



# Micromachining of Silicon Carbide using femtosecond lasers

M. Farsari<sup>1</sup>, G. Filippidis<sup>1</sup>, S. Zoppel<sup>2</sup>, G. A. Reider<sup>2</sup>, C. Fotakis<sup>1</sup>

<sup>1</sup> Institute of Electronic Structure and Laser, Foundation for Research and Technology – Hellas, P.O. Box 1527, 71110 Heraklion, Crete, Greece  
<sup>2</sup> Vienna University of Technology, Photonics Institute, Gusshausstr. 27-29/387, 1040 Vienna, Austria

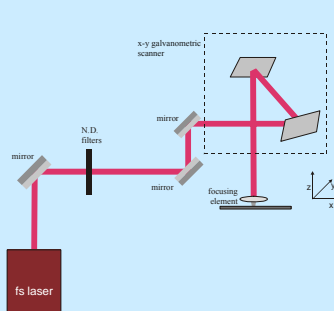
## Introduction

Silicon Carbide (SiC) is a very attractive material in the field of microelectronics and MEMS due to its chemical inertness, mechanical strength and wide band gap. Currently, the main method used for patterning and drilling is reactive ion etching (RIE). Laser processing has been recently proposed as an alternative to RIE for both surface patterning and via drilling. It promises fast removal rates and does not require masking or other pre-lithographic treatments. Due to the low thermal diffusion, femtosecond laser writing produces results superior to conventional laser micromachining. Up to now, high-power Ti:Sapphire oscillator–amplifier systems have been used for the femtosecond laser micromachining of SiC. Because such systems are operating exclusively at kilohertz repetition rates, they severely limit the maximum processing speed desirable for many applications.

We demonstrate that surface micromachining of bulk SiC can be achieved by the use of a tightly focused beam from a compact, infrared femtosecond laser oscillator operating at 50 MHz. As the limiting factor in laser scribing is the laser repetition rate, this work shows that the scribing speed can potentially increase by more than four orders of magnitude.

In addition, we show that very good quality, high aspect ratio through vias as needed for wafer through-connections, can be drilled using a focused amplified femtosecond laser combined with a commercially available scanner, eliminating the need to mask the processing field and increasing the processing speed while reducing the cost.

## Experimental Set-up



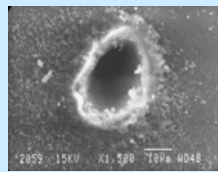
## Surface Micromachining Equipment

- ◆ Laser  
Amplitude Systems t-pulse laser femtosecond oscillator, 1028 nm, pulse duration of less than 200fs, repetition rate of 50MHz. Maximum laser power on the specimen is 500mW. Maximum energy of a single pulse at the sample: 10nJ.
- ◆ Beam Steering.  
x-y-galvanometric mirror scanner (Scanlabs Hurryscan II)
- ◆ Beam Focusing-Microscope objectives.  
50x, N.A.=0.8,  $f = 0.61\lambda / N.A. = 780$  nm.
- ◆ Beam control.  
mechanical shutter (Uniblitz).
- ◆ Control Software.

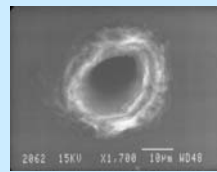
## Laser Drilling Equipment

- ◆ Laser  
Amplified mode-locked Ti:Sapphire laser (Spectra Physics), repetition rate of 1 KHz giving a final pulse width of 150 fs.
- ◆ Beam Steering.  
x-y-galvanometric mirror scanner (Scanlabs Hurryscan II)
- ◆ Beam Focusing  
Telescopic scan lens with a focal length of 56.6 mm (Sill Optics).
- ◆ Pulse energy control  
Neutral density filters. Energy varied from 10 to 90  $\mu$ J.
- ◆ Samples  
400- $\mu$ m thick 3C-SiC wafers.

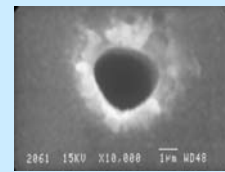
## SEM images of drilled vias



Top of via before cleaning



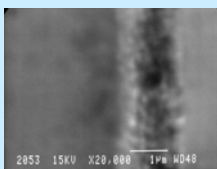
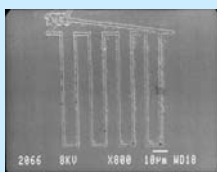
Top of via after cleaning



Bottom of via without cleaning

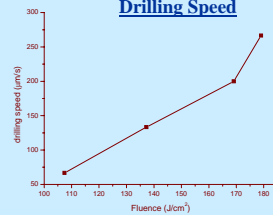
Before cleaning, around the via there is a loose arrangement of nanoparticles, which can be very easily removed by plain washing and scrubbing. The surrounding area has minimal chipping and visible heat-affected areas. The bottom side of the via does not require cleaning. The via pictured was drilled with fluence of 137 J/cm<sup>2</sup> and duration 3 seconds.

## SEM images of scribed structures



The ablation threshold is 7.8 nJ, corresponding to a fluence of 0.55 J/cm<sup>2</sup>

## Drilling Speed



Through via drilling speed as a function of the laser fluence. For fluences lower than 100 J/cm<sup>2</sup>, it was not possible to drill through the wafer. Above a fluence of 100 J/cm<sup>2</sup>, the through-via drilling speed increased almost linearly, up to the maximum available fluence of 180 J/cm<sup>2</sup>. The quality and the dimensions of the vias did not appear to change with fluence.

## Conclusion

To conclude, we have demonstrated that by employing tightly focused femtosecond laser pulses, surface micromachining of 3C-SiC can be achieved with pulse energies that can be obtained without amplification. This eliminates the need for laser amplification therefore increasing the micromachining speed by more than four orders of magnitude while significantly reducing the likely costs as an industrial process. In addition, we have shown that by employing an amplified femtosecond laser, high aspect ratio, tapered through vias can be drilled in a single step.

## References

M. Farsari, G. Filippidis, S. Zoppel, G. A. Reider, C. Fotakis, *Efficient femtosecond laser micromachining of bulk 3C-SiC*, J. Micromech. Microeng. **15** (2005) 1786–1789