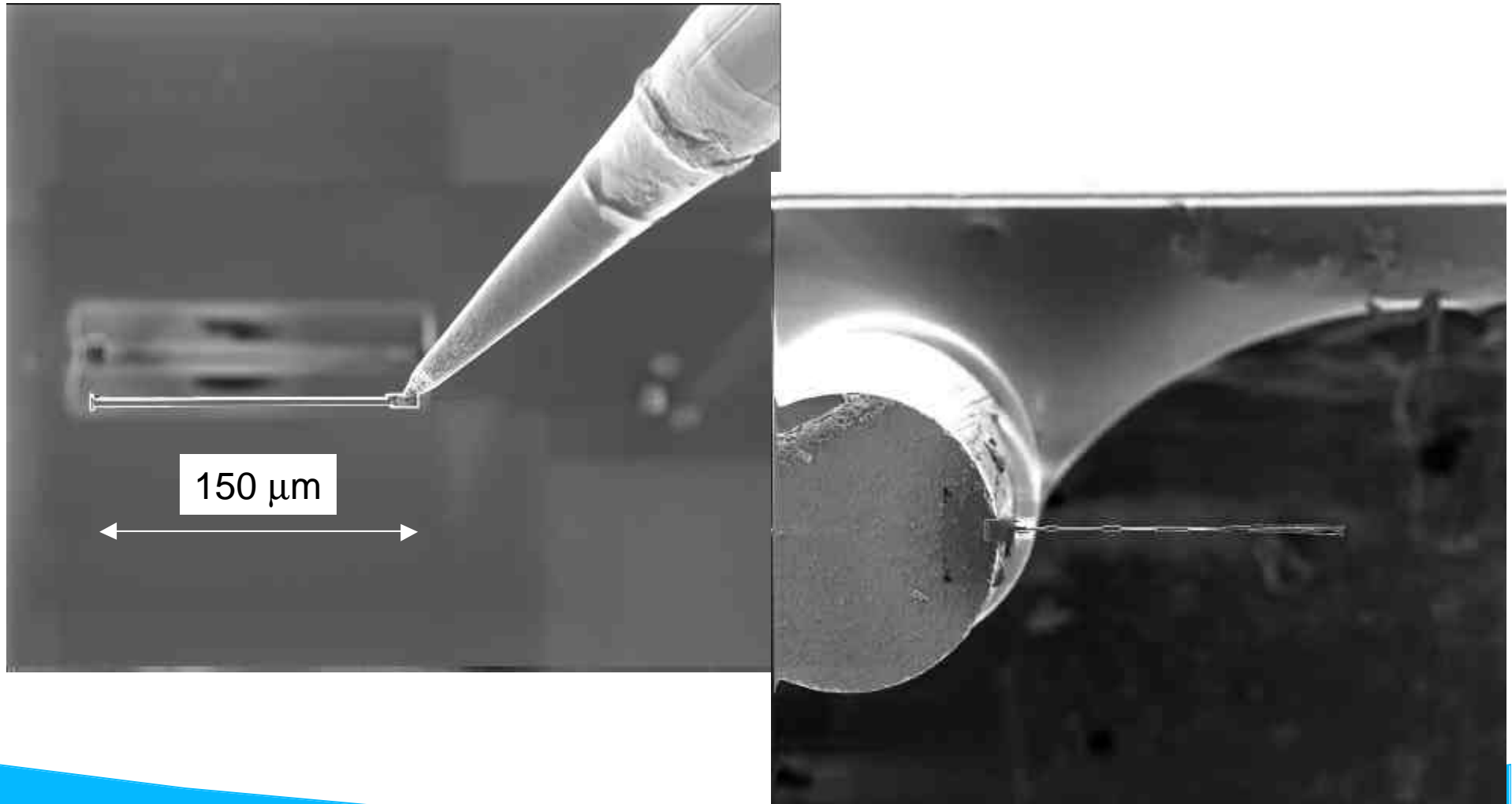
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World record 150 μm long TEM X-section

