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Comparison of commercial systems for two-photon polymerization direct laser writing

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Introduction. Introduced for rapid prototyping in 1980, 3D printing has evolved in the last decade as a versatile technology with applications in various fields, including aerospace, medical devices, and optics [1]. Among the different 3D printing techniques, two-photon polymerization (2PP) generates 3D structures with resolution and feature size down to nanometric scale while removing the need of supports for full freedom in sample design [2,3]. With regards to the recent upsurge of commercial 2PP printing systems, this work aims at benchmarking two printers and provide an overview of the capabilities of those two systems.

Methodology. To cover a large range of needs in 3D printing, two test structures were designed for this study: Design A represents an object with a complex shape with intersecting curved surfaces and a non-uniform porosity (**Fig. 1**), and Design B is a structure including pillars and holes at different printing angles (**Fig. 2**) chosen to evaluate the minimal achievable feature sizes. Both structures were 3D printed by using the UpNano system NanoOne$_{250}$ and the Nanoscribe Photonic Professional GT+ in the respective proprietary inks UpBrix and IP-Dip. SEM images were captured to characterize the structures.

Results. For Design A, the vertical pores and roughness were investigated by capturing a top view image of each structure. While no relevant differences were detected in the pore quality, the UpNano printer showed a smoother surface compared to the Nanoscribe system (**Fig 1**). For Design B, generally both printers showed a better printing quality for the structures on the 0° plane compared to the 45° plane (**Fig. 3**). On the 0° plane, both systems printed all the pillar sizes but just the 0.3 µm pillars obtained with UpNano remained straight. For the holes, sizes below 1µm resulted clogged for the UpNano system. On the 45° tilted plane, the obtained pillars with the smallest feature were 0.5 µm and 1 µm for Nanoscribe and UpNano systems, respectively. Unexpectedly, the UpNano printer printed all the holes down to 0.3 µm on the tilted plane while some features resulted clogged with the Nanoscribe system. For both planes of the design B, the Nanoscribe print showed generally smoother surface. UpNano printed the Design A and the Design B 2.2 and 1.5 times faster than the Nanoscribe system.

Conclusions. Our study is a first attempt to compare commercial two-photon printers to identify advantages and disadvantages when printing different types of structures under different conditions. Visually, the UpNano printer seems to result in smoother curved surfaces and rougher in planar surfaces, compared to the Nanoscribe printer, although a further AFM investigation would be required to quantify the results. Further structures will be designed to identify the strengths and weaknesses of the two systems.

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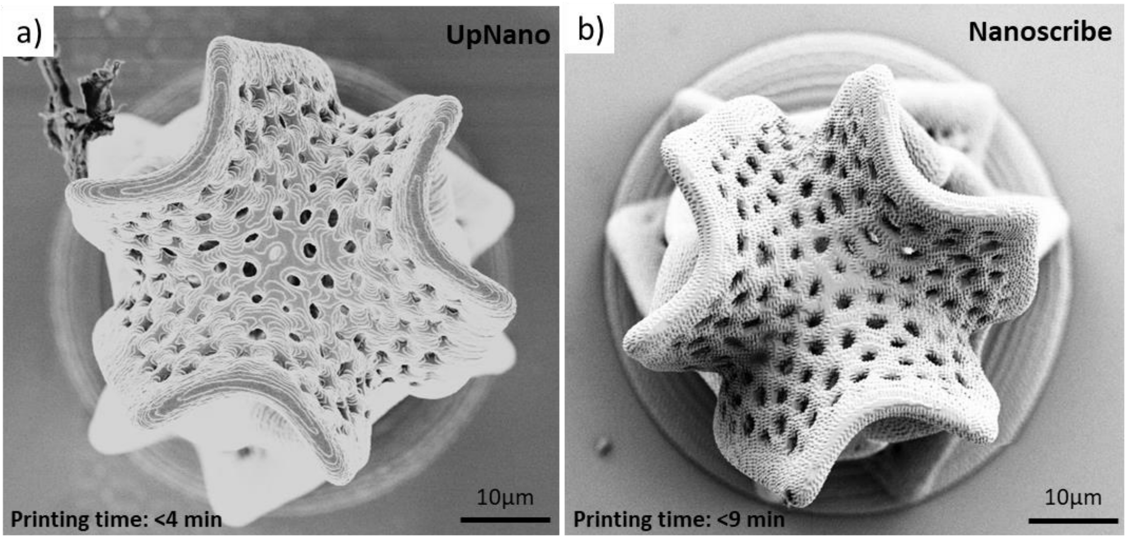

