Laser processing of semiconductor materials for failure analysis

Michael Grimm, Philipp Greif, Bernd Keiper, Henry Spott
3D-Micromac AG, Technologie Campus 8, 09126 Chemnitz
Bernd Krüger, Stefan Waginger,
Infineon Technologies AG, Am Campeon 1-15, 85579 Neubiberg
Dominique Carisetti
Thales Group, 1 ave Augustin Fresnel, Campus Polytechnique, 91120 Palaiseau (FR)
Michael Krause,
Fraunhofer IMWS, Walter-Hülse-Straße 1, 06120 Halle

Company Headquarter

3D-Micromac AG

GPS: 50°48'59''N, 12°55'32''O

Production area: 3 production halls with 4450 m^2

Target Markets

Photovoltaics	Semiconductor/ MEMS	Microdiagnostics	Display & Smart Glass	Medical Device Technology
				
microCELL™	microDICE™	microPREP™	microSHAPE™	OEM Laser Systems

Target Markets

Photovoltaics

microCELL™

Semiconductor/ MEMS

microDICE™

Microdiagnostics

microPREP™

Display & Smart Glass

microSHAPE™

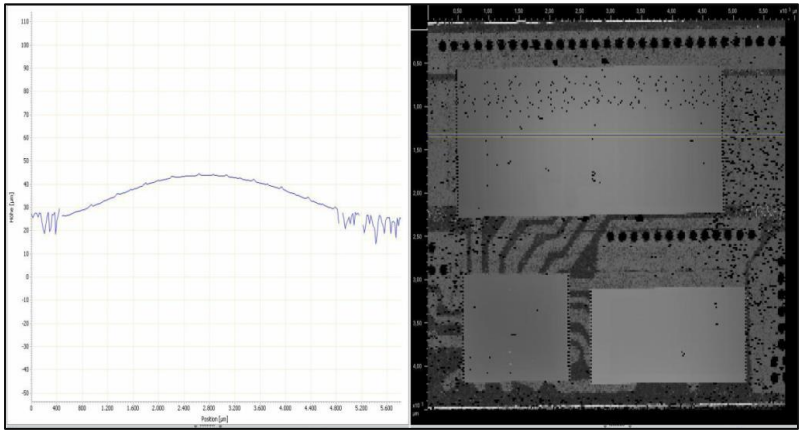
Medical Device Technology

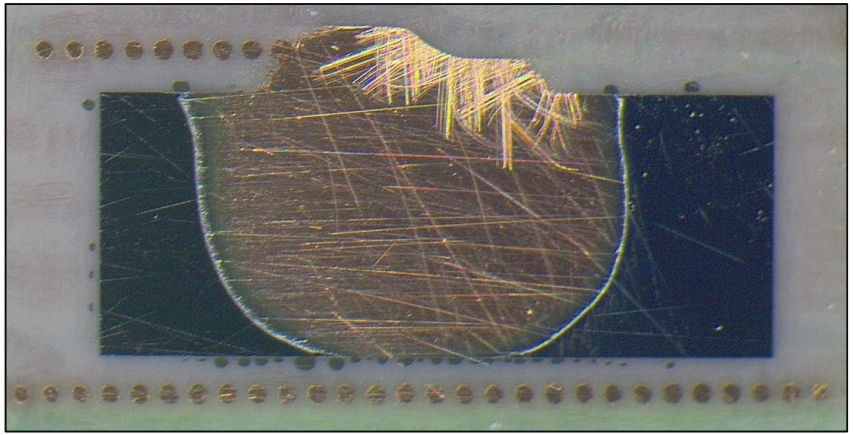
OEM Laser Systems

Content

Motivation

- Failure analysis using infrared microscopy or SAM
- Remaining thickness down to 10 µm (highly doped power semiconductors)
- Thinning of samples with a warpage – not possible by mechanical grinding
- Conformal thinning required – by 3D laser ablation
- Low roughness required for infrared transmission