Prepared by in-situ plucker tool

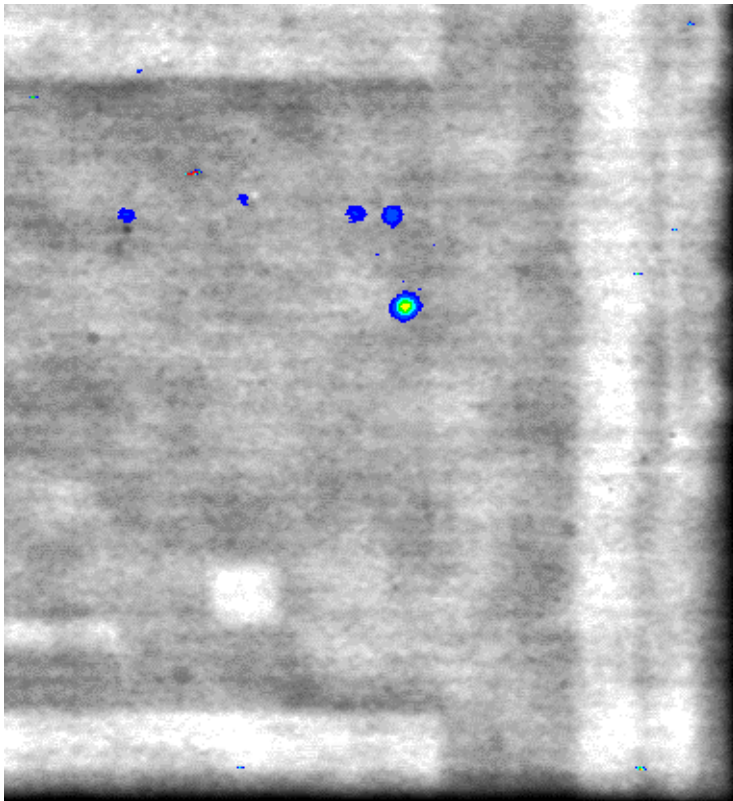


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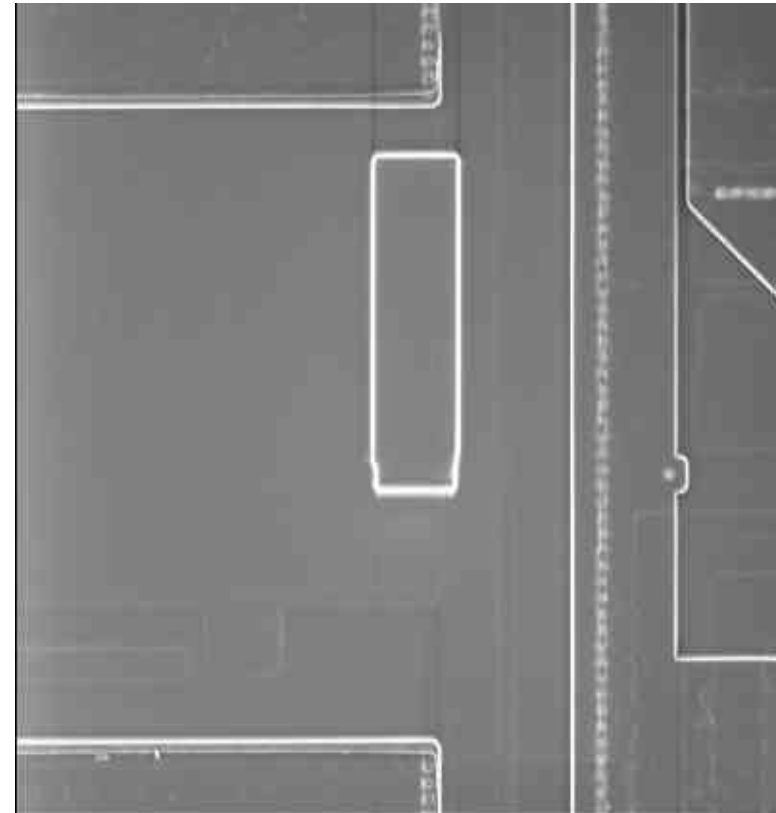


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Example lift-out: Diffusion barrier problem



Find fault location by backside Photo Emission Microscopy.



