Laser-Micromachining for Failure Analysis:

from TEM Sample Preparation to Large Area SEM Inspection (and more)

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Content

3D-Micromac – Micromachining Excellence

We are the leading specialist in laser micromachining.

Our mission:

- Development of powerful, user-friendly, and future-oriented micromachining processes
- Manufacturing of
  - Laser micromachining systems and
  - Roll to roll processing systems
- All processes and system with superior production efficiency
- Reliable and fast service for micromachining systems worldwide

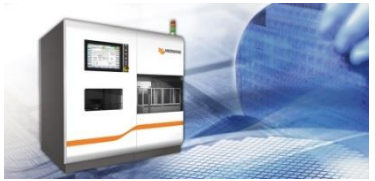
"Our international customers place great value on future-oriented and user-friendly processes. Our solutions help them increase production efficiency and lower cost".

Tino Petsch, CEO

Production Solutions for Innovators and Growth Markets

microDICE™ Systems for Semiconductor Industry

- Production equipment for the separation of semiconductor wafers using TLS-Dicing™



microCELL™ Systems for Photovoltaics

- High throughput laser processing of crystalline solar cells
- Laser structuring of PERC solar cells • Half cell cutting to increase PV module power

microPREP™ Laser Based Microdiagnostics Sample Preparation

- Enables high-throughput, clean, and efficient laser ablation for the preparation of samples for microstructure diagnostics and failure analysis

microSHAPE™ Systems for Machining of Displays and Smart Glasses

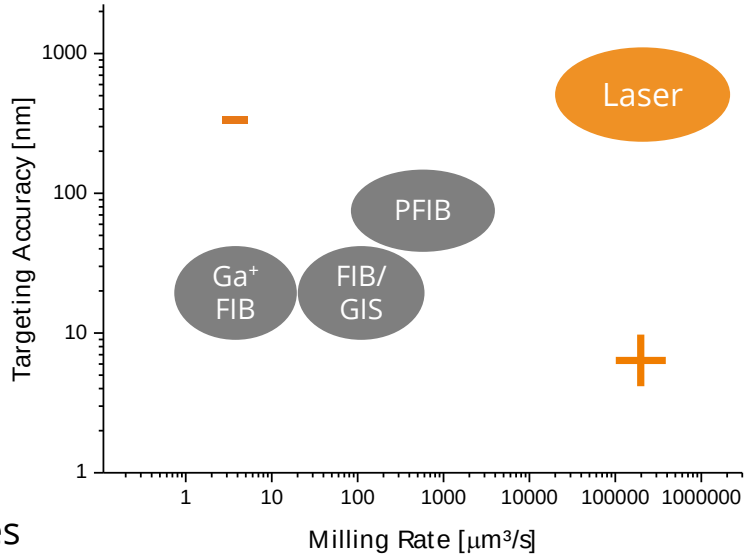
- Laser cutting of conventional and tempered glass and sapphire • FSLA™ Flow supported laser ablation for high quality production of complex microstructures

Content

Sample Preparation with Laser

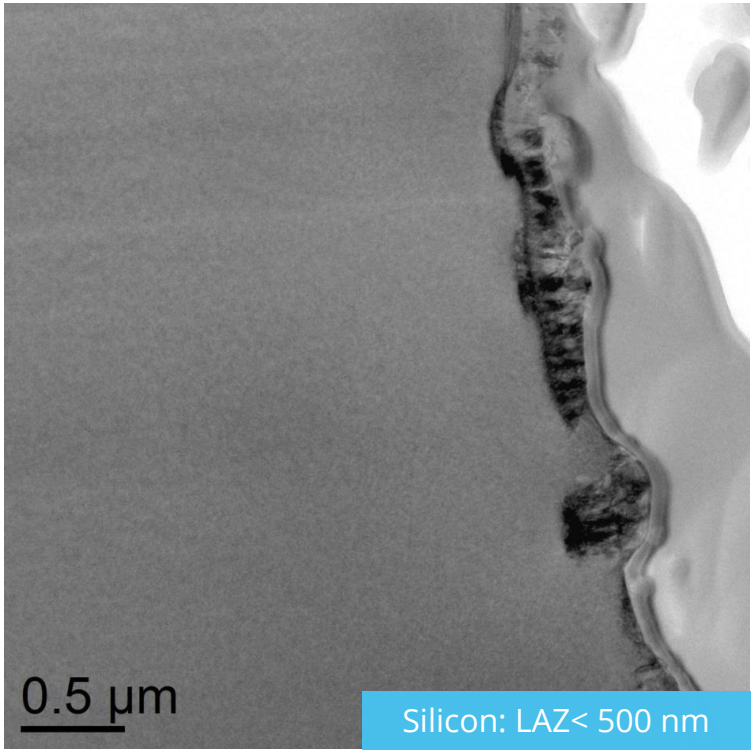
Motivation

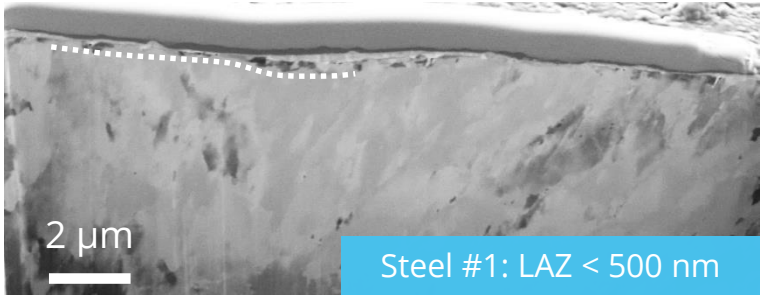
- Easy to use
- Low running costs
- Just photons → clean in terms of contamination
- Precise local positioning and focusing
- High power densities → Materials ablation
- High fluence → non-linear optics:
  Multi-photon absorption → Machining even
  of transparent-at-the-wavelength materials feasible
- Only short FIB fine polishing of laser prepared samples
- Saving expensive machine time of the FIB or broad ion beam tools