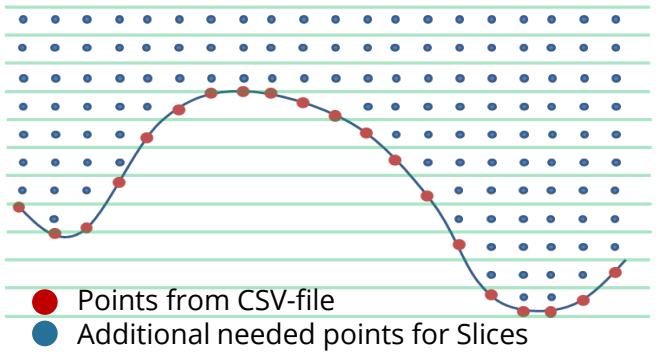


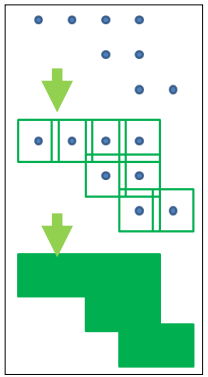


Conformal Die Thinning

Software solution:

- CSV-data imported to 3D-Micromac-Software
- Assignment of the points (x, y) to the layers (slices) depending on local thickness – generating of additional points
- Generation of closed contours around each point (square of 1.5 x line distance)
- Generation of outlines and fillings of slices



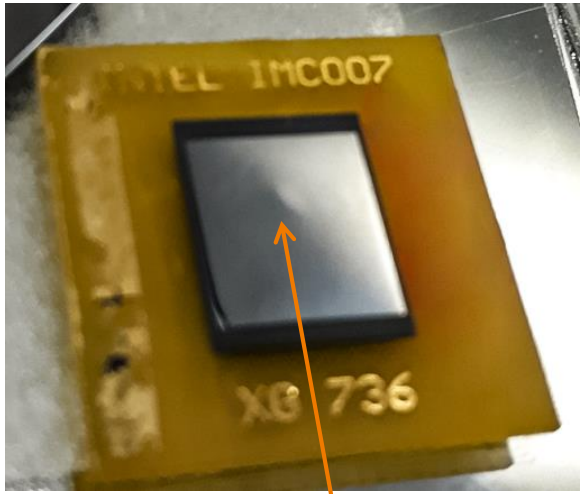


Layer n (top view)

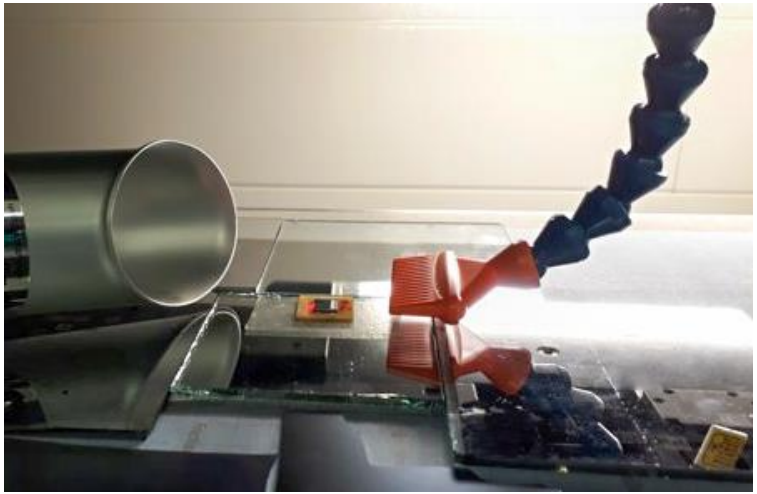
- Generation of additional points for each layer (slice)
- Generation of closed contours around each point
- Merge of overlapping contours – generation of outlines of slices