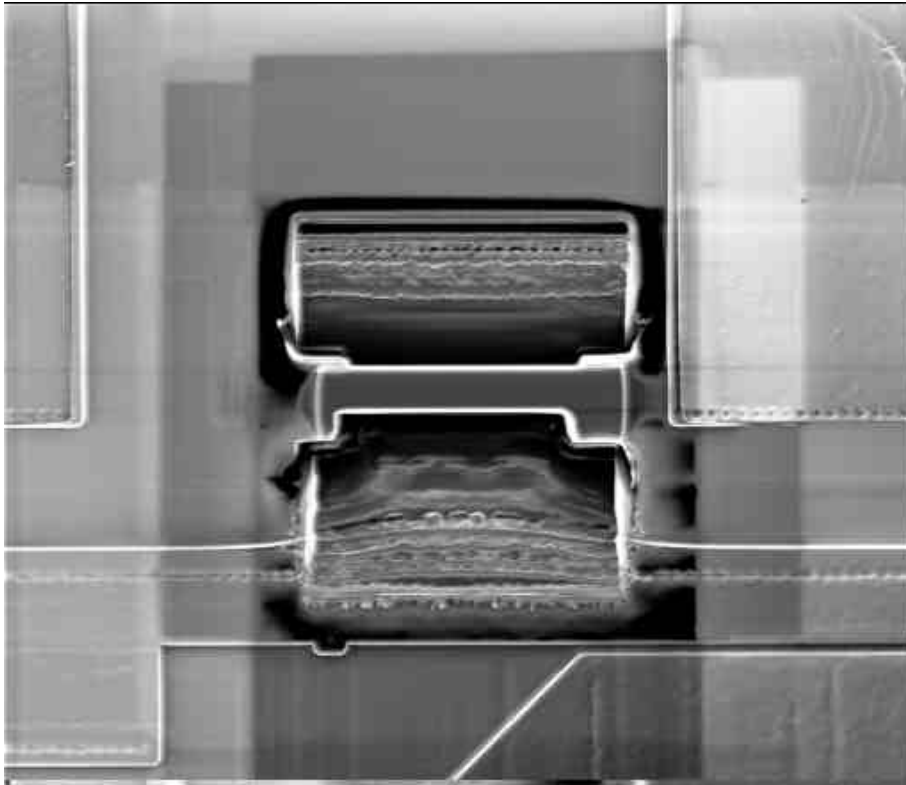
FIB image of fault area. Location of PEM spot covered with protective Pt layer.

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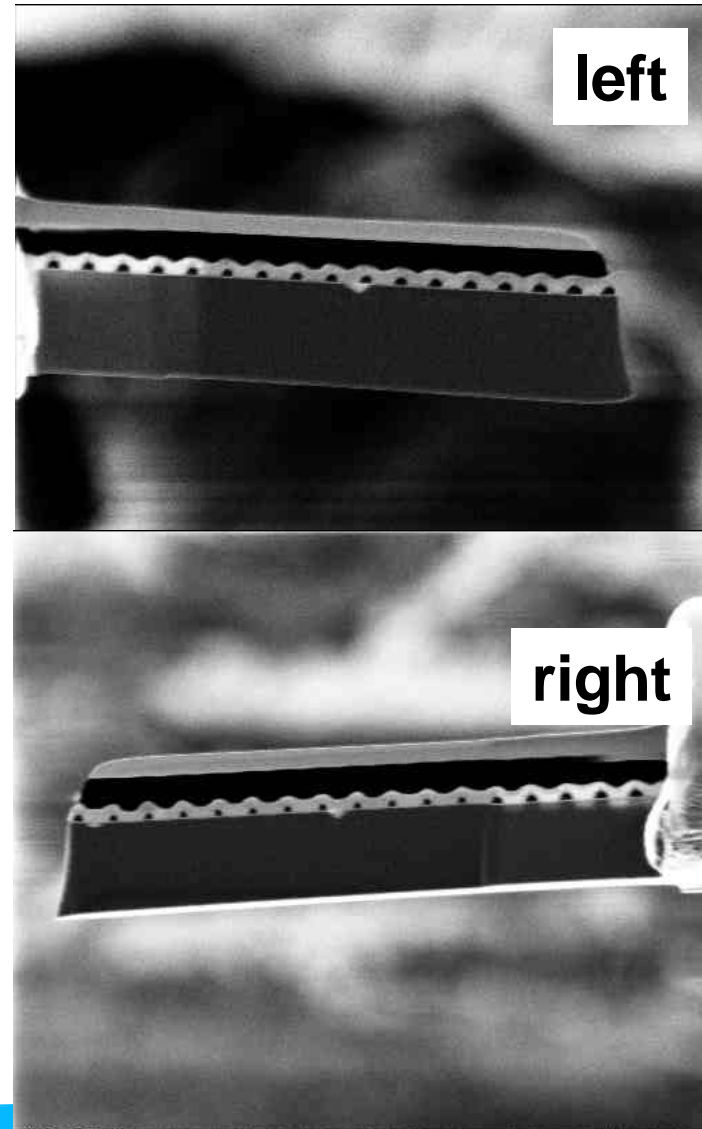


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Example lift-out : Diffusion barrier problem



