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Micro 3D printing and microrobotics for life science applications

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INTRODUCTION

We use a commercial two-photon polymerization direct laser writing (DLW) system from Nanoscribe to fabricate micro 3D structures for e.g. model cell membranes [1], microrobotics [2], or antireflective surfaces [3]. DLW allows for the fabrication of micro- and nanostructures with full 3D freedom.

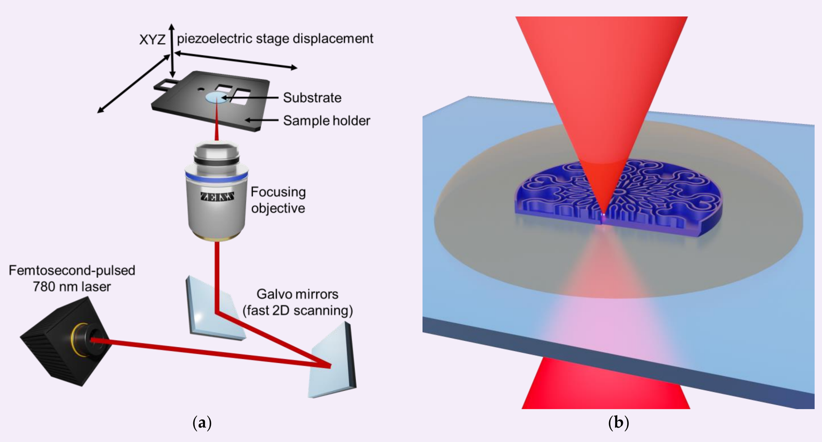
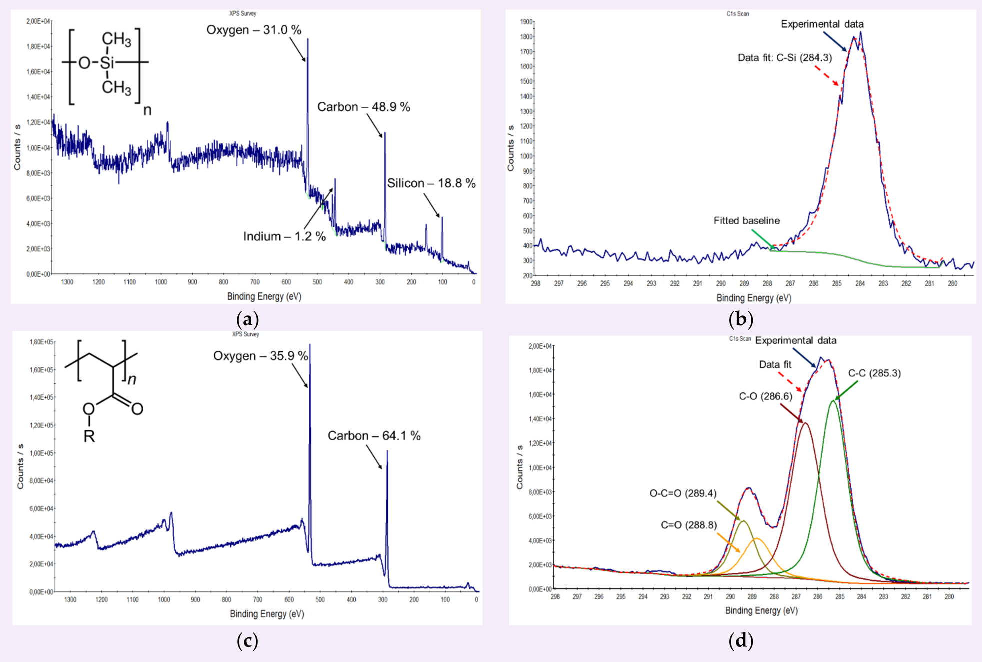


Fig. 1 [4] Schematic representation of two-photon polymerization direct laser writing. (a) The beam coming from a femtosecond-pulsed laser is scanned in 2D using a high-speed galvo mirror system and subsequently focused into the sample through a microscope objective. The stage on which the sample is located can be also be displaced in X, Y or Z by a piezo system. (b) By scanning the laser focal point, the target structure is written voxel-by-voxel into the liquid resin.

MATERIALS



We print using commercial resins from the IP-series, as well as using home-made smart responsive polymers formulations.

Fig. 2 [4] X-ray photoelectron spectroscopy (XPS) analysis of flat 3D printed structures. (a, b) IP-PDMS. (c, d) IP-L 780. (a, c). Survey spectra showing the quantified elements and their relative abundance. Insert shows the chemical structure of the polymer. (b, d). High-resolution C1s spectra with peak deconvolution showing the types of chemical bonds identified.