Conformal Die Thinning

Setup: Hyperrapid 50, <15 ps, 532 nm, 400 kHz

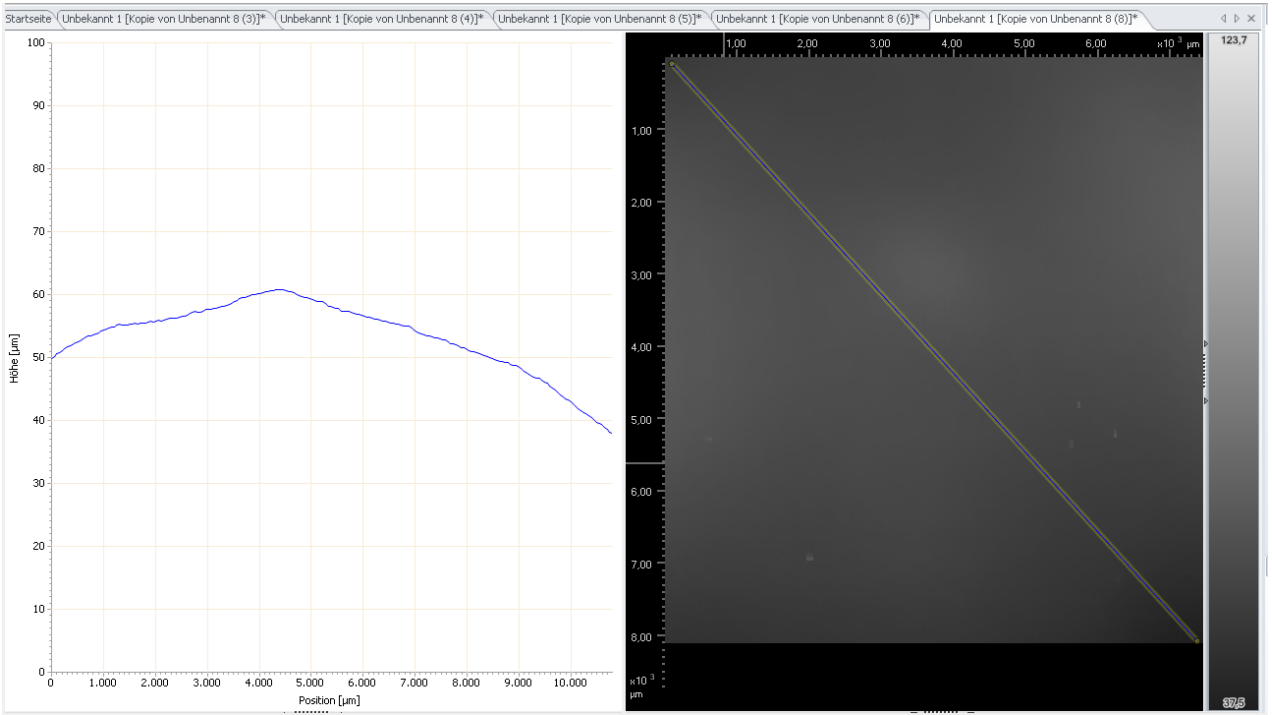


Slight elevation visible before machining



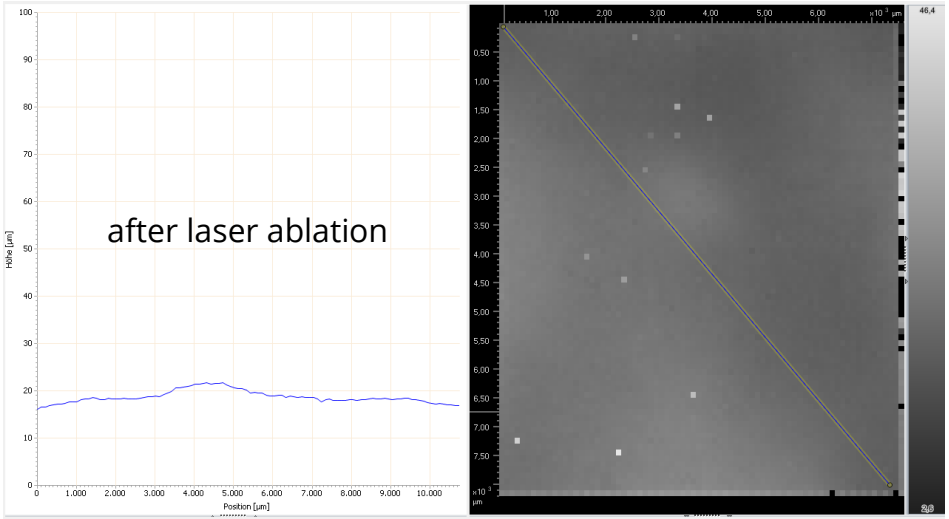
Conformal Die Thinning

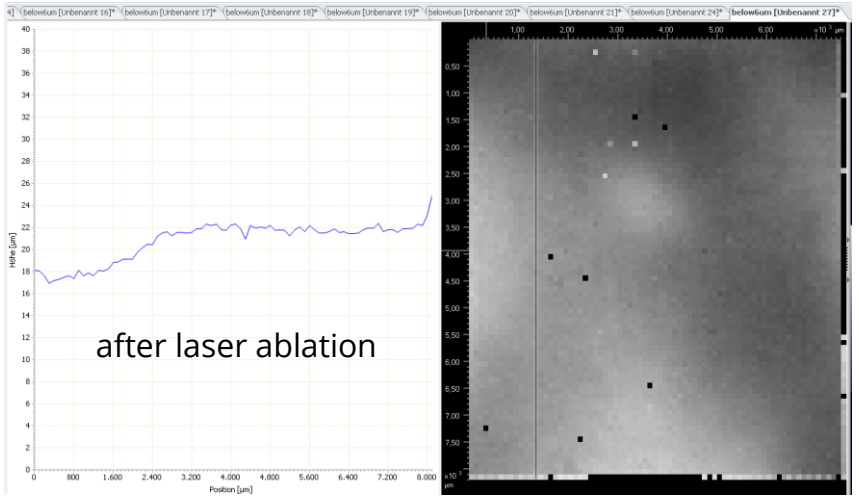
Height distribution of SiP device before laser ablation



Conformal Die Thinning

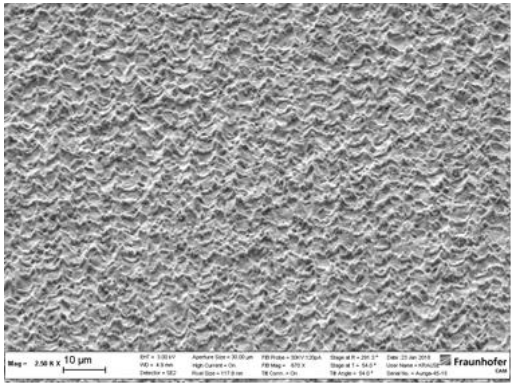
Target: Conform thinning down to remaining Si thickness of 20 µm



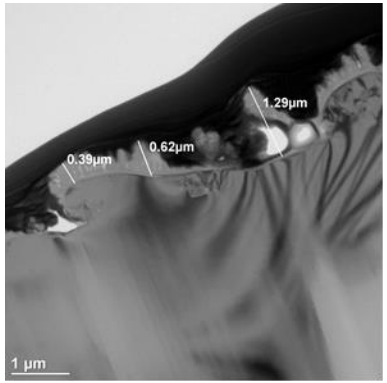


Roughness of Si Surface

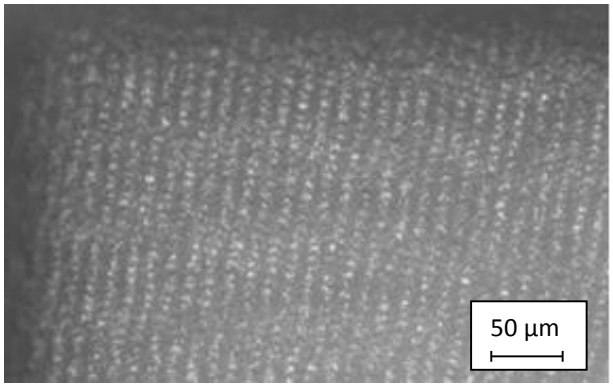
- Laser parameters were optimized regarding roughness
- Using picosecond laser roughness was decreased down to R_a = 0.3 µm
- Laser affected zone is low (about 1 µm)
- No infrared transparency, the relatively low roughness is still to high



Silicon surface after micro-machining using picosecond laser source, optimized roughness R_a = 0.3 µm



TEM-image (cross section) of the surface revealing a thickness of the Laser affected zone in the order of 1 µm



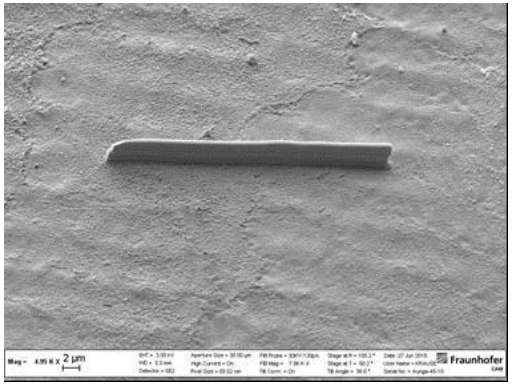
Infrared microcopy view of a laser thinned sample. Due to still too high roughness no infrared transparency observed

