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Use of a polymeric sacrificial release layer in photopolymer-based micro-3D printing

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Within the recent years, additive manufacturing, most commonly referred to as 3D printing, has been a very heavily discussed subject in various fields of research. Advances in photopolymer-based 3D printing technologies, such as digital light processing (DLP)-based 3D printing, stereolithography (SLA) or two-photon polymerization and continuously increasing print resolution have made 3D printing accessible for the field of microfabrication [1]. Hence, 3D printing is for example widely used for the fabrication of microfluidic chips as well as molds for microfluidics [2].

In most cases of micro-3D printing, the micrometer-sized parts are just a feature on a bigger part or attached to a likewise 3D printed base. Therefore, it is practically not feasible to obtain small single objects, as the printed structures have to be manually detached from the substrate and/or build surface, often using tools such as scrapers and pliers, thus risking damage to the delicate structures.

The use of sacrificial layers is widely employed in the area of micro- and nanofabrication. This concept was further expanded by the use of water-soluble polymeric sacrificial layers [3]. By taking inspiration of these concepts, the presented work aims at making the 3D printing of micrometer-sized objects more practicable and convenient. Thus, we propose a method that enables the DLP- or SLA-3D printing on a release layer, which acts as a carrier during the printing procedure (Fig. 1) and is easily dissolved afterwards. Thereby, micrometer-sized single objects can be obtained without risking damage to them.

In the presented study, we used a commercially available DLP-based 3D printer with a resolution of 30µm voxel size to print on a sacrificial release layer. It is important to choose a material for the release layer that can be solubilized by a solvent that does not dissolve the 3D printed structure. The used printing material was as well commercially acquired and is not affected by the solvent that acts to dissolve the sacrificial release layer. We tested the compatibility of the printing material with the release material by determining a molecular fingerprint using Raman spectroscopy (Fig. 2) and comparing samples with potential contamination after successive time points with an uncontaminated control sample. Doing so, we could not observe any difference in the recorded spectra and thereby we conclude that no interaction between the two materials has taken place. Additionally, we could observe that the release material did not dissolve in the 3D printing material. Finally, we chose two different 3D models for demonstration of the printing process, a star-shaped pattern of micrometer-sized cones (Fig. 3A) and a complex 3D lattice made of micrometer-sized trusses (Fig. 3D) [4]. The photograph and SEM micrographs in Figure 3 show that the structures were printed successfully on the sacrificial release layer, without exhibiting any defects at the interface between the 3D printed part and the release layer. Furthermore, we could observe that after the release from the sacrificial layer, the interfacing areas of the 3D printed structures revealed smooth and intact surfaces (Fig. 3F).

Altogether, we could show that the proposed method is compatible with the 3D printing procedure and suitable for a mild release and harvesting of 3D printed microstructures.

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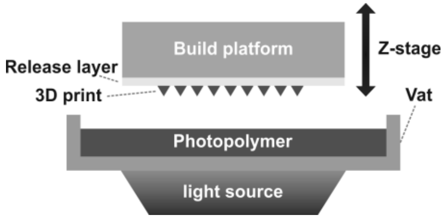

Figure 1. Schematic illustration of digital light processing (DLP)-based 3D printing with sacrificial release layer.

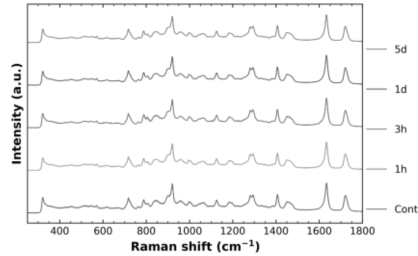

Figure 2. Raman spectroscopy of the used 3D printing photopolymer after it was in contact with the release material for 1h, 3h, 1d and 5d. The control was not in contact with the release material.

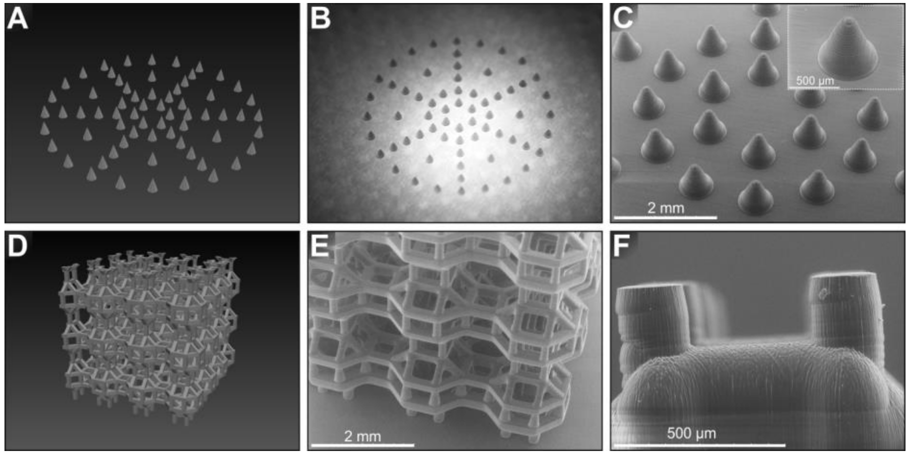

Figure 3. CAD designs and SEM micrographs of exemplary 3D prints. A) CAD design of first exemplary structure. B) Photograph of 3D print on release layer. C) SEM micrograph of 3D printed structures on release layer. D) CAD design of second exemplary structure. E) SEM micrograph of 3D print on release layer. F) Close-up of released structure. The protrusions have been standing on the release layer.