*Manual preparation of TEM lamella.
Lamella can be observed from three sides.*

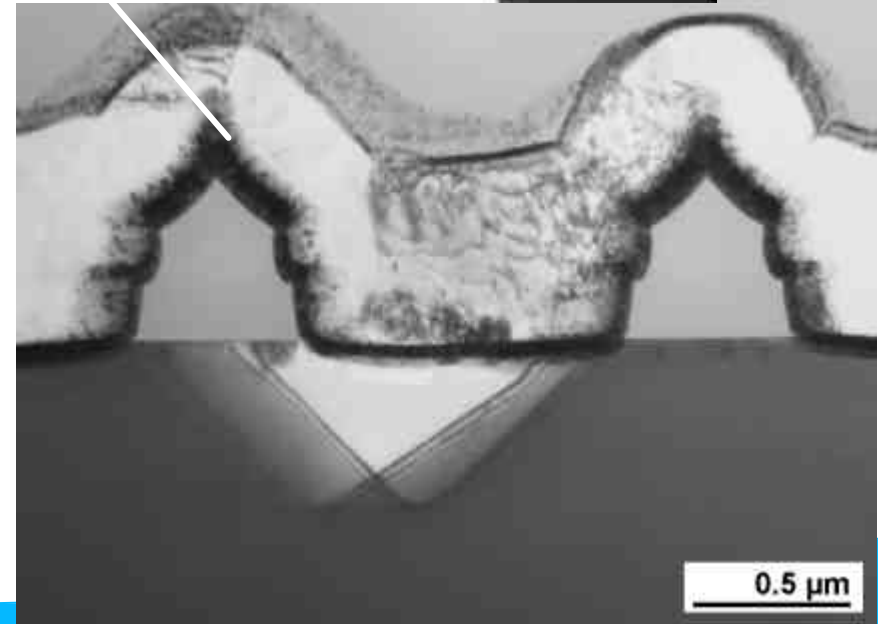
