Laser micromachining of 3C-SiC single crystals

S Zoppel[1,3], M Farsari[2], R Merz[3], J Zehetner[3], G Stangl[4], G A Reider[1] and C Fotakis[2]

[1]Vienna University of Technology, Photonics Institute, Gusshausstr. 27-29/387, 1040 Vienna, Austria
[2]Foundation for Research and Technology – Hellas, Institute of Electronic Structure and Laser, P.O. Box 1527, 71110 Heraklion, Crete, Greece
[3]Vorarlberg University of Applied Sciences, Research Centre for Microtechnologies, Hochschulstraße 1, 6850 Dornbirn, Austria
[4]Vienna University of Technology, Institute of Sensor and Actuator Systems, Gusshausstr. 27-29/366, 1040 Vienna, Austria

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introduction

SiC has long been recognized as an excellent material for high power, high frequency and high temperature electronics due to its outstanding properties. It has a wider band gap, higher breakdown field , higher thermal conductivity and higher saturation velocity than silicon. Because of its high thermal conductivity, good chemical resistance and mechanical hardness SiC is now receiving added attention for its potential in microelectromechanical systems (MEMS) where Si is currently the leading material in this technology area. Using SiC potentiates the placement of MEM devices in harsh temperature, wear, chemical and radiation environments. Compared to silicon structuring of SiC is sophisticated because of its chemical inertness.

Laser ablation is another possibility of microstructuring silicon carbide offering a clean and simple method with high etch rates. The sample used in our work was a polished 3C-SiC wafer. We studied the ablation with focus on the influence of the pulse duration and the wavelength. The experiments at 193 and 248 nm and a pulse duration in the nanosecond time scale has been carried out with conventional excimer lasers. Additional experiments have been carried out with solid-state lasers providing radiation in the IR (1040 nm and 1026 nm) with pulse durations of 300 fs and 400 fs, respectively.

experimental

Laser Systems:

Diode-Pumped Solid-state Laser (HighQLaser)
Pulse duration: 300 fs
Wavelength: 1040 nm

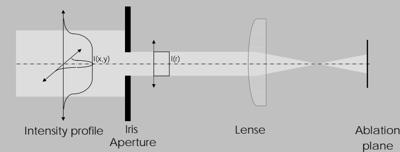
Diode-Pumped Solid-state Laser (S-Pulse, Amplitude)
Pulse duration: 400 fs
Wavelength: 1026 nm

KrF-Excimer Laser (LPX 200, Lambda Physik)
Pulse duration: 34 ns
Wavelength: 248 nm

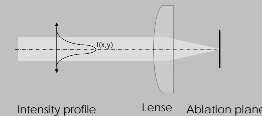
ArF-Excimer Laser (LPF220, Lambda Physik)
Pulse duration: 25 ns
Wavelength: 193 nm

Setup

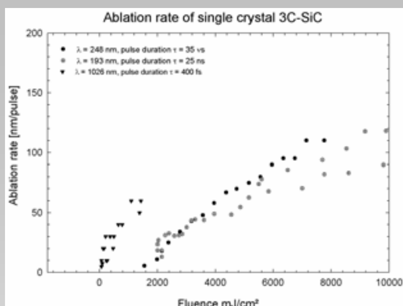
Excimer lasers: An iris aperture was imaged by means of a single lens.



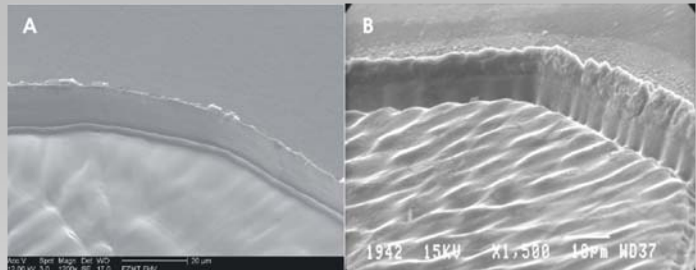
Solid-state Lasers: Direct focussing of the Gaußian beam shape



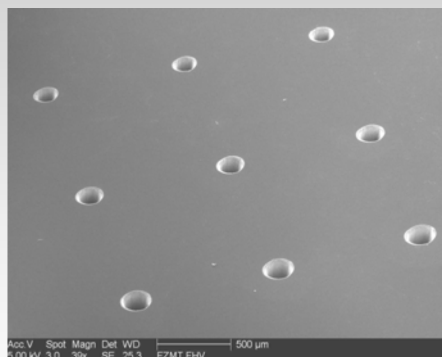
results & conclusions



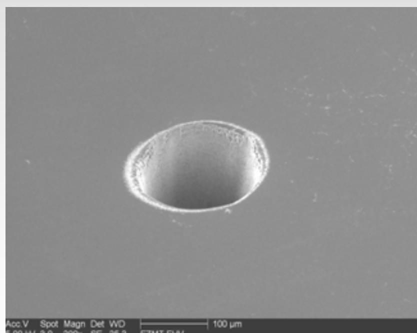
Ablation rate of 3C-SiC for three different sets of laser parameters. The ablation rate of the two excimer lasers are comparable. The higher ablation rate and the lower ablation threshold for femtosecond laser pulses is due to the greatly reduced thermal diffusion during exposure time.



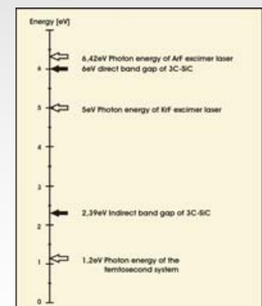
Comparison of cavities ablated with excimer lasers with pulse durations in the ns time scale and a wavelength of 193 nm (A) and 248 nm (B), respectively. In both cases the sample was treated with a train of 100 pulses. In machining with excimer lasers the quality of the ablated structures in 3C-SiC could be highly increased by using the ArF line (A). The sidewalls are smooth, steep and in addition the upper edge is very sharp. The bottom area is slightly undulated compared to the KrF experiments where the bottom area is much more corrugated.



Array of through-vias in a 3C-SiC wafer with a thickness of 400 µm drilled with a solid-state laser providing pulses with a duration of 300 fs at a wavelength of 1040 nm.



Via drilled in 3C-SiC with a pulse duration of 300 fs at a wavelength of 1040 nm. Although a relatively low fluence of 10,6 J/cm² was used, through via drilling was possible by employing trepan drilling where the beam moves along a circular path. The drilling speed of approx. 10 to 15 µm/s is significantly higher than the one of RIE which is in the range of a view microns per minute. Of course, depending on the application, the RIE process is more efficient by parallel processing, while for single vias or as a flexible tool for preliminary studies the laser could be a serious option. The drilled vias exhibit smooth sidewalls and the surrounding area is not affected by the drilling process.



Direct and indirect band gap of 3C-SiC in comparison to the photon energies of lasers used. Excimer lasers, with 5 and 6,42 eV are above the direct and indirect band gap, respectively. With IR laser radiation, very high peak intensities provided by ultrashort pulse lasers allow ablation based upon two-photon absorption.

FHplus

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