Roughness Reduction

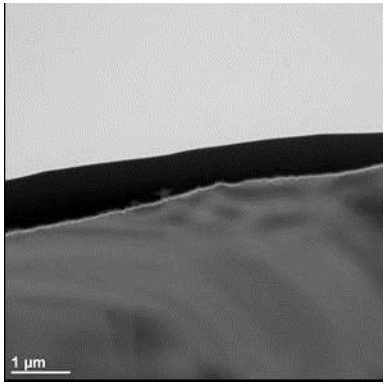
- Picosecond-laser (< 15 ps pulse duration) and burst machining
- Single laser pulses divided in, to a burst of pulses (25 ns time between two pulses)
- Laser irradiated material is not fully relaxed between consecutive pulses in the burst
- Gentle and smooth material removal from the sample surface is possible
- Optimized process regarding pulse energy and the number of pulses in the burst
- Best results with a roughness down to a R_a of 0.04 µm were obtained using 6 pulses in the burst
- Disadvantages of the gentle process are the longer process time as well as the higher cost of the required laser

Roughness Reduction of Si

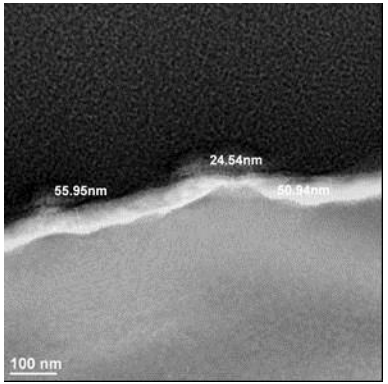
Reduced laser affected zone by burst machining to values well below 0.1 µm



Protective Pt-layer deposited on the overlapping area between two adjacent layers for subsequent FIB-lamella preparation



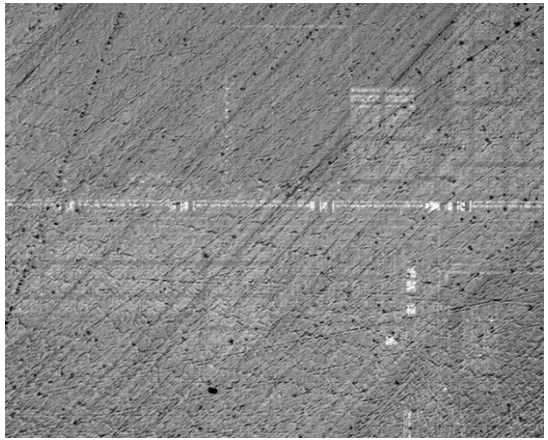
TEM-image (overview) of the surface cross section



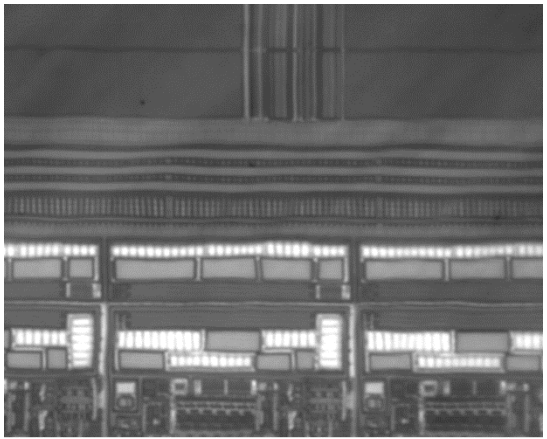
TEM-image (detail) of the surface revealing a thickness of the Laser affected zone of less than 100 nm

Roughness Reduction of Si

- Reduced roughness down to 0.4 µm
- Due to the layer structure (different ablation depth at different chip positions) roughness slightly increased to 0.9 µm
- Infrared microcopy: the chip structure at the front side can be observed through the laser processed back side for further analysis



IR image (magnification 5x)



IR image (magnification 100x)

Conclusion

- Laser processing enables new approach for conformal laser thinning of chips,
- sample preparation for failure analysis using SAM was presented,
- infrared microscopy without further polishing of the sample is feasible too, but image quality is limited,
- The very gentle process is relatively slow: typical preparation time for remove of 50 µm Si is ≈2 h (70 mm^2 chip area).

This work has been 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 are funded 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!

3D-Micromac AG
Dr. Michael Grimm
Technologie-Campus 8
09126 Chemnitz, Germany

http://3d-micromac.com
Phone: +49 371 400 43 0
E-Mail: grimm@3d-micromac.com