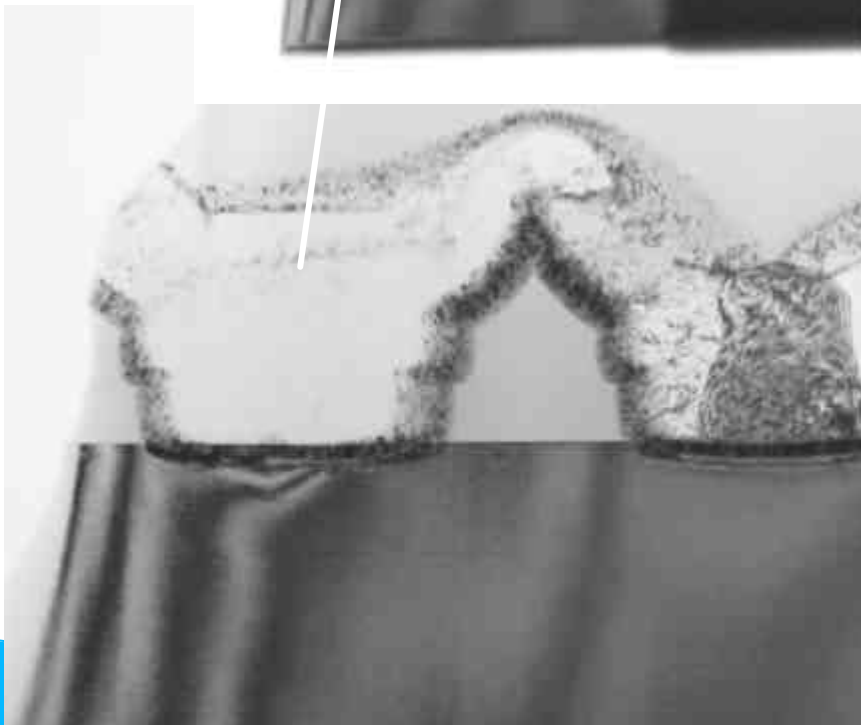
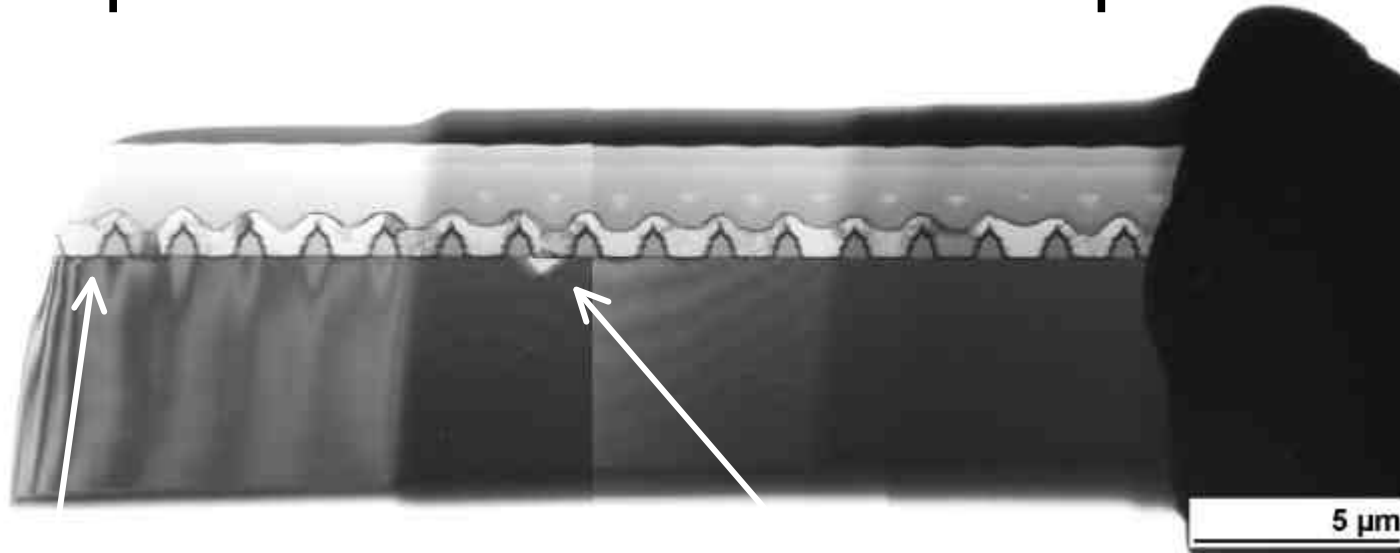