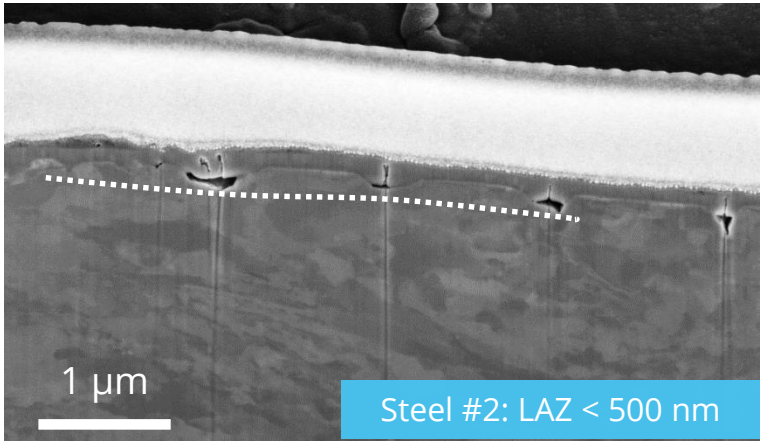


» Does the laser harm the sample material? «

Laser Affected Zone using ps Laser







Traditional Preparation Steps

FIB

Analysis

- TEM
- SEM
- XRM
- …

Preparation ~ 2 - 20 hours

Time to final sample ~ 2 – 20 hours

Combined Sample Preparation using Laser

Laser

FIB

Analysis

- TEM
- SEM
- XRM
- …

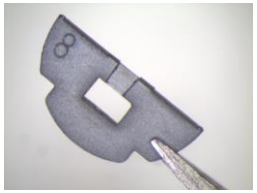
Preparation time < 15 min + Polishing ~ 45 min

Time to final sample ~ 60 min

Content

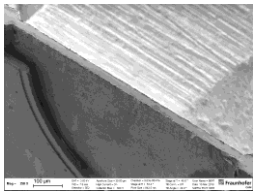
3D-Micromac's microPREP™ - Patented Workflows

1. In-plane geometries and bulk samples



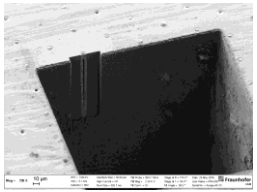
or

2. X-sections



or

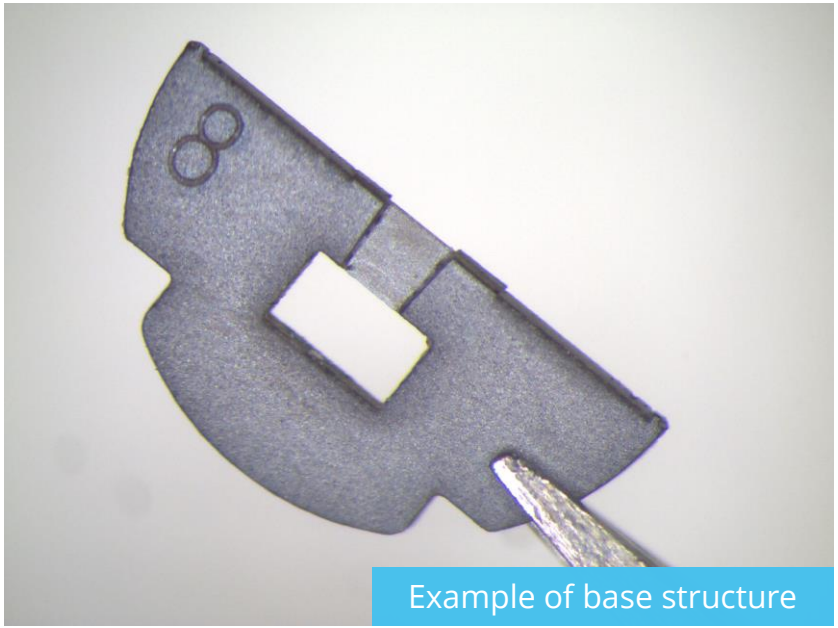
3. 3D-structures



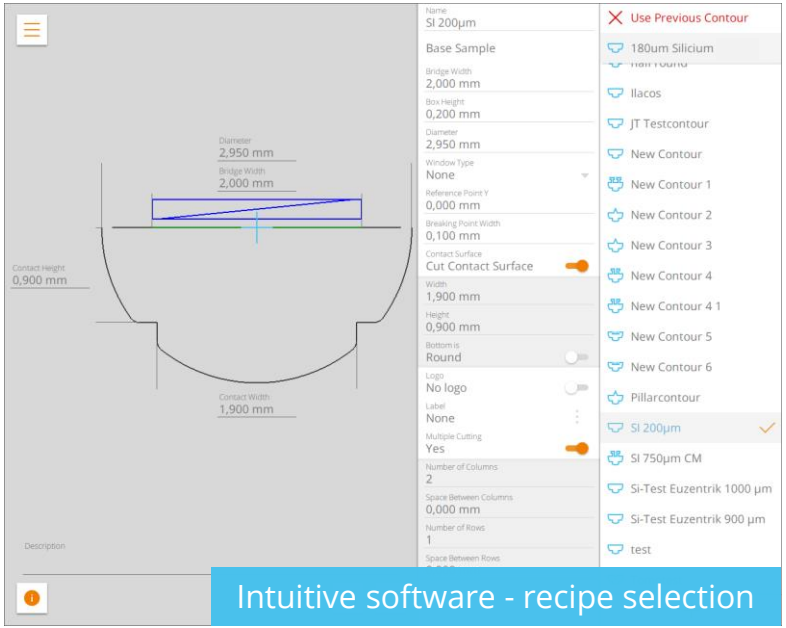
» microPREP™ provides a best known method (BKM) library for ease-of-use «