Figure 1. Scanning electron micrographs of Design A fabricated using the a) UpNano and b) Nanoscribe systems

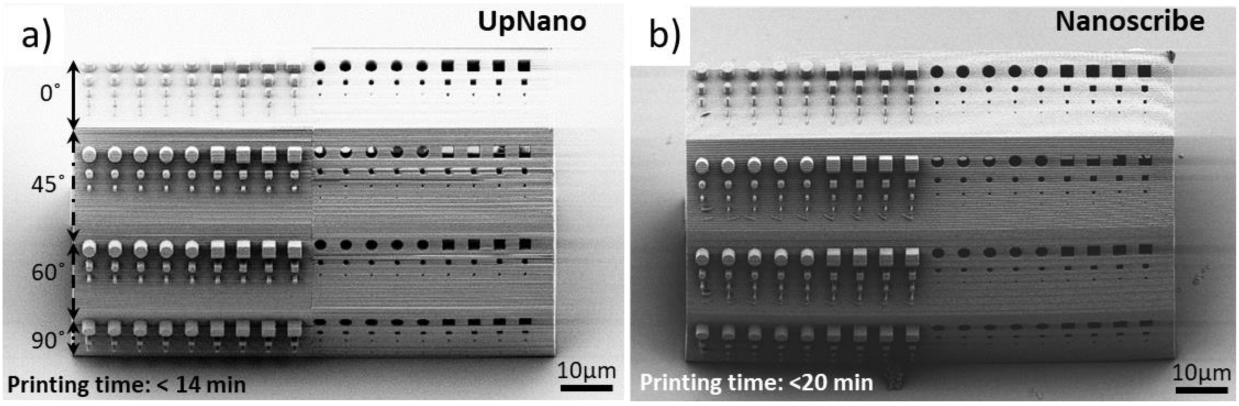

Figure 2. Scanning electron micrographs of Design B fabricated using the a) UpNano and b) Nanoscribe systems.

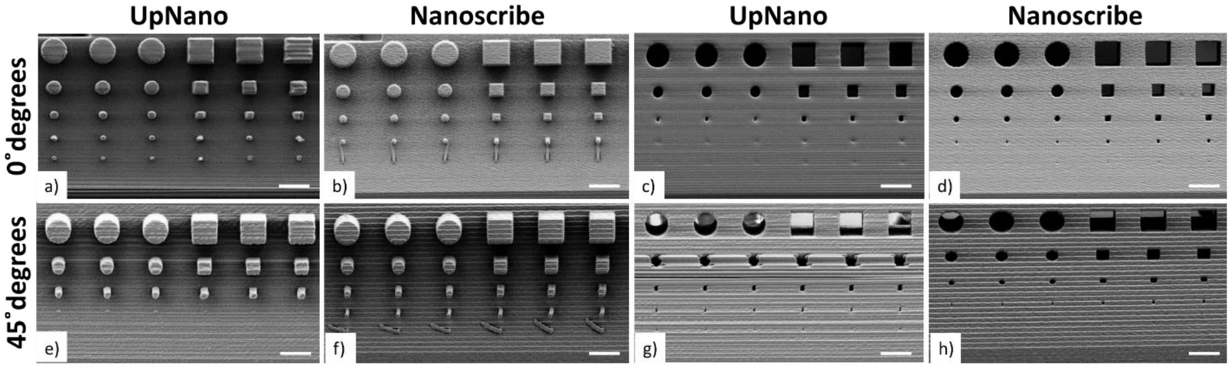

Figure 3. Magnification of the features on the planes. The pillars and holes arrays printed on a 0° degrees plane using the a) and c) UpNano, b) and d) the Nanoscribe systems. The pillars and holes arrays printed on a 45° degrees plane using the e) and g) UpNano, f) and h) the Nanoscribe systems.Scale bar=5µm