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MDPI

Supplementary Material

Micro 3D Printing by Two-Photon Polymerization: Configurations and Parameters for the Nanoscribe System

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Abstract: 3D printing by two-photon polymerization enables the fabrication of microstructures with complex shapes and critical dimensions of a few hundreds of nanometers. On state-of-the art commercial two-photon polymerization systems, an immense 3D design freedom can be put into practice by direct laser writing using a precise fabrication technology, which makes this approach highly attractive for different applications on the microscale, such as microrobotics, micro-optics, or biosensing. However, navigating the different possible configurations and selecting the optimal parameters for the fabrication process often requires intensive testing and optimization. In addition to the more established acrylate-based resins, there is a growing interest in the use of soft materials. In this paper, we demonstrate the fabrication of various microscale structures by two-photon polymerization using a Nanoscribe Photonic Professional GT+ commercial system. Furthermore, we describe the different configurations of the system and parameter selection, as well as commercial resins and their chemical and mechanical properties. Finally, we provide a short guide aiming to serve as starting point for the two-photon polymerization-based fabrication of various microscale architectures with distinct characteristics.

Keywords: 3D printing; two-photon polymerization; direct laser writing; microfabrication; surface chemistry

S1. 3D design files (.STL)

All .STL files were downloaded from the website https://www.thingiverse.com/ , with the exception of the random porous structure, which was designed in SolidWorks. The sizes of the structures were adapted for printing on the Nanoscribe directly in the DeScribe software. Figure S1 shows renders of the 3D design files and Table S1 shows the sizes employed for the various structures fabricated.

