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doi:10.1017/S1431927613006326

Microsc. Microanal. 19 (Suppl 2), 2013

New Approach For Rapid Prototyping Using The Combination of Pulsed Laser Ablation and FIB Milling.

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Today, focused ion beam (FIB) technology is a standard technology for rapid prototyping and direct write processes. Also laser micro machining and lithography is a well-known technique for structuring tasks. Both methods have their advantages, whereas the FIB patterning is restricted in terms of time efficiency and dimensions of the area that can be structured. On the other hand, the laser has its advantages in the structuring of large patterns very time effective in an industrial scale. The laser is able to remove material volumes of up to several millions of cubic microns per second with an accuracy in the µm range. The limitations of laser structuring lying clearly in resolution and with correlation to that in the minimal producible structure size.
The advantages of the combination of both technologies are obvious. It allows patterning applications of large scaled (mm) objects (Figure 1 A)) with feature size of down to 10 nm (Fibure 1 B)) in a reasonable time.

The Auriga Laser® fulfills the demand of such a combination. It combines a pulsed ns-laser (355 nm) with an Auriga CrossBeam® FIB/SEM. The main purpose of this instrument are applications where the laser is used to remove huge amounts of material (several 100 μm^3 to 10 mm^3) in order to get a quick access to a region of interest inside the sample. The rapid material removal can be followed by a FIB preparation and subsequent SEM analysis in the same instrument. This workflow covers applications from back-end failure analysis [1] over trimming of soft, brittle or laminated materials/samples where ever standard preparation methods are whether to slow or just not applicable [2].

For a proper usage of the laser it is necessary to find material and application specific process parameters like the hatching or laser output power (Figure 2 A)). All laser process parameters are crucial for the outcome of the experiment. On the one hand it is possible to choose dedicated ablation parameter to achieve the highest possible material removal rate without taking care about the side wall smoothness. On the other hand there are parameter sets where just one side wall and nothing else is very smooth which is ideal for cross sectioning (Figure 2 B)). And in addition it is possible to set the laser in that way that no actual ablation takes place but restructuring of the surface (Figure 2 C) [3]). This feature can be used to functionalize a surface in order to obtain e.g. hydrophilic or hydrophobic characteristics [3]. For micro machining or direct write applications the most important is to find parameter sets to achieve smooth side walls and trench bottoms at the fabricated structures.

All these capabilities in combination with the high precession of the FIB structuring raise a whole new application space for rapid prototyping in e.g. photonic, plasmonic and micro/nano fluidic topics.

This contribution will show new strategies for laser and combined FIB ablation. In particular the presentation will focus on direct write patterning applications using the combination of laser and FIB ablation.

References:
[1] M. Petzold et al., Proc. 60th Electronic Compon. and Technol. Conf. (ECTC) (2010) 1296.
[2] H. Stegmann et al., Microsc. Microanal. 17 (2011).
[3] James Edward Carey III, PhD Thesis, Harvard University, 2004

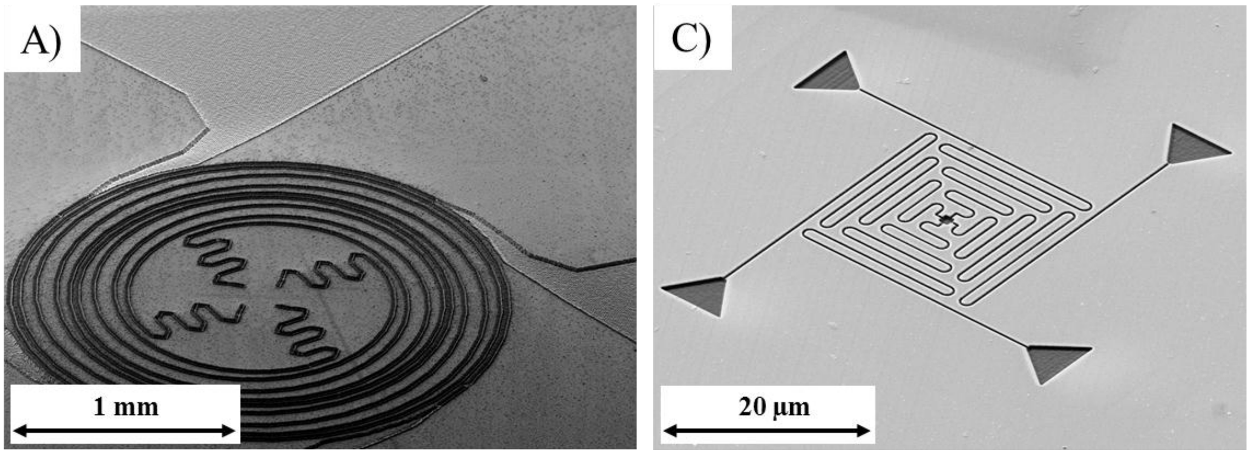

Figure 1. A) SEM image of a as laser fabricated structure. B) SEM image FIB structured rapid prototyping pattern for micro fluidic application using the nano patterning and visualization engine from FIBics (Image is courtesy of Mike Phaneuf).

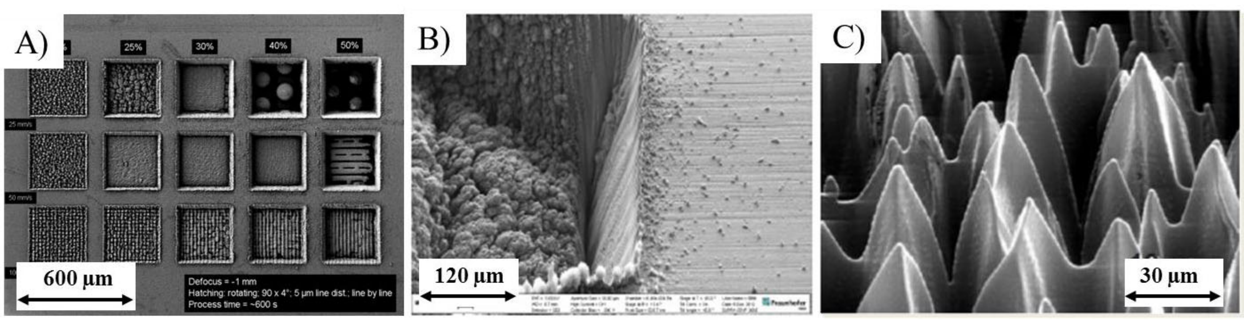

Figure 2. A) SEM image of a typical parameter matrix experiment to find material and application specific optimized laser parameter. B) SEM image of a as machined laser cross section in steel (Image is courtesy of Prof. Thomas Hoeche and Martin Ebert Fraunhofer IWMH). C) SEM image of a laser functionalized silicon surface (taken from [3]).