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Example TEM: Diffusion barrier problem

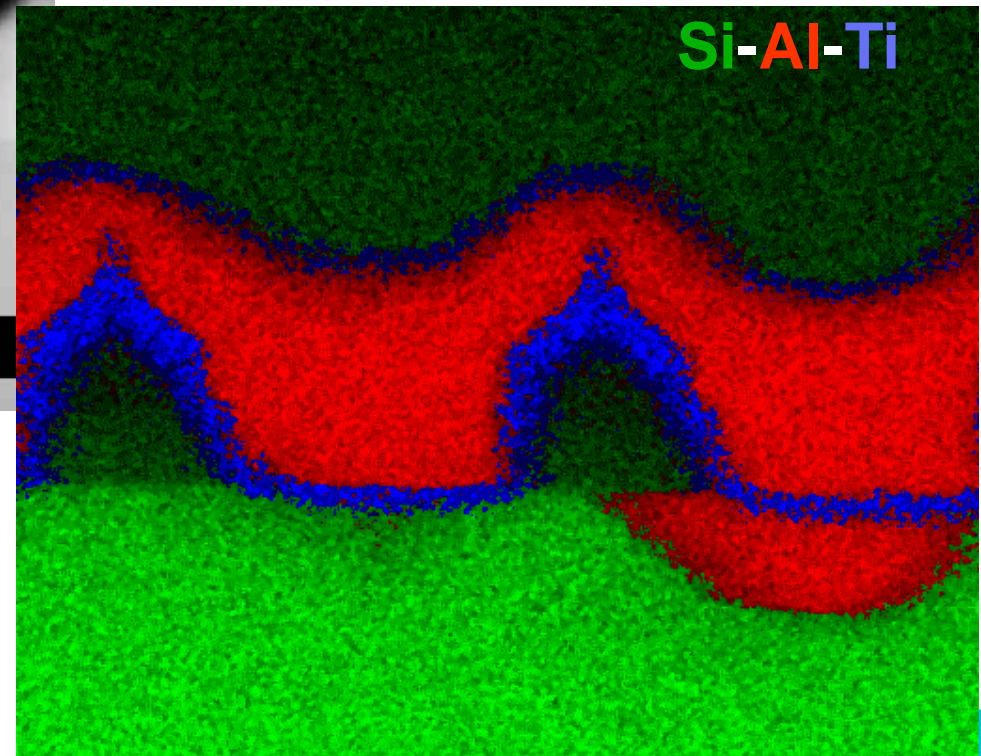
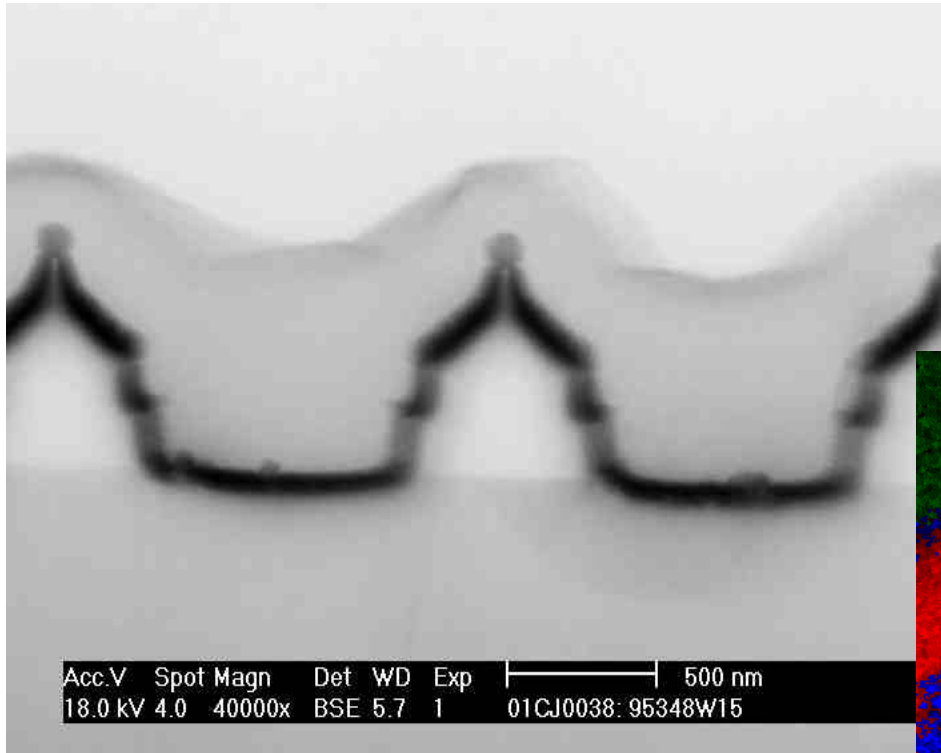