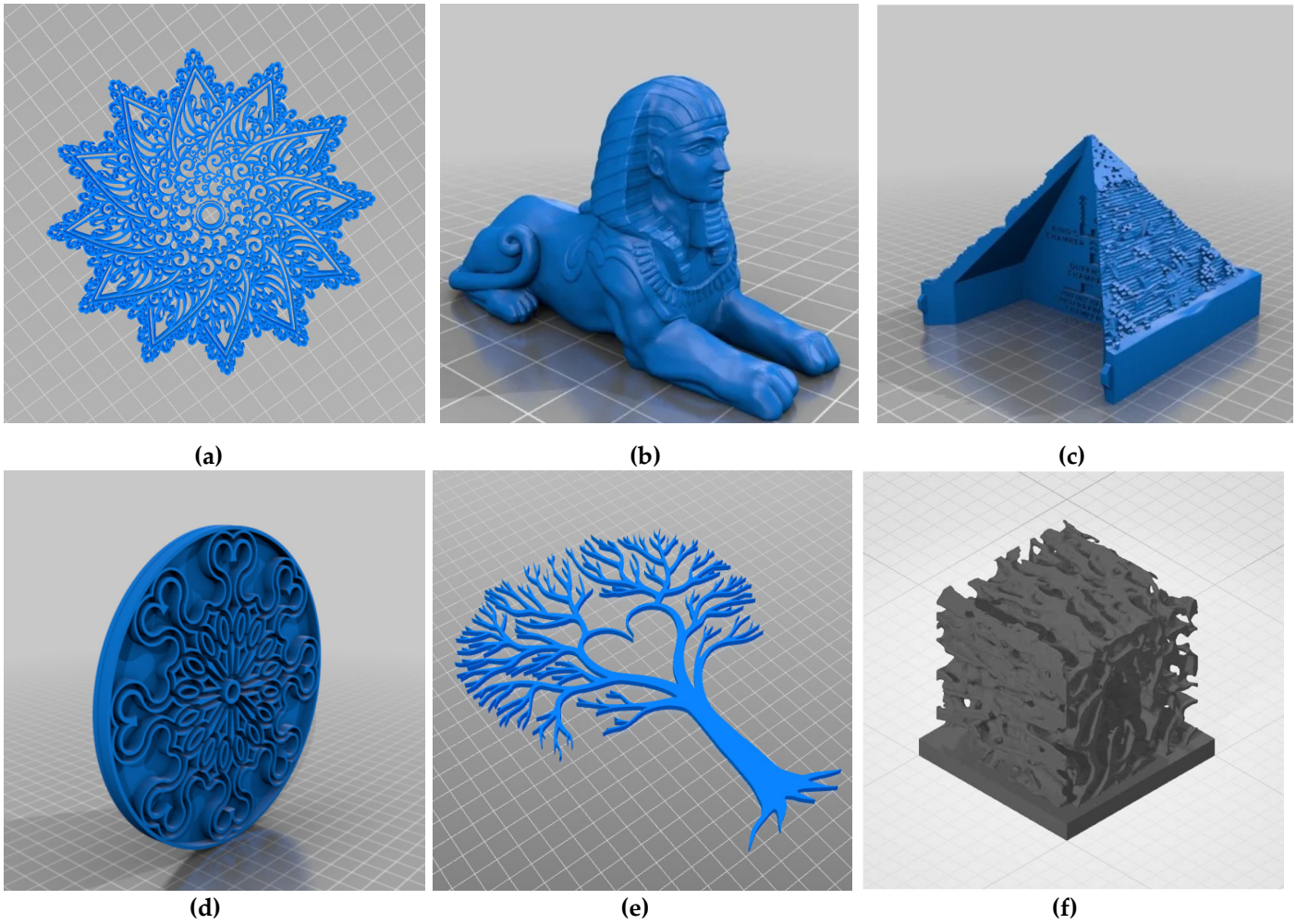

Figure S1. 3D renders of the designs employed for fabricating the structures shown in the main text. (a) Mandala structure, Licensed under the Creative Commons – Attribution – Share alike license, Copyright https://www.thingiverse.com/thing:684171. (b) Sphynx structure, Licensed under the Creative Commons – Attribution license, Copyright https://www.thingiverse.com/thing:182366. (c) The great pyramid of Giza structure, Licensed under the Creative Commons – Attribution license, Copyright https://www.thingiverse.com/thing:296260. (d) Rosette window cookie impression structure, Licensed under the Creative Commons – Attribution license, Copyright https://www.thingiverse.com/thing:4166489. (e) Yggdrasil structure, Licensed under the Creative Commons – Attribution license, Copyright https://www.thingiverse.com/thing:4717818. (f) Random porous scaffold with square base.

Table S1. Sizes defined in DeScribe for the various structures fabricated.

	Size in XY plane (μm)	Size on Z axis (μm)
Mandala	Ø 140	2
Sphynx	90× 40	53
Pyramid	139 × 139	107
Cookie master	Ø 300	17
Yggdrasil	560 × 435	2
Porous scaffold + base	133 × 133 + 150 ×150	133 + 15

S2. Printing file preparation (.GWL)

The 3D designs require conversion to a printable file format, which contains the information defining the trajectory and parameters for the direct laser writing (DLW) process, before the fabrication step can take place. For this purpose, each .STL file was imported into the DeScribe software, where the structure size and the print parameters were defined, and the .GWL printable file was generated. The parameter choice was based on the configuration employed, as well and on the dimensions and features of individual scaffolds.

In DeScribe, each 3D structure was first sliced into layers. The slicing distance represents the separation between adjacent layers. After defining the layers, the trajectory of the laser focal spot for the DLW process is defined by hatching the layers of the 3D structures. As the focal point of the laser is an ovoid with an extended size in Z as compared to that in the XY plane, the hatching distance is typically lower than the slicing distance. Here, the hatching angle was set to 90°, meaning that the trajectories in two adjacent layers will be perpendicular. This reduces the risk for obtaining structures that are deformed on the X or Y axis. Together, the slicing and hatching of the 3D design define the laser scanning path for the fabrication process.

To improve the smoothness of the print and as additional measure to prevent structure deformation, contour lines were added during the .STL to .GWL conversion process. This means that, for each layer defined during slicing, the laser will first write a contour line following the outline of the layer, before following the trajectories defined during hatching. The number of contour lines is defined in DeScribe as the contour count.

After defining the slicing, hatching and contour lines, the final .GWL printable file was generated. The .GWL file can be read by the Nanoscribe 3D printer through the NanoWrite software. Finally, the .GWL file prepared as detailed above was imported into the NanoWrite software, which was used for controlling the Nanoscribe DLW process.