In-Plane Geometries and Bulk Material

- Defining base structure of lamella



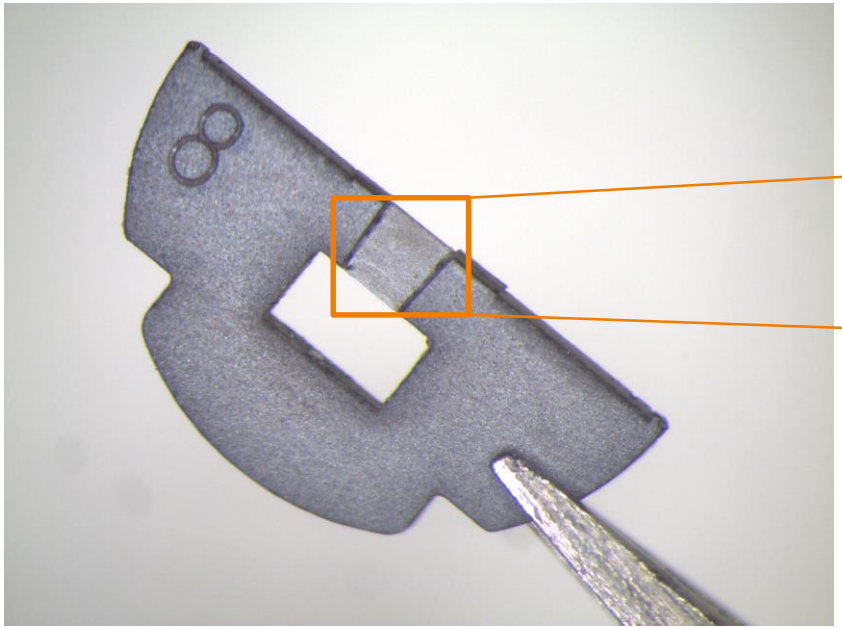
Example of base structure

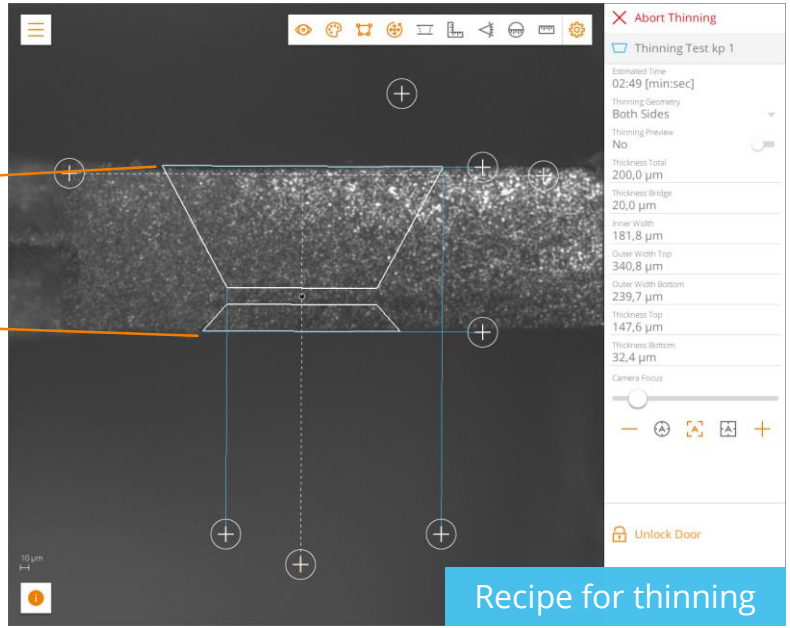


Intuitive software - recipe selection

In-Plane Geometries and Bulk Material

- Defining thinning area

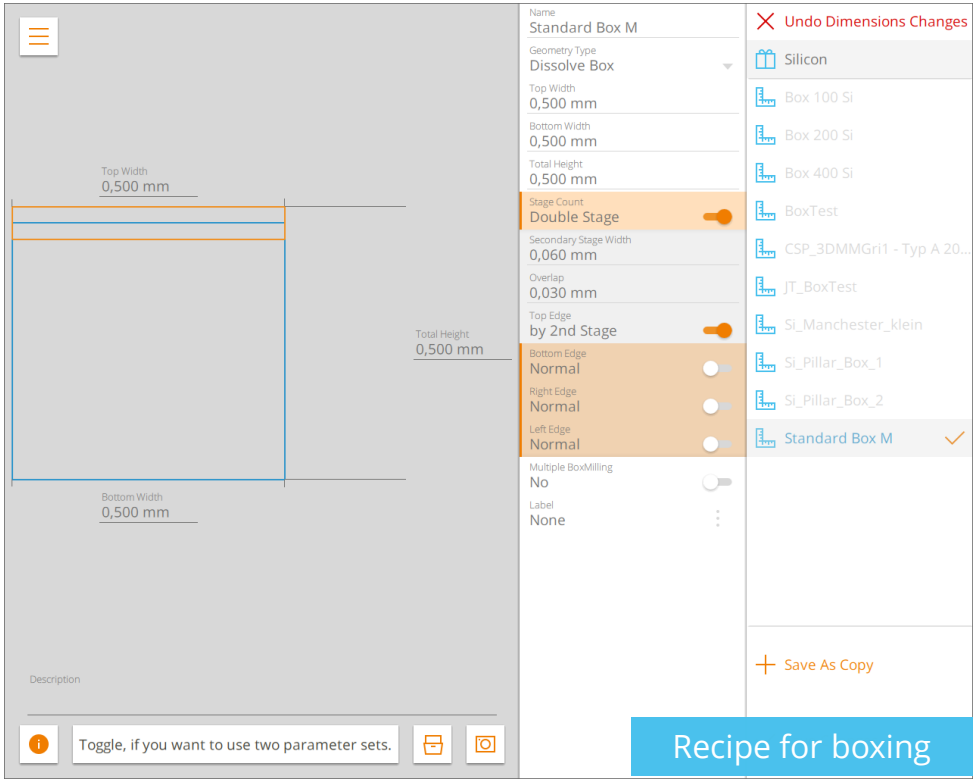




Preparation of 3D Structures

Box Milling

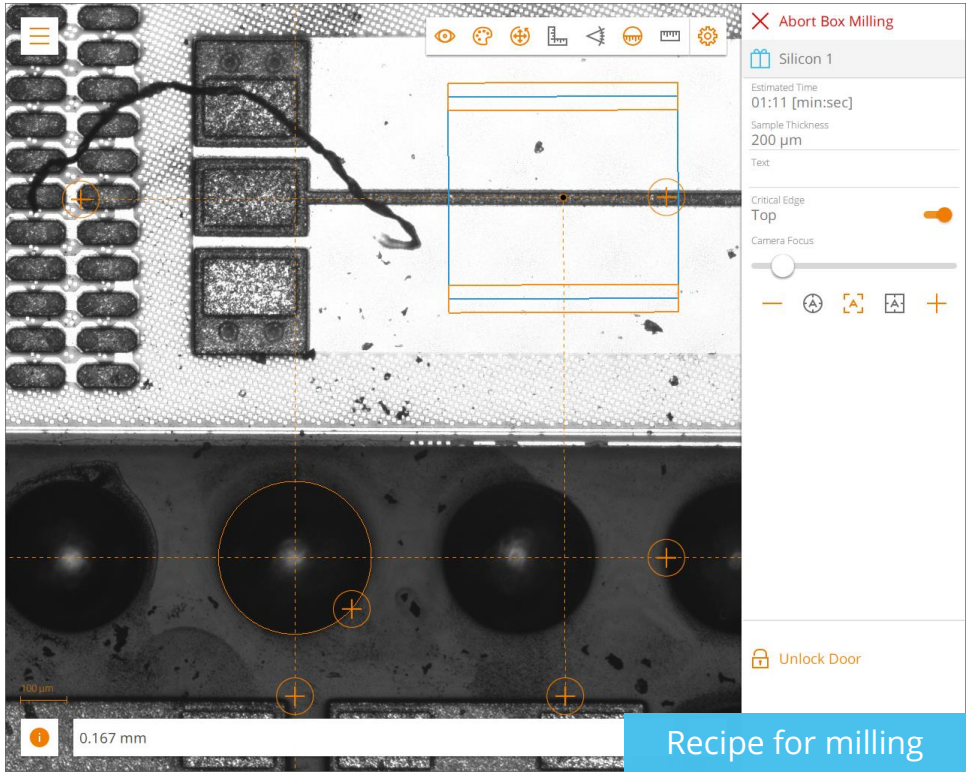
- Defining box area



