Polymeric freestanding structures by direct write laser without sacrificial layers

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In order to reduce production cost for functional microsystems, significant effort has been invested during the last decades in the development of materials with improved intrinsic properties. Among the large variety of polymers, SU-8 resist is widely used due to its outstanding properties, which allows generating ultra thick geometries with vertical sidewalls[1]. In the fabrication of SU-8 based microsystems it is common to use a sacrificial layer to release the freestanding structures[2]. However, the use of sacrificial layers is one of the most critical steps in the fabrication of micro-mechanical structures[3]. In this paper we take into advantage the sensitivity of the newly developed mr-DWL_5 XP material (micro resist technology GmbH, Germany) to wavelengths over 400 nm to yield epoxy-based freestanding micro-structures without additional sacrificial layers. The proposed fabrication process is schematically depicted in **Fig 1**. First a 100-µm-thick layer of conventional SU-8 is processed by standard UV-lithography at i-line (365 nm), which results in a uniform layer with both crosslinked and non-cross-linked SU-8 areas, as shown in **Fig1a**. Then, a layer of mr-DWL_5 XP is processed by direct write laser[4] at a wavelength of 405 nm, as schematized in **Fig 1b**. In this process the non-crosslinked SU-8 is also exposed but this layer is not crosslinked since it is not sensitive. After DWL exposure a post exposure bake is done at 85ºC to fully crosslink the mr-DWL_5 XP (**Fig 1c**). Development of both non-crosslinked SU-8 and mr-DWL_5 XP is carried out simultaneously in PGMEA and rinsed in isopropanol. At this point the freestanding structures patterned in the mr-DWL_5 XP layer are released (**Fig 1d**). Two different micromechanical structures have been developed as proof of concept of the novel 3D patterning technology: double clamped beams and cantilevers. **Fig 2a** shows a SEM picture of an array of 400-µm-long double clamped beams with widths ranging from 3 to 7 µm. As can be seen, the shape of the beams is very accurate. **Fig 2b** shows a side view SEM picture of double clamped beams. These beams are 2000 µm long and have widths ranging from 1 to 20 µm. As can be seen these long beams with up to 3 µm width are too soft to sustain from collapsing. However, all the beams wider than 3 µm are straight and do not present any deformation. **Fig 2c** shows single-clamped cantilevers with widths ranging from 4 to 9 µm and lengths of 35, 65 and 95 µm. The fabricated freestanding microstructures do not exhibit any bending due to stress or defect. A more detailed SEM image of one polymeric cantilever with 95 µm length and 10 µm width can be seen in **Fig 2d**. Due to some diffusion of the mr-DWL_5 XP into the SU-8 the bottom surface of the cantilevers is rounded, which may be exploited as unique feature of such structures. The proposed new technique represents a new and attractive way for the direct, hence cost-efficient fabrication method for polymeric MEMS.

1 M. Despont, et al. Proceedings MEMS'97, H. Lorentz et al., Sens Act A, 1998.

2 A. Llobera et al., JMEMS 2007.

3 G.M.Whitesides et al., Small 2005.

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Figures:

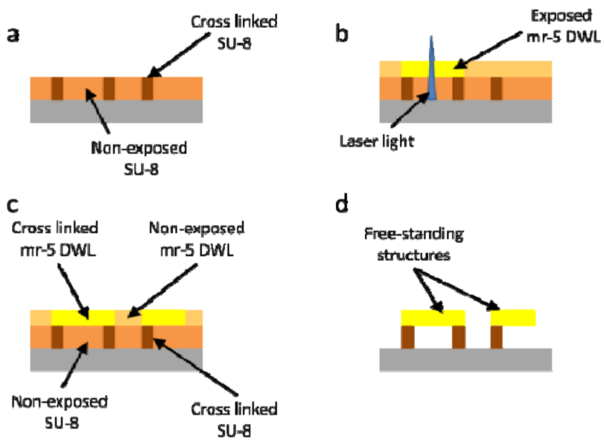

Figure 1. Schematic illustration showing the freestanding epoxy structure fabrication. a) UV lithography of the SU-8 layer. This layer is not developed. b) Spin coating and DWL exposure of the mr-DWL_5 XP. c) The exposed mr-DWL_5 XP is crosslinked, but not the SU-8. d) Both non-exposed SU-8 and mr-DWL_5 XP are removed during development and the freestanding structures are released.

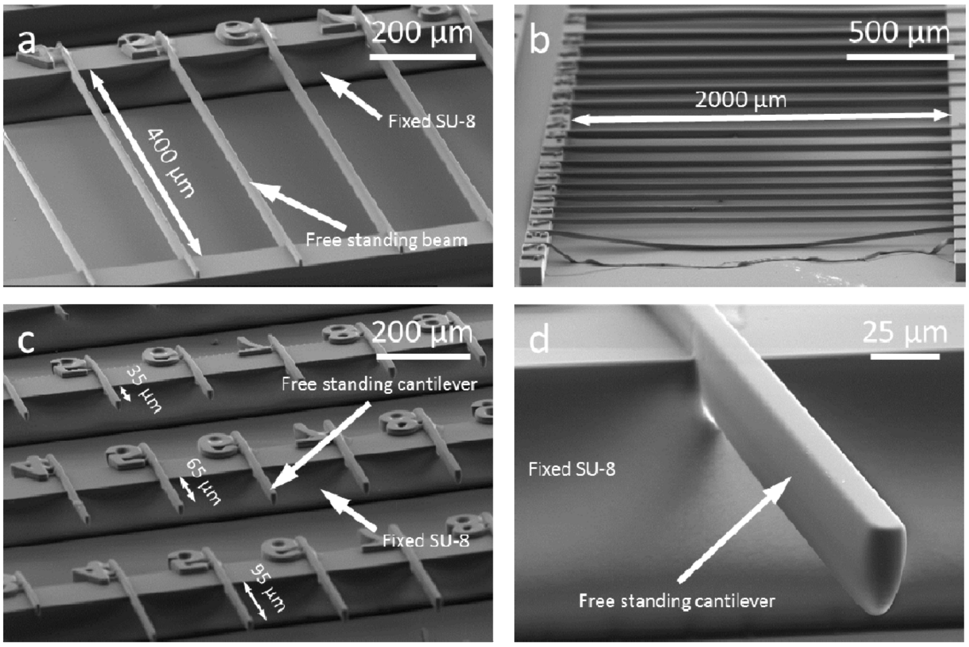

Figure 2. SEM images of different free standing structures: (a) double clamped bridges with widths ranging from 3 to 7 µm and a longitude of 400 µm. (b) Side view double clamped bridges having widths ranging from 4 to 20 µm and a length of 2000 µm. (c) An array of cantilevers with widths between 4 and 9 µm for different longitudes. (d) Detailed view of a single cantilever with rounded bottom surface.