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2-photon polymerization – benchmarking commercial printers to access the nanometric scale in 3D printing

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Introduction: 3D printing has been implemented as a reliable manufacturing technology in various fields including microfluidics. More recently, two-photon polymerization (2PP) not only allowed the 3D fabrication with resolution and feature size down to nanometric scale, but also opened to a full freedom in sample design [1],[2]. The development of new inks and faster printing systems has paved the way to an increasing amount of commercial 2PP printing systems. In this work, the ability of two printers to print high-resolution structures is compared.

Theory and Experimental procedure: A structure was designed to cover different printing features, *i.e.* pillars and holes, placed on solid planes positioned at different angles (**Fig. 1**) to evaluate the minimal achievable feature sizes. The structure was 3D printed by using NanoOne$_{250}$ (UpNano) and the Photonic Professional GT+ (Nanoscribe) in the respective proprietary inks UpBrix and IP-Dip, and characterized using SEM imaging.

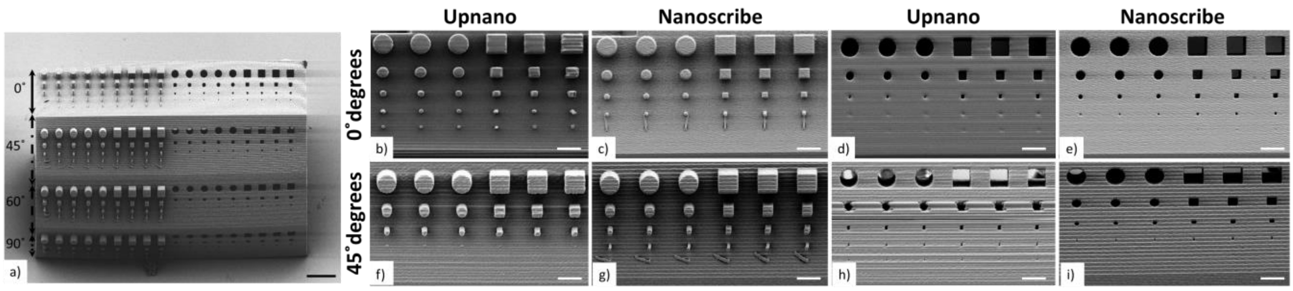

Figure 1: *Scanning electron micrographs of the design. a) Overview. Scale bar = 10 µm. b-i) Magnification of the features on the planes. The pillars and holes arrays printed on a 0° degrees plane using the NanoOne$_{250}$ (b) and d)) and the Photonic Professional GT+ (c) and e)) systems respectively. The pillars and holes arrays printed on a 45° degrees plane using the NanoOne$_{250}$ (f) and h)) and the Photonic Professional GT+ (g) and i)) systems respectively. Scale bar = 5 µm*

Results: For the structure, both printers generally showed a better printing quality for the features on the 0° plane compared to the 45° plane (**Fig. 1**). On the 0° plane, both systems printed all the pillar sizes but just the 0.3 µm pillars obtained with NanoOne$_{250}$ remained upright. For the holes, sizes below 1 µm were 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 Photonic Professional GT+ and NanoOne$_{250}$, respectively. Unexpectedly, the NanoOne$_{250}$ printed all the holes down to 0.3 µm on the tilted plane, while the equivalent holes were clogged on the Photonic Professional GT+. For both planes, Photonic Professional GT+ print showed generally a smoother surface. The NanoOne$_{250}$ printed the structure 1.5 times faster than the Photonic Professional GT+.

Conclusion: Our study is a first attempt to compare commercial two-photon printers to identify advantages and disadvantages in different conditions. The Professional GT+ seemed to result in smoother surfaces compared to the NanoOne$_{250}$, but this advantage came with the drawback of a slower printing. Further AFM investigations will be required to quantify the surface roughness and more designs will be analyzed to identify the strengths and weaknesses of the two systems.

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