Preparation of 3D Structures

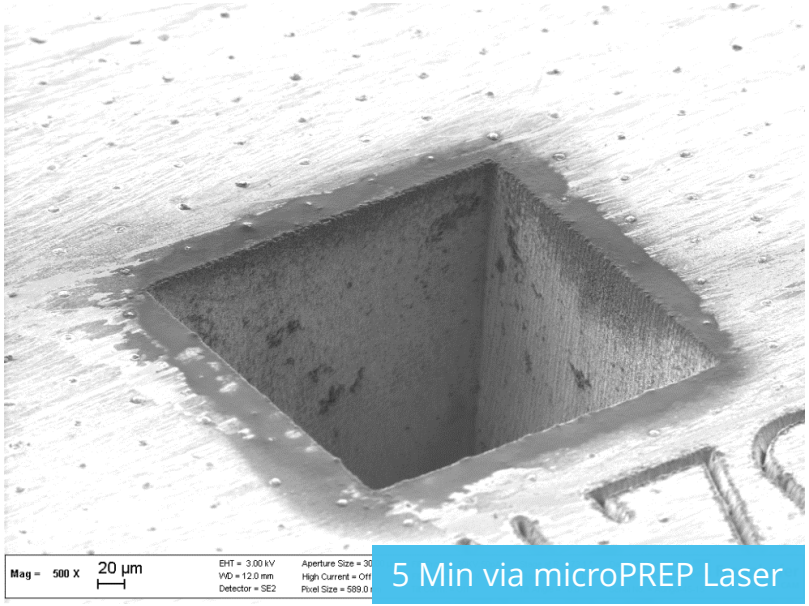
Box Milling

- Place box on sample

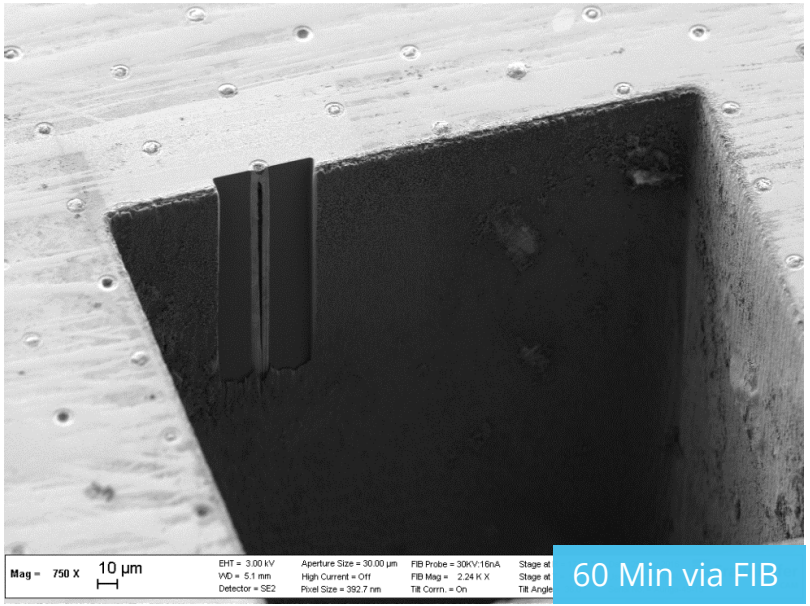


Examples – 3D Structures Sample Preparation for SEM

Advanced laser box-milling for subsequent FIB polishing for diagnostic of TSVs



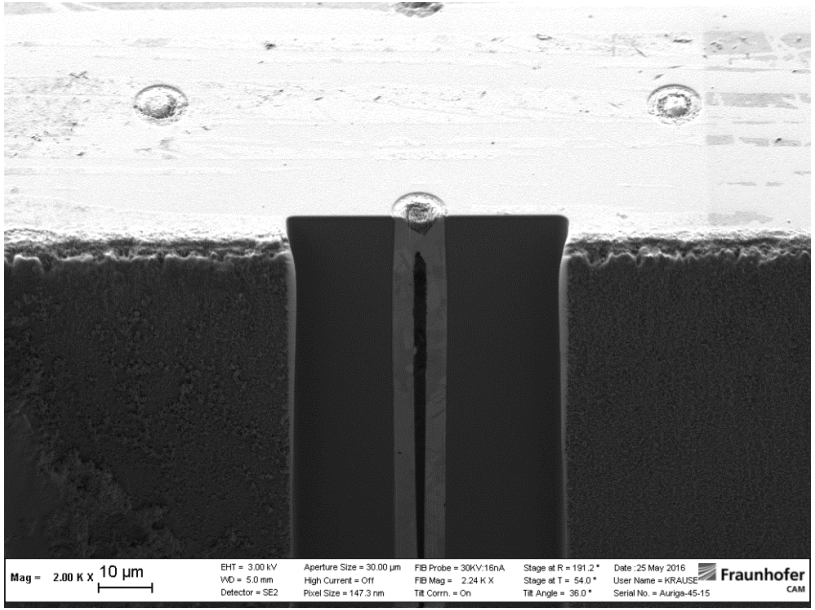
5 Min via microPREP Laser

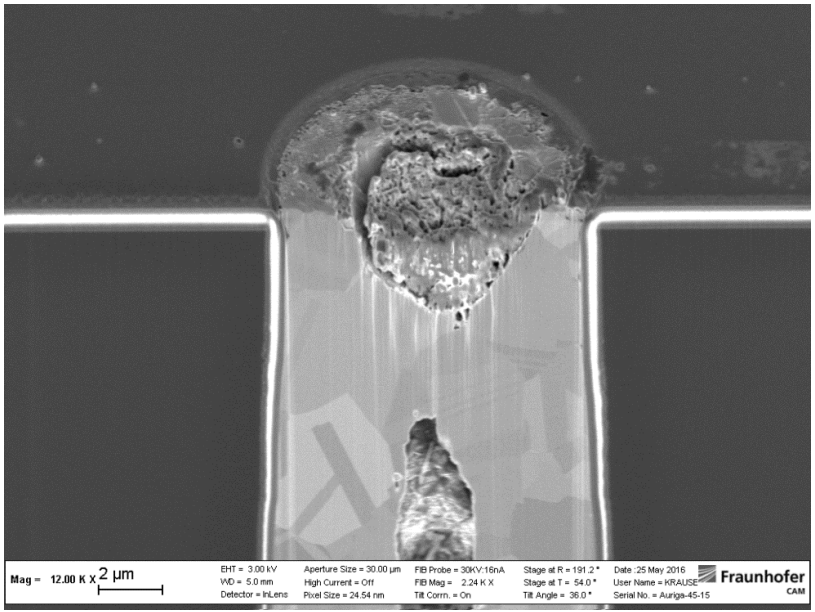


60 Min via FIB