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Example SEM/EDX: Diffusion barrier problem

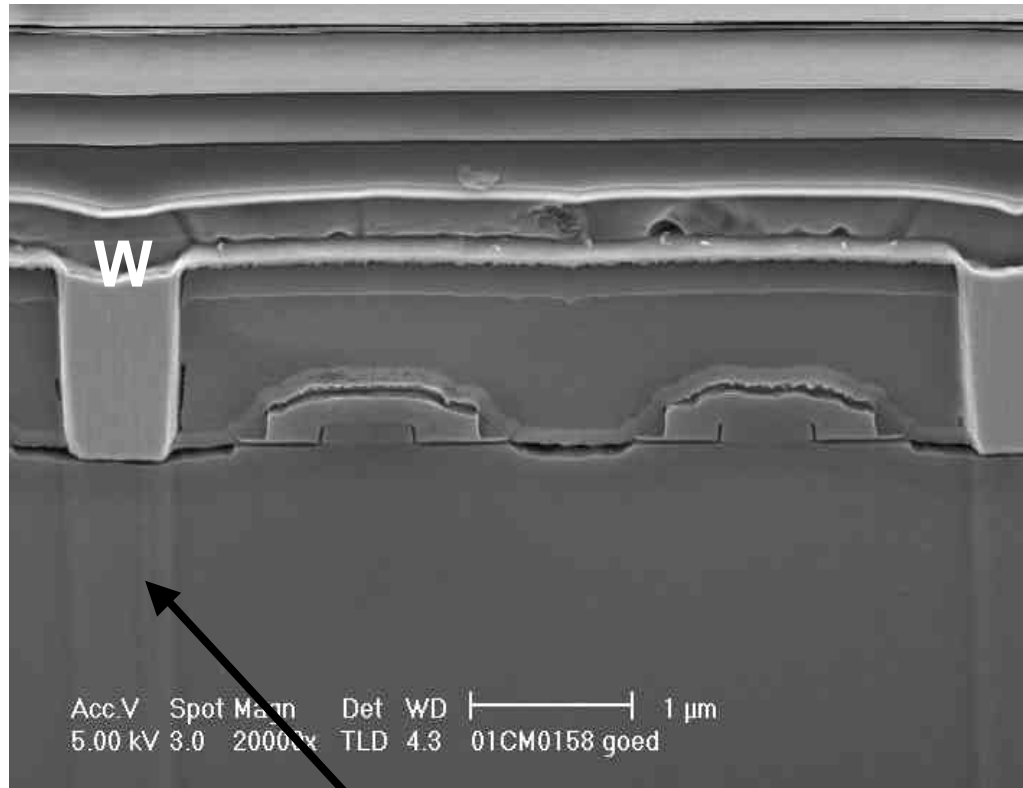


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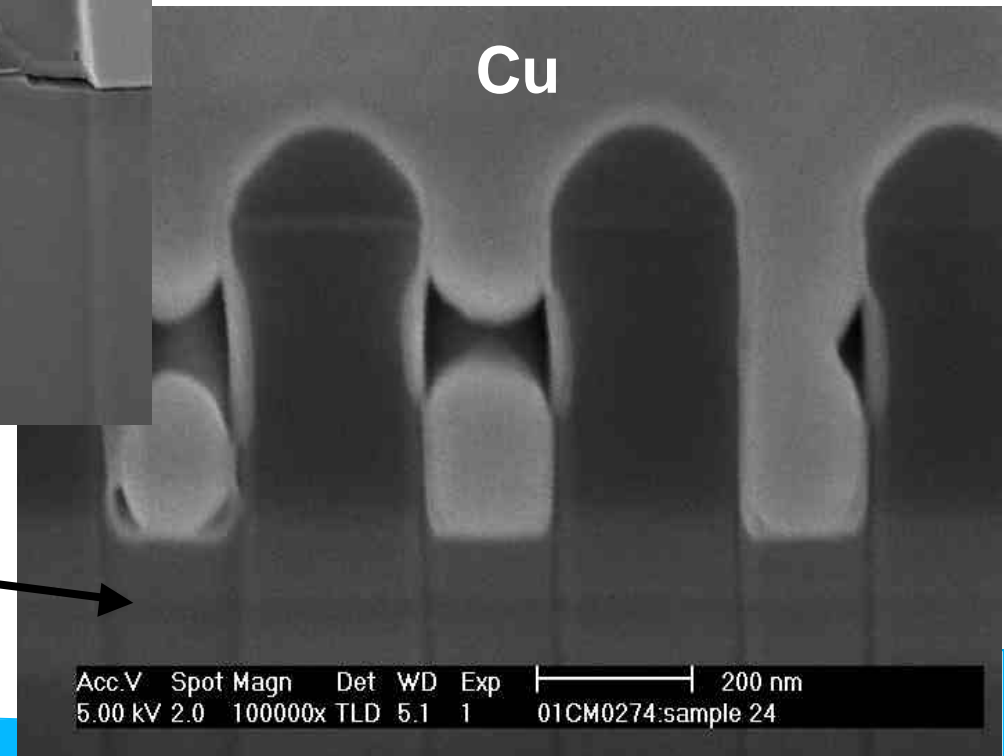


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Example lift-out: Reduction of FIB artefacts



FIB artefacts in Si under Cu and W plugs due to material and density variations.