EXAMPLES OF STRUCTURES

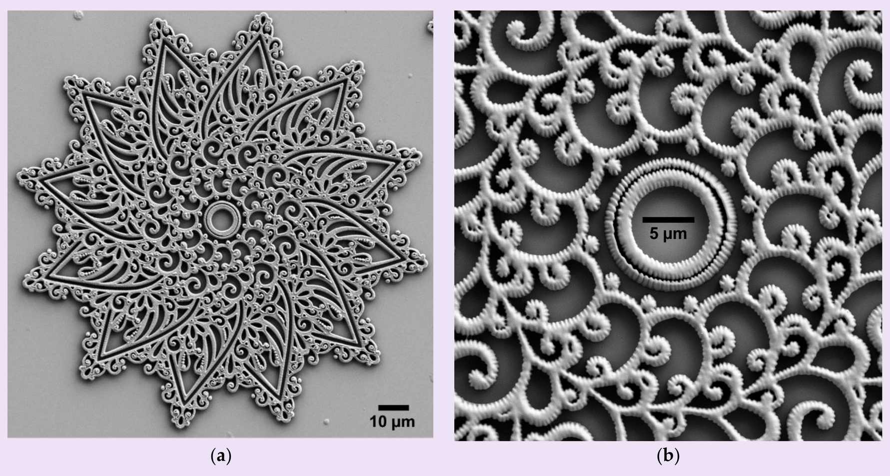


Fig. 3 [4] SEM of a mandala structure **emphasizing the 3D printer's high resolution for 2.5D structures**. The mandala has a diameter of 140 µm, a thickness of 2 µm, and features individual lines and dots with widths below 500 nm. The structure was printed in ~ 7 min in the IP-L 780 resin onto a 170 µm thick borosilicate glass coverslip substrate using the 63×/1.40 microscope objective.

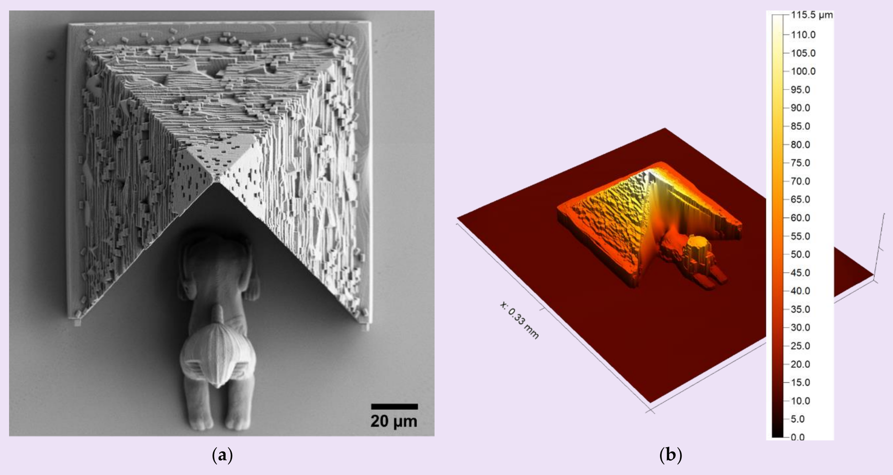


Fig. 4 [4] Pyramid with guarding sphynx structure **emphasizing the 3D printer's high resolution for 3D structures**. The pyramid has a base length of 139 µm and a height of 107 µm, and the sphynx has a height of 51 µm. The structures were printed in ~ 25 min in the IP-Dip resin on a fused silica substrate using the 63×/1.40 microscope objective. (a) SEM. (b) Natural proportion image from optical profilometry.