Examples – 3D Structures Sample Preparation for SEM

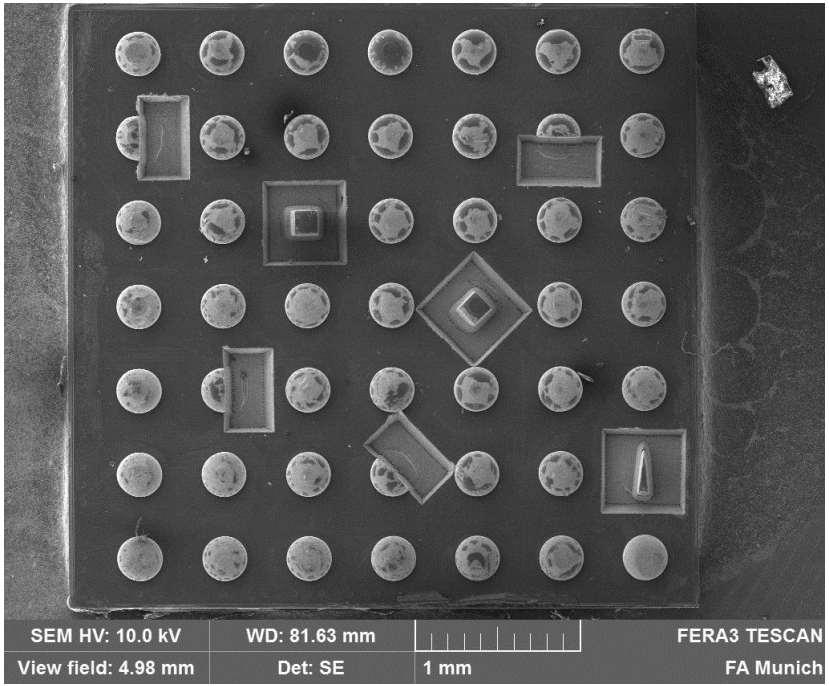
Advanced laser box-milling for subsequent FIB polishing for diagnostic of TSVs



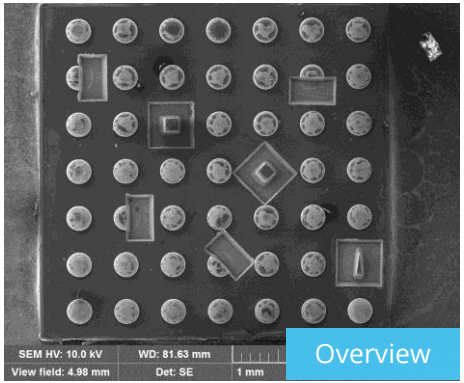


Examples – 3D Structures

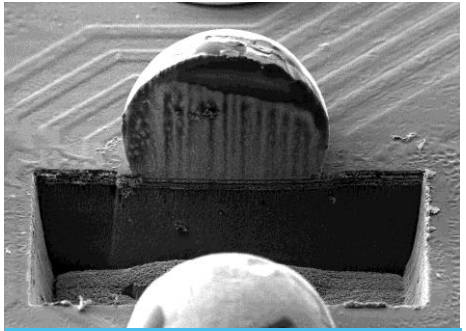
- Advanced laser box-milling,
- Including cutting of solder balls,
- Subsequent FIB polishing,
- Diagnostics of electrical connections and of the structures at chip level