FIB artefacts

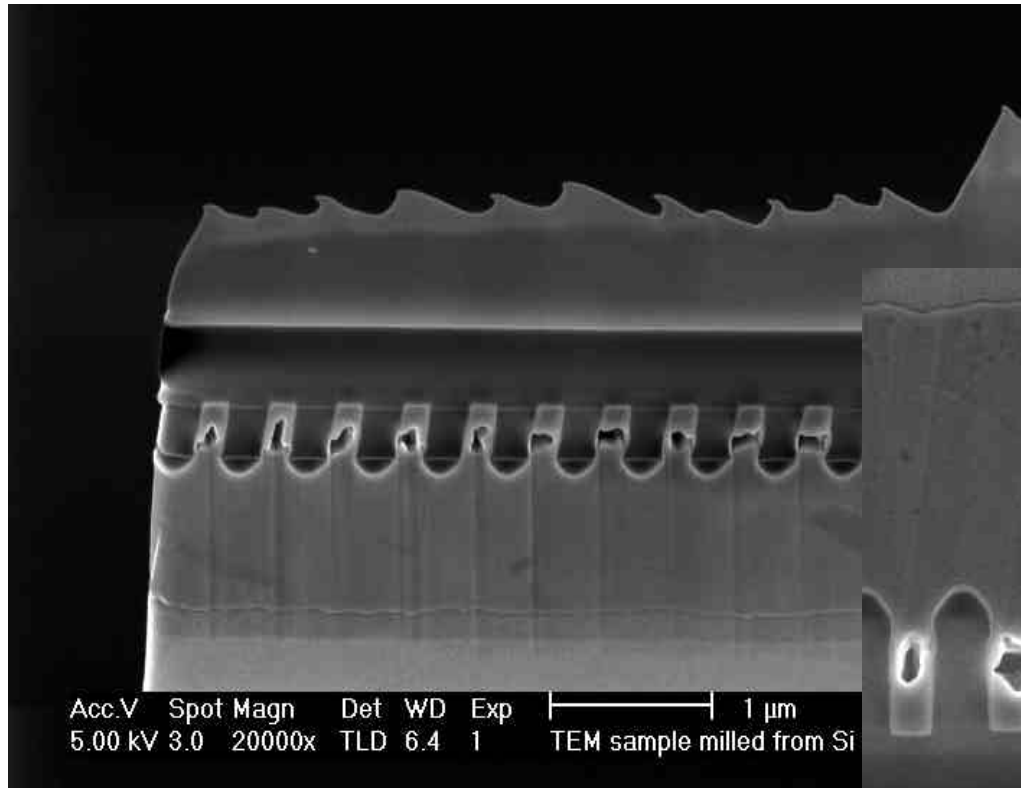
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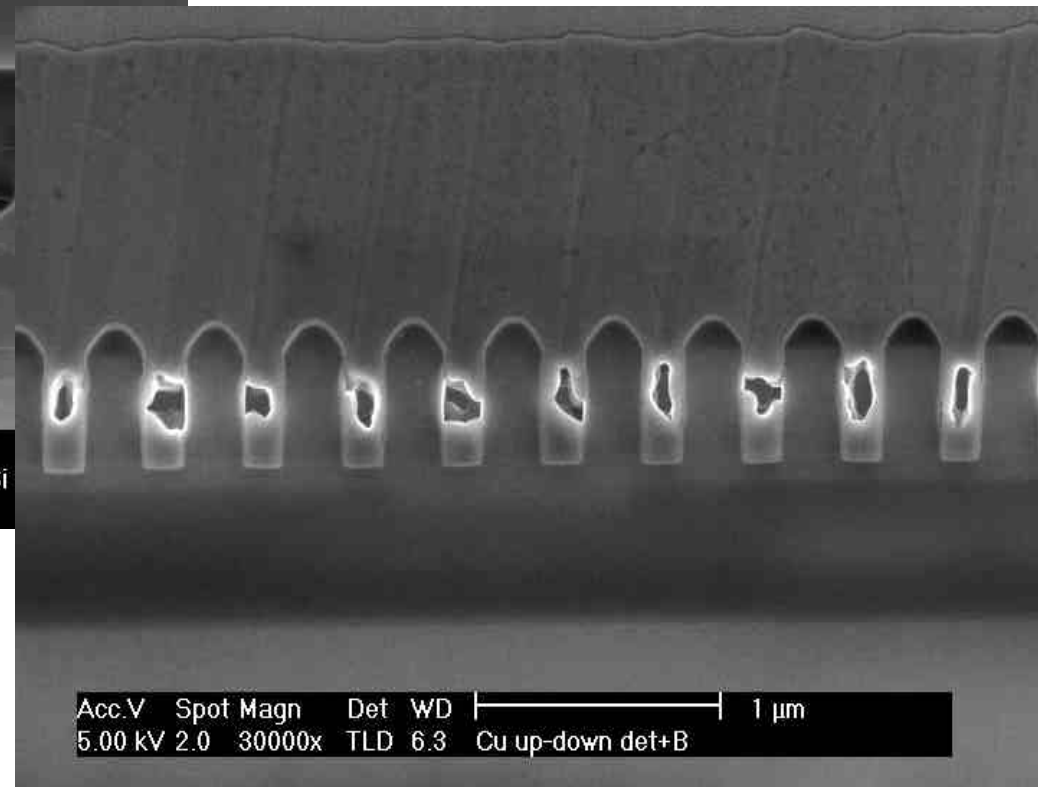
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Example lift-out: Reduction of FIB artefacts

Cu on Si: sample up side down



FIB artefacts now in Cu,
Si substrate free of artefacts.



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Summary

- **In situ plucker technique using 1 DOF W tip and accurate stage is a viable technique requiring little effort.**
- **Lamella can be taken from small and irregular shaped samples (i.e. packages) and re-thinned.**
- **Lamella is free hanging:**
 - **Minimal deformation and optimal contrast during final thinning.**
 - **Observable from 3 sides (left, right, sideways)**
 - **Sample can be thinned bottom up.**
 - **No shadowing of (X-ray) detectors.**
- **High success rate of sample removal.**
- **Development part of Medea (T304-Diamant) project.**

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