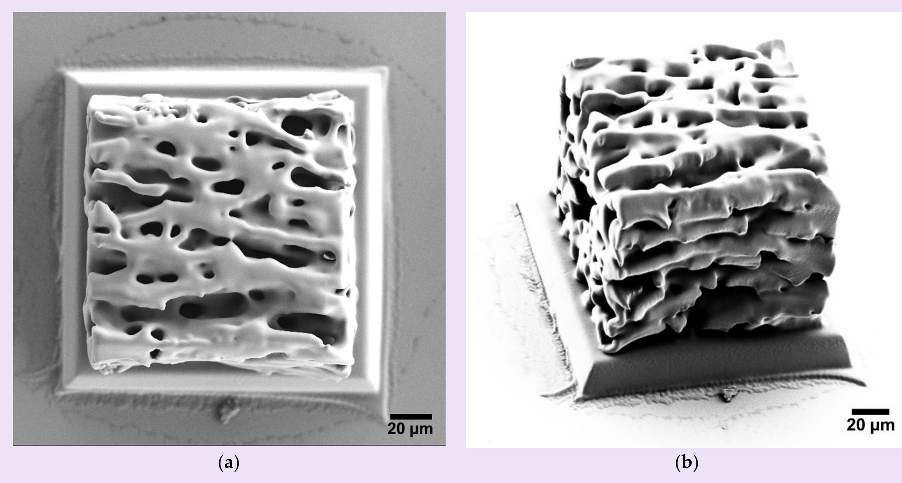


Fig. 5 [4] SEM of a **porous scaffold structure mimicking the shape and mechanical properties of connective tissue**. The porous structure itself is a cube with a side length of 133 µm, and is printed onto a solid base of 150 µm × 15 µm. The structure was printed in ~ 41 min in the IP-PDMS resin on a plasma treated ITO-coated fused silica substrate using the 25×/0.80 microscope objective. (a) Top view. (b) Tilted view (45°).

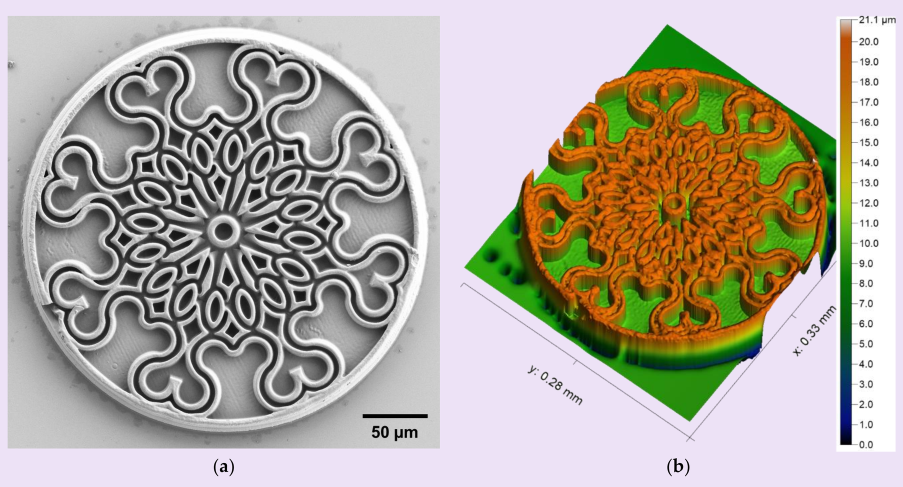


Fig. 6 [4] Rosette window cookie **soft master mould** structure. The entire structure has a diameter of 300 µm, a total thickness of 18 µm and its walls are 9 µm tall. The structure was printed in ~ 22 min in the IP-PDMS resin on a plasma treated ITO-coated fused silica substrate using the 25×/0.80 microscope objective. (a) SEM. (b) Natural proportion image from optical profilometry.

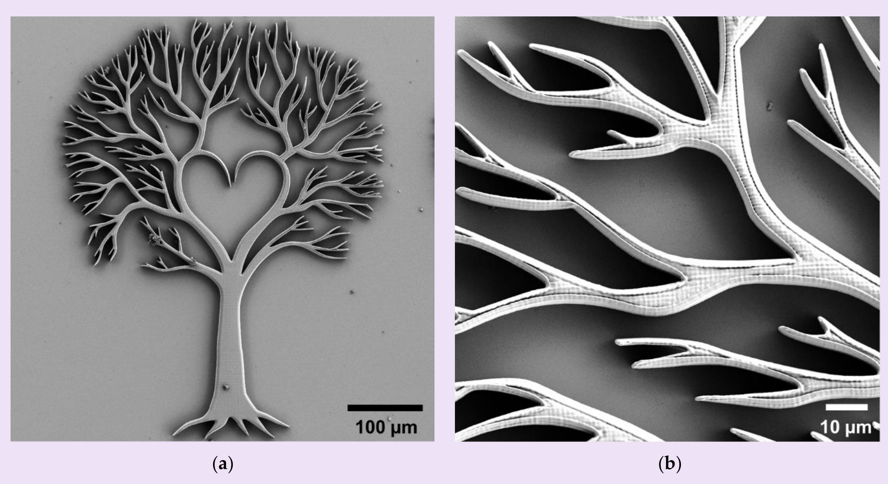


Fig. 7 [4] SEM of a **macroscale** Yggdrasil structure imaged using different magnifications. The entire structure has a size of 560 µm × 435 µm and a thickness of 2 µm. The structure was printed in ~ 7 min in the IP-L 780 resin on a 170 µm thick borosilicate glass coverslip substrate using the 20×/0.50 microscope objective.

