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Materials processing using femtosecond laser pulses

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Introduction

Comprehensive results on femtosecond-laser microstructuring obtained at the laser institute of the University of Applied Sciences Mittweida will be presented. The investigations have been carried out using a femtosecond laser micromachining station equipped with a Ti: Sapphire-Laser from Clark-MXR Inc. Michigan. The ablation behaviour of fused silica, pyrex® glass as well as that of silicon was investigated. Based on the investigations, microstructures like holes, channels and cavities were produced in those materials. Finally, we will present several 3d demonstrator structures meant for the production of microsystems.

Experimental setup

Femtosecond-laser micromachining station FS150-10 from the 3D Micromac AG Chemnitz, Germany

- Fig.1 shows the schematic experimental setup consists of the laser source, the attenuator, the beam expander, the objective, the positioning system and the camera
- The station is equipped with a Ti: Sapphire-Laser CPA 2010 from Clark-MXR Inc. Michigan

Technical data

wavelength λ = 775 nm
pulse duration τ_H= 130 fs
repetition rate f_P= 1 kHz
pulse energy $Q_{pulse,\ max}$ = 1 mJ

objectives:
f = 100 mm, focal diameter = 12 µm
f = 50 mm, focal diameter = 6 µm
f = 8 mm (reflecting objective), focal diameter = 2 µm

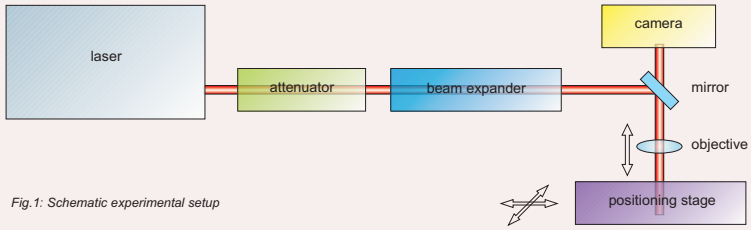

Fig.1: Schematic experimental setup

femtosecond laser ablation of

Fused Silica

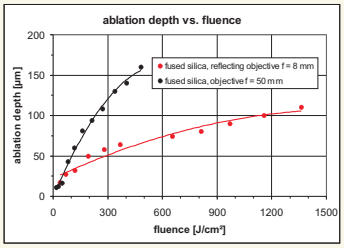

Fig.2: Ablation depth as a function of the laser energy

- Increasing ablation depths with higher laser energy fluence
- No linear correlation, gradually decrease at higher fluences
- Higher ablation depths obtained with objective f = 50 mm

Pyrex®

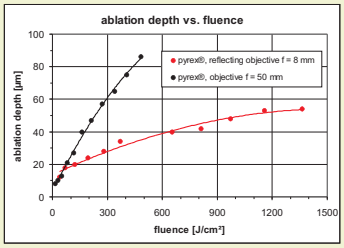

Fig.3: Ablation depth a function of the laser fluence

- Similar behaviour like fused silica
- Approximately half of values for ablation depth in contrast to fused silica at identical parameters

Monocrystalline silicon

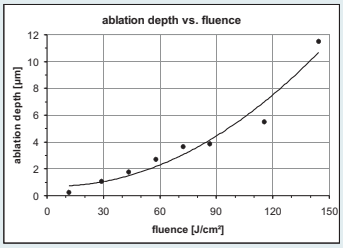

Fig.4: Ablation depth as a function of the laser fluence

- Progressive increase of the ablation depth with higher laser fluences
- Significant lower values for the ablation depth in contrast to fused silica and pyrex® at identical parameters

Microstructures in different materials

3d microstructures in fused silica

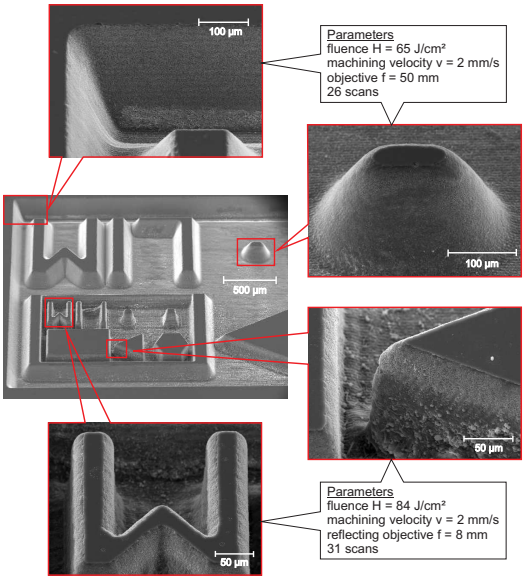

Fig.5: SEM micrographs of microstructured fused silica

Reservoirs and channels in fused silica

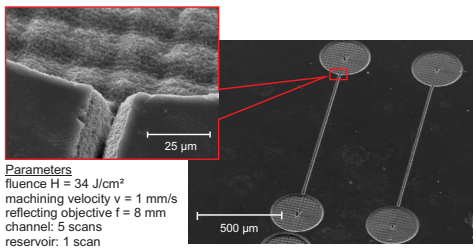

Fig.6: SEM micrographs of reservoirs and channels produced in fused silica

Diamond like carbon (dlc) film on silicon substrate

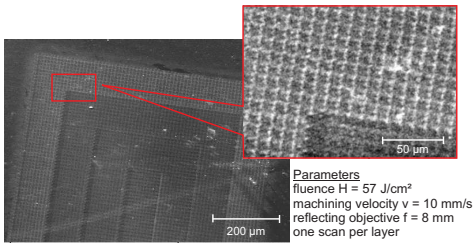

Fig.7: SEM micrographs of ablated rectangular dlc-layers in a 1 µm thick dlc film

3d microstructures in silicon

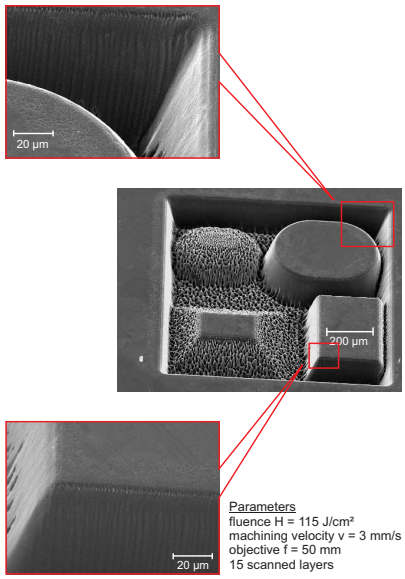

Fig.8: SEM micrographs of microstructured monocrystalline silicon

Conclusions

This poster presents results on materials processing using femtosecond laser pulses. There are considerable higher values of the ablation depth in dependence of the laser fluence for insulator materials like fused silica and pyrex® glass compared to silicon as semiconductor material. In the SEM micrographs microstructures in different materials like silicon, fused silica and diamond like carbon thin films are shown. Especially in fused silica no cracks can be observed. The generation of microstructures like holes, channels and cavities allows also complex 3d combinations of them used for further applications in microsystems.

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