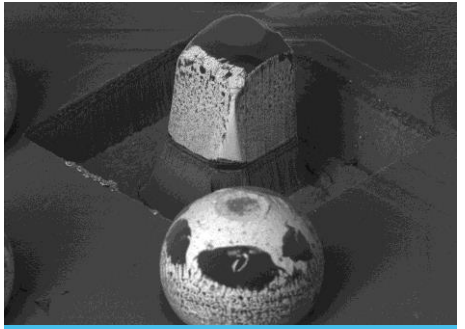


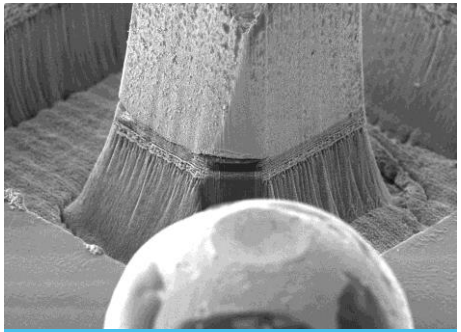
Examples – 3D Structures

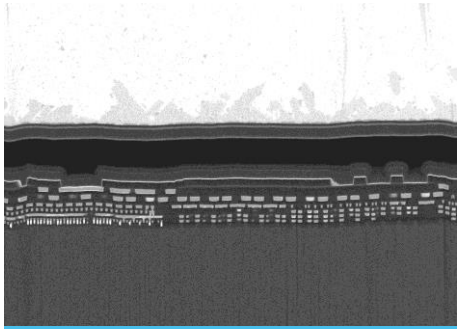


Overview

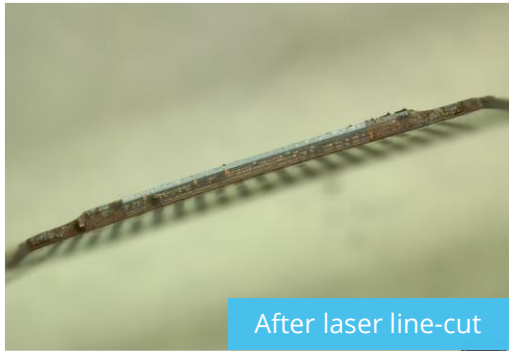

Box milling & cut of solder ball

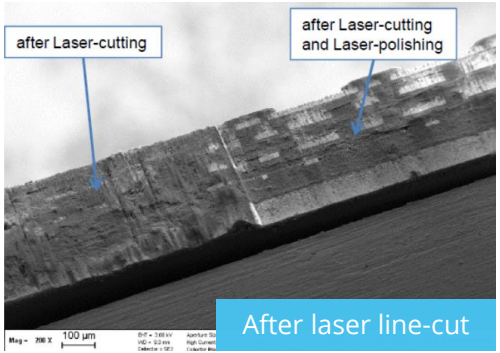

Four-sided preparation


Four-sided preparation

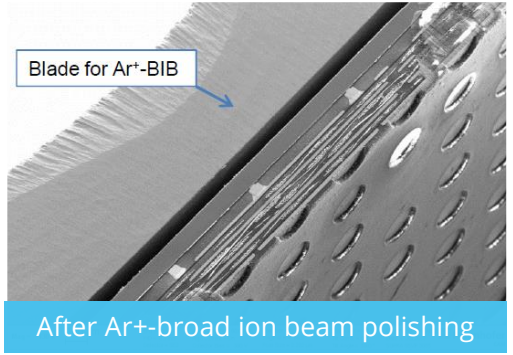

Chip level investigation

Examples – SiP Sample Preparation for SEM

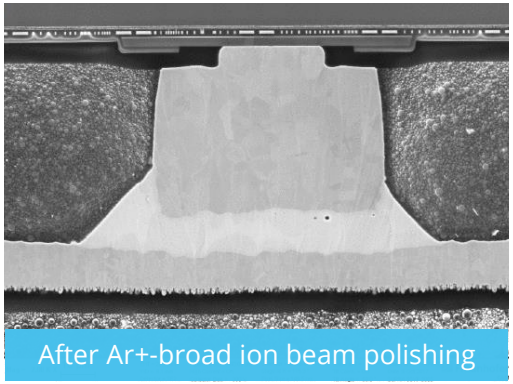

After laser line-cut

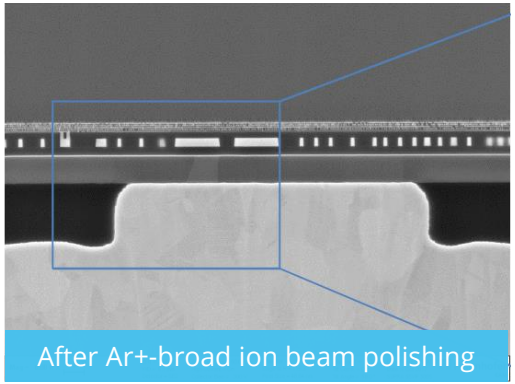


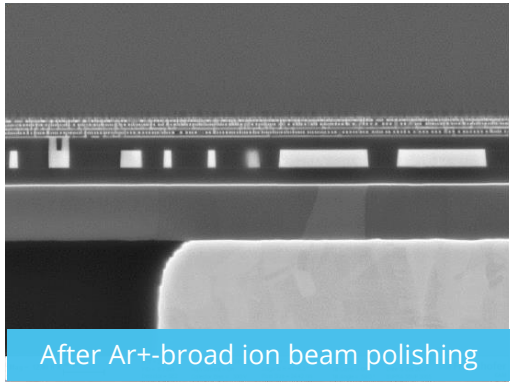
After laser line-cut



After Ar+-broad ion beam polishing


After Ar+-broad ion beam polishing

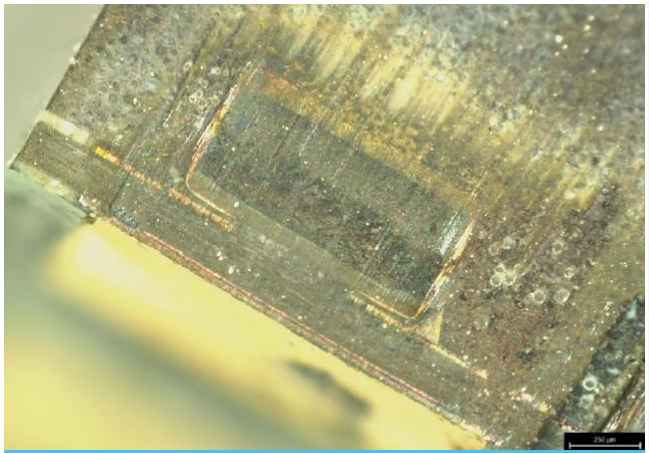

After Ar+-broad ion beam polishing


After Ar+-broad ion beam polishing

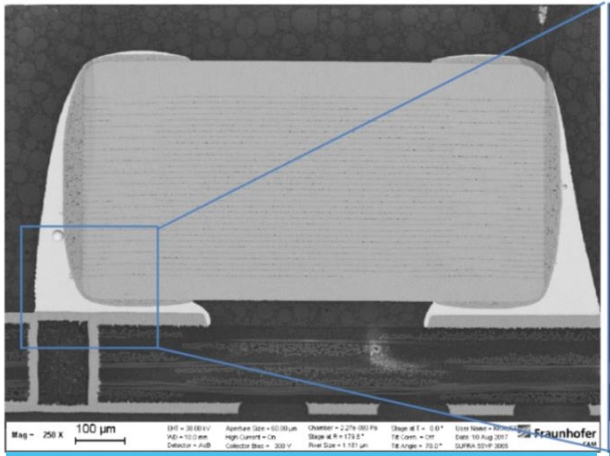
SiP (Infineon)

Examples – SiP Sample Preparation for SEM

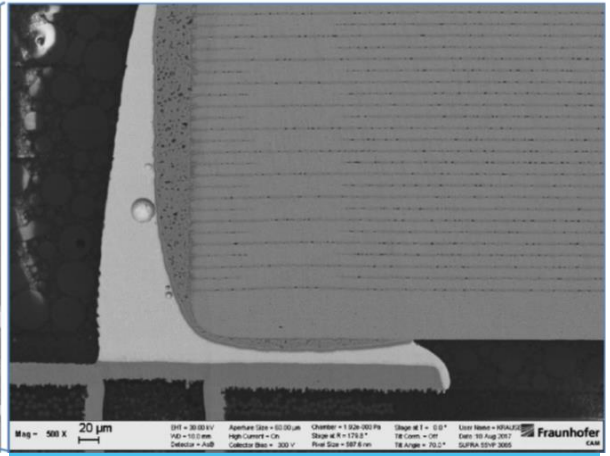
- Preparation (line-cut) of a SiP device, detail with capacitor