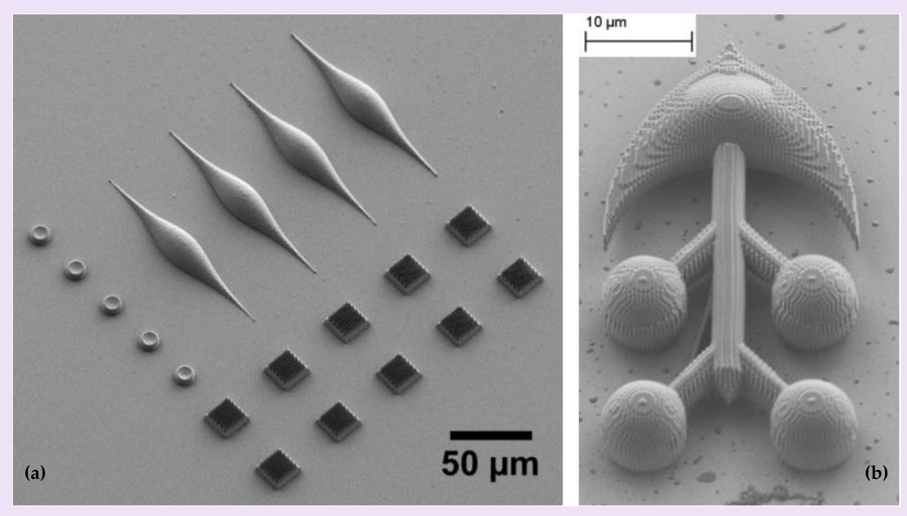
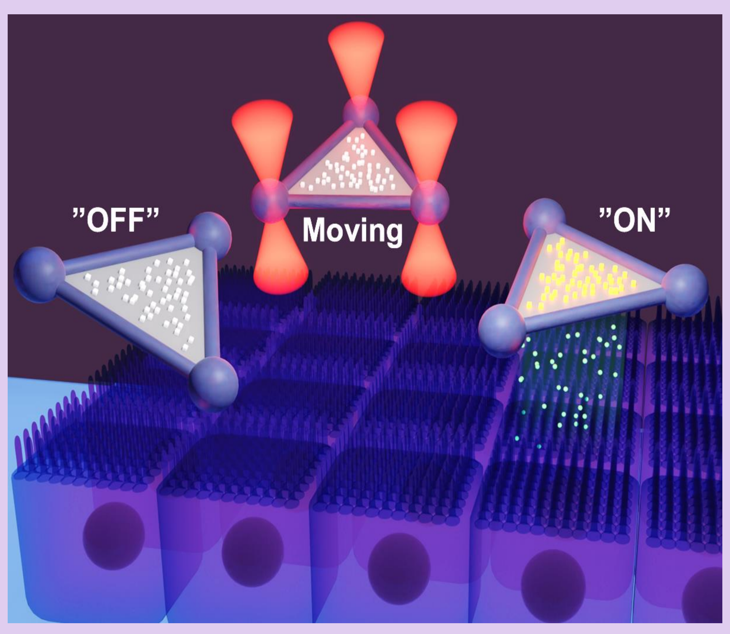


Figure 8. SEM images of structures for life sciences and microrobotics 3D printed using IP-L 780. (a) **Cell-like scaffolds with biomimetic shape and size** employed as substrates for model cell membranes [1]. (b) "Racing car" **microrobot** for localized mucus melting. The four spheres enable optical trapping for extremely precise manipulation.

PERSPECTIVES

We are working on developing a toolbox of 3D printed microrobots for life science applications such as localized sensing and drug delivery, microscale manipulation, micromixing etc. Micro 3D printing allows us to fabricate complex shapes in polymers with various properties, including soft responsive materials. This should prove useful for the aforementioned applications.



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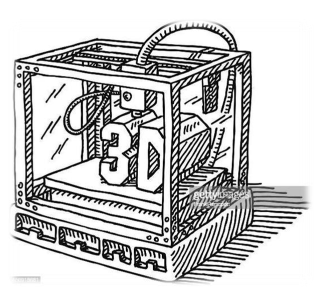
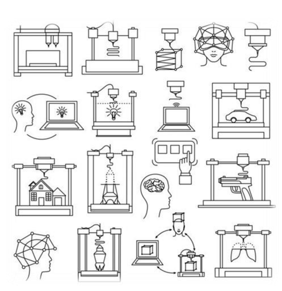
VILLUM FONDEN
DANMARKS FRIE FORSKNINGSFOND





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