Direct write laser at visible wavelength for patterning of high aspect ratio epoxy materials

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A significant effort has been invested lately in the development of polymer technology due to their outstanding properties. Concretely, epoxy materials have received a great interest due to their optical and mechanical properties in several fields, such as MEMS [1] and MOEMS [2]. Usually these materials are processed by standard photolithography using an UV illumination thru a chrome mask [3]. Although this method is widely used and very efficient, it has some limitations: only planar substrates with reduced dimensions can be processed, and fast prototyping is not possible since the fabrication of the mask is a high cost process. In order to overcome these drawbacks, the use of direct write laser (DWL) for the exposure is proposed. In this paper the structurability and limitation of perform this process using a laser with a wavelength in the visible range (λ@413nm) are presented.

The selected material for the development of the proposed process is based on Epocore, a negative tone resist with low optical absorption in the visible and IR regions. Standard Epocore is not sensitive to the working wavelength and the photoacid generator of this material has to be substituted by a new photoinitiator system, which is sensitive at the laser emission, to obtain the photoinduced cross linking. Figure 1 shows the absorption spectra of the standard and modified Epocore. The modified material presents absorption at 413 nm and, therefore it is sensitive at the wavelength of the laser. Layers of this modified material, with thicknesses ranging between 5 and 20 μm, were obtained by spin coating on 4" silicon wafers (fig 2a). After a pre-bake (@80ºC) the layers were exposed in a Heidelberg DWL200 tool using a Kr Laser as a light source (fig 2b). Different exposure conditions were used in order to obtain the focus exposure matrix (FEM) and determine the optimal processing conditions. Finally, a post exposure bake (@85ºC) was performed (fig 2c), followed by the development step in PGMEA (fig 2d). Thus no mask was needed to obtain the final structures.

Results of the FEM for a layer of 20 μm thickness are shown in figure 3a. Resolution is defined as the minimum width of an array of lines separated by the same distance, exposure power (P) is defined as the power at the output of the laser, and defocusing (D) as the displacement of the focus from the surface of the layer. This measurement was done for all the fabricated layers, with similar results. Figure 3 shows scanning electron microscope (SEM) pictures for the optimal exposure conditions for layers of 5 μm and 20 μm thickness. Dense lines of 2.5 μm (a) and 6 μm (b) were obtained with good pattern quality and nearly vertical sidewalls. On isolated structures it was possible to obtain lines 1 μm for a layer thickness of 5 μm (c), while for the 20 μm layer thickness, the smallest feature had a width of 6 μm. The maximum resolution for dense lines in front of the layer thickness was also measured (fig. 4). A linear behaviour of the pattern resolution as a function of the film thickness is observed in the studied range.

The presented results prove the capability to use DWL for structuring epoxy materials with high quality for thickness layers up to 20 μm. Hence, the presented technique is an excellent candidate for fast prototyping of epoxy based optical and mechanical structures, applicable on non standard substrates.

References

[1] A. Voigt, et al., *Improved properties of epoxy nanocomposites for specific applications in the field of MEMS/NEMS*. Microelec. Eng., 2007, **84,** 1075–1079.
[2] A. Llobera, et al., *SU-8 optical accelerometers*. J. of Microelectromechanical Sys., 2007, **16**(1), 111-121.
[3] H. Lorenz, et al. *High-aspect-ratio, ultrathick, negative-tone near UV photoresist and its applications for MEMS.* Sens. Actuators A. 1998, **64**(1) 33-39.

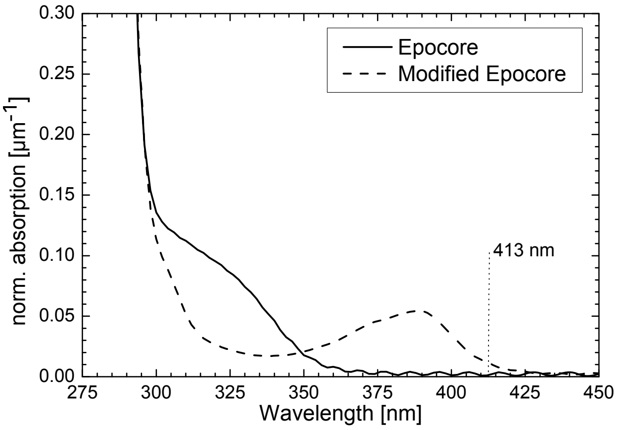

Fig. 1: Normalized absorption of the standard and modified Epocore.

