Towards vertical sidewalls: direct write lithography of up to 100 µm thick epoxy resist structures for microfluidics

M. R. Haq, K. Jefimovs, H. Schift
Paul Scherrer Institut, Forschungsstrasse 111, 5232 Villigen PSI, Switzerland
refatul.haq@psi.ch

J. Erjawetz
XRnanotech, Forschungsstrasse 111, 5232 Villigen PSI, Switzerland

Direct write lithography is a versatile maskless lithography for fast prototyping, and cost-efficient fabrication of microstructures [1,2]. With the DWL 66^+, Heidelberg Instruments Mikrotechnik GmbH offers high-resolution patterning on wafer scale at 405 nm (h-line) wavelength. Although using a focused laser beam with a non-negligible aperture, that is different from the collimated light of a mask aligner, high aspect ratio (AR) patterning has been demonstrated (using a DWL200 with a 413 nm krypton laser) with AR up to 40. The negative-tone epoxy-based resist is chemically similar to SU-8 from MicroChem Corp. (now Kayaku Advanced Materials Inc.), thus enabling the fabrication of structures for so-called UV-LiGA technology, and are commercialized as mr-DWL by micro resist technology GmbH [3]. Due to their high transparency and adapted viscosity, they are suitable for a wide thickness range with over 100 µm.

For microfluidic and optical application, the shape and quality of the sidewalls is of high interest, furthermore, for molding, using nanoimprint molds, vertical sidewalls with no undercuts or even sidewalls with a defined draft angle would be advantageous (Fig. 1). This becomes more critical because of the limited depth of focus and the beam widening. Here, the focal length of the lens determines the numerical aperture of the beam, its minimum resolution and depth of focus. For the DWL 66^+, two focusing lenses with different focal lengths of 4 and 10 mm (write modes, WM I and III) are most suitable for patterning microstructures for microfluidics. They have trade-offs in resolution and throughput. Contrary to expectations, for WM I higher sidewall angles can be achieved for thicker resists, i.e., 86° for 100 µm instead of the 74° for 20 µm (Tab. 1, Fig. 2). Interestingly, for 20 µm thickness, similar angles can be achieved for the binary negative-tone mr-DWL 40 as for the low-contrast positive-tone resist ma-P 1275G. It seems that this is a characteristic of the exposure rather than of the material. Almost vertical sidewalls can be achieved for higher resist thickness, for which the mr-DWL and the 405 nm laser wavelength are a perfect match. The next step would be to compare different write modes and use simulation software such as GenISys BEAMER for proximity correction and LAB to investigate intensity distribution inside the resist as well as the concentration of activated PAC [4].

[1] A. Grushina, Adv. Opt. Techn. 8(3–4) (2019) 163–169.
[2] V.J. Cadarso et al., J. Micromech. Microeng. 21 (2010) 017003.
[3] H. Lorenz et al., Sensors and Actuators A 64 (1998) 33-39.
[4] J. Erjawetz et al., Micro. Electron. Eng. (2021), submitted.

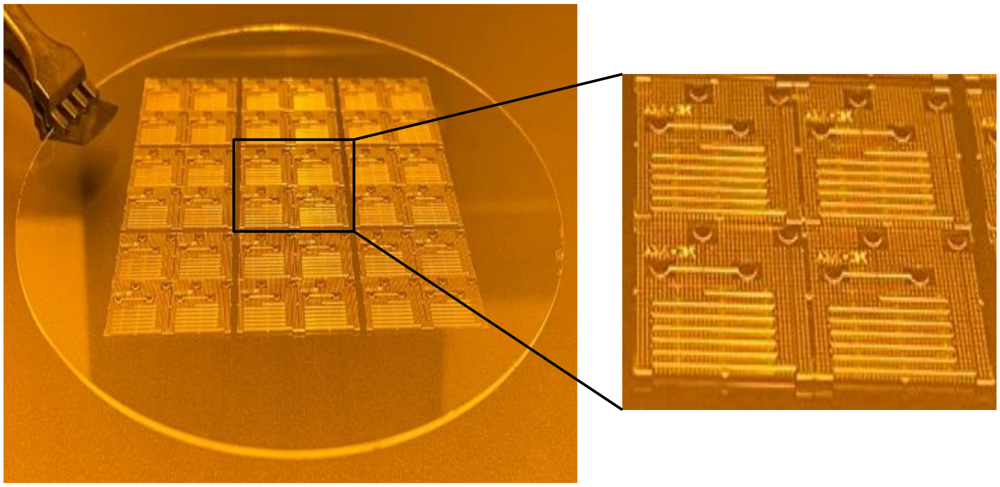

Figure 1: Resist structures as molds for microfluidic structures with 100 µm channel width in 67 µm thick mr-DWL 40 (on 100 mm Borofloat glass wafer).

Table 1: Sidewall characteristics measured via confocal microscope using write mode WM I (focal length 4 mm, beam waist diameter 0.8 mm) for different resist thicknesses in mr-DWL 40.

	20 µm	67 µm	100 µm
Sidewall angle	74°	85°	86°

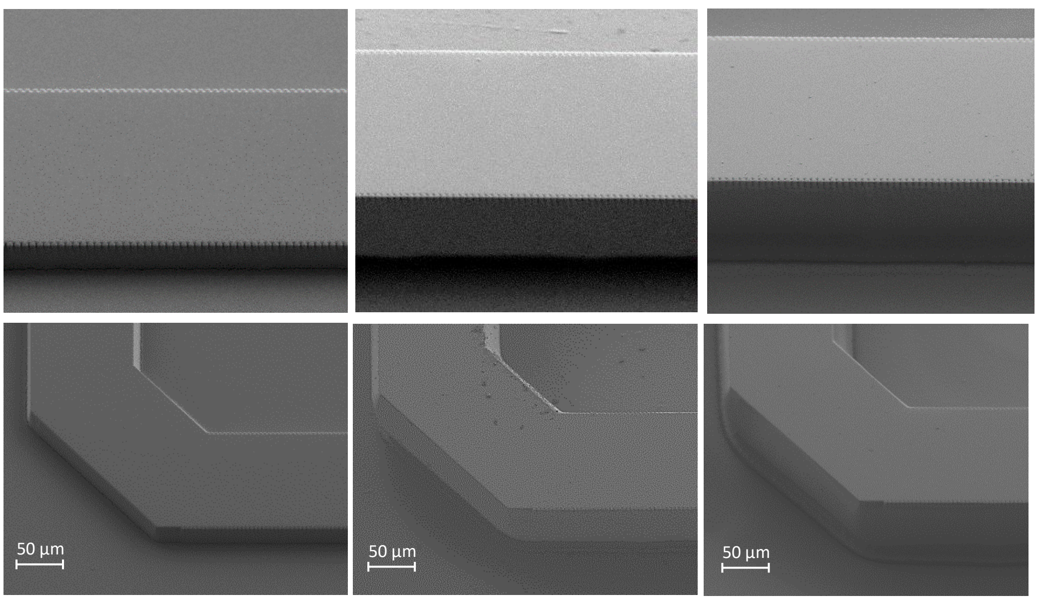

Figure 2: SEM micrographs (30° tilt) of 20 µm (left), 67 µm (center) and 100 µm (right) thick mr-DWL 40 negative resist structures, exposed using the DWL 66$^+$ with WM I, top row: straight ridges (inverted channels), width 100 µm, bottom: 90° bend. The ripples at the top of the straight sections are stemming from 2 µm corrugations that were intended to check for resolution. Due to lateral development, they are smeared out at 3 µm depth.