Sample after laser line-cut



View of line-cut and subsequent Ar+-broad ion beam polishing

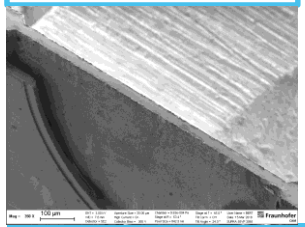


Detail of the capacitor

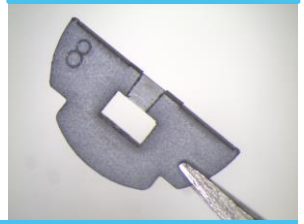
SiP (Bosch)

microPREP™ – Applications

X-sections

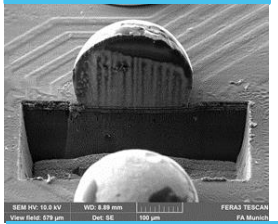


In-plane geometries or bulk samples

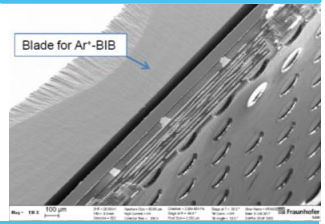


TEM-investigations

Box milling
Fast and flexible target preparation



Full line cut:
Complex investigation of whole devices

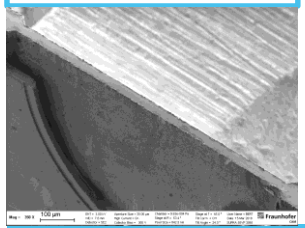


SEM-investigations

Content

microPREP™ – Applications

X-sections



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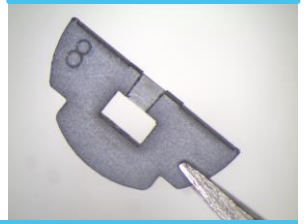

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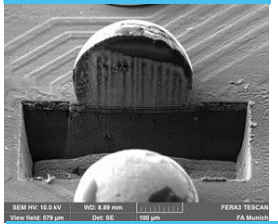

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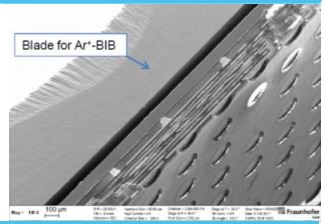
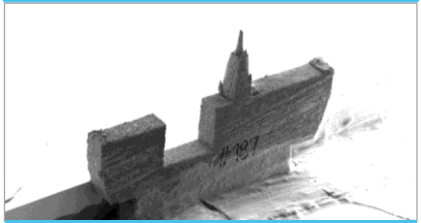