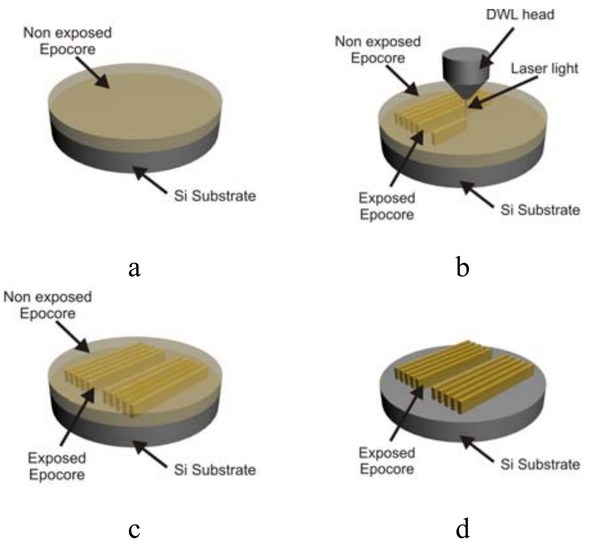

Fig. 2: Fabrication process. a) Spin coating of the modified Epocore on the Si wafer. b) Exposure of the structures using the DWL tool. c) After exposure a post exposure bake is perform and the exposed structures get cross linked. d) Development in PGMEA is performed to remove the non exposed material.

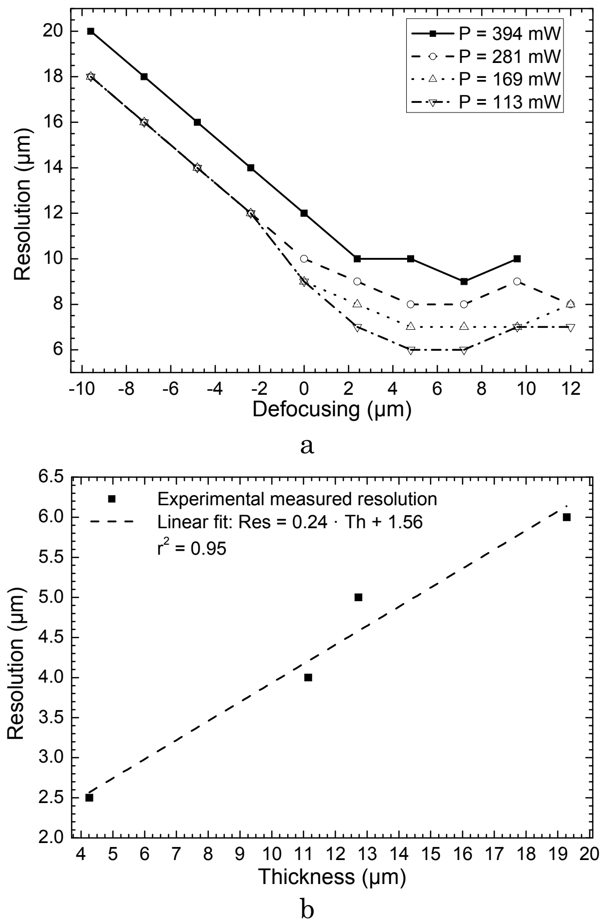

Fig. 3: a) Resolution in front of defocusing, for different powers at the laser output (P). b) Experimental maximum resolution in front of the layer thickness.

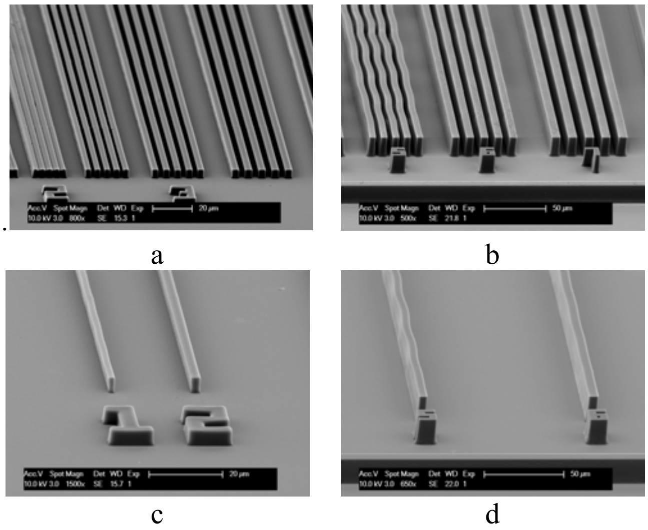

Fig. 4: SEM images of dense and isolated structures for 5 µm (a and c, respectively) and 20 µm (b and d, respectively) thickness.