SEM-investigations

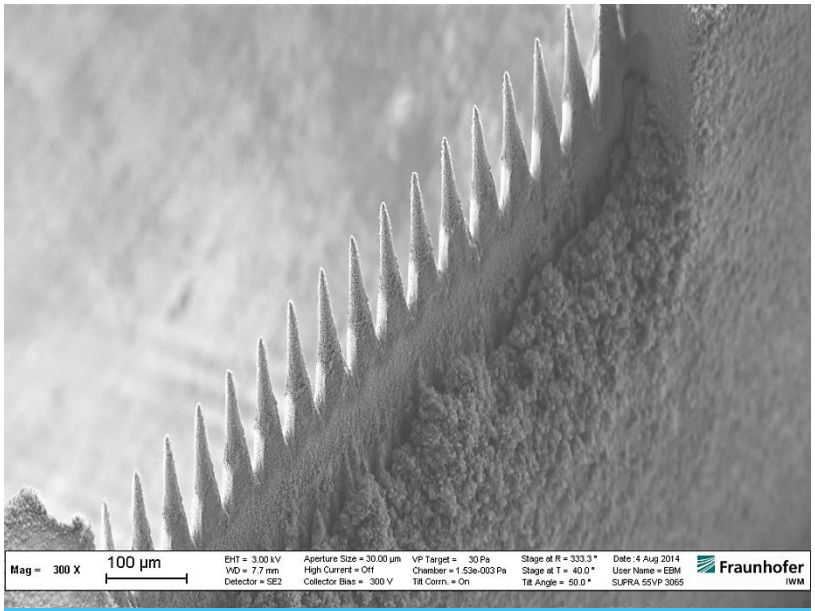
Enabling Entirely New Types of Samples



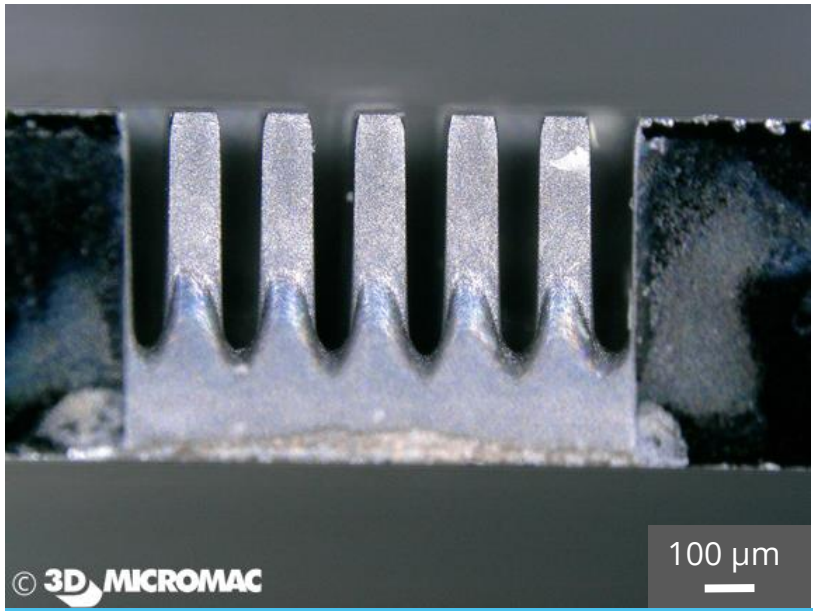
Additional applications, e.g. XRM, TLM & µTLM, mechanical tests, …

Preparation of Special Structures

- Picosecond laser-machined line of pillars in silicon



Line of small pillars with sharp tips



Line of pillars 100 µm x 100 µm, depth 500 µm

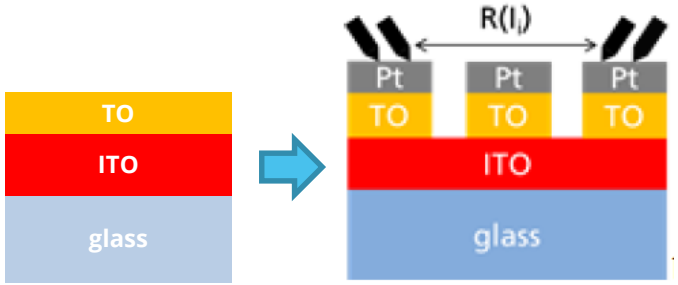
Laser pattering for microscopic TLM measurements

Question

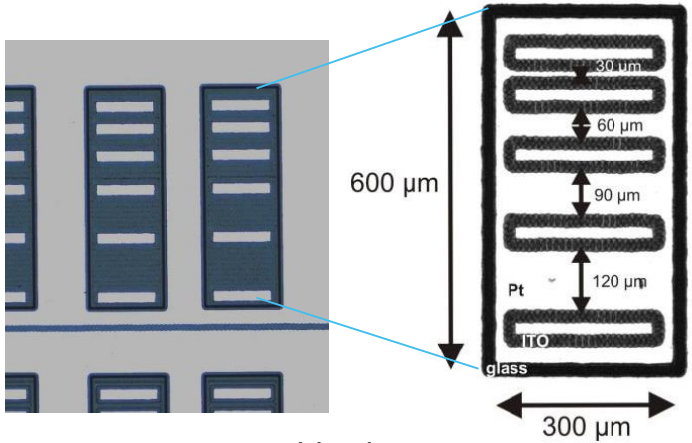
- Resistivity measurement of thin layers on top of layers with lower sheet resistance
- Up to now top layer with highest resistivity cannot be characterized by means of TLM*

Solution

- Microscopic test patterns by material selective laser ablation**
- Benefits
- Quick preparation
- Reliable TLM measurements
- Access to single layer properties



Material selective patterning for TLM



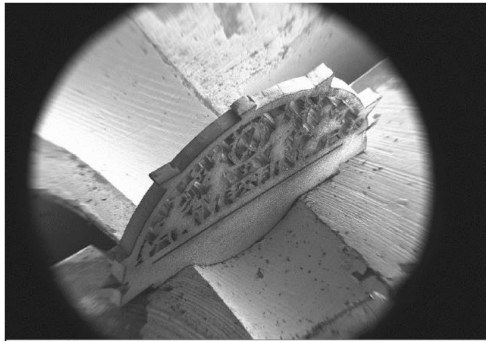
Test patterns prepared by laser

1. 3D-Micromac – Micromachining Excellence
2. Laser: a powerful tool for sample preparation
3. From TEM to SEM: workflows and examples
4. Outlook
5. **Conclusion**

Conclusions

Value Proposition

- ✓ User friendliness due to `Simple use' concept
- ✓ Up to 10.000 times faster than FIB
- ✓ Keeps your FIB instrument clean
- ✓ Reproducible & automatable
- ✓ Artefact-free
- ✓ Large areas and/or depth cuts
- ✓ Very Attractive costs of ownership
- ✓ BKM library – Fixed workflows for bulk and x-sections
- ✓ Easy workflow adoption – user definable and customized
- ✓ Meets the essential requirements of the SEMI S2/S8



Acknowledgement

This work has been (partly) performed in the project SAM3, where the German partners are funded by the German Bundesministerium für Bildung und Forschung (BMBF) under contract 16ES0347 and the French partners by the French Ministry for Industry and Economy.
SAM3 is a joint project running in the European EUREKA EURIPIDES and CATRENE programs.

GEFÖRDERT VOM

Bundesministerium
für Bildung
und Forschung

Thank you for your attention!

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09126 Chemnitz, Germany

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