3D PRINTING BY TWO-PHOTON POLYMERIZATION

S. Mckee[1*], A. Lutey[1], F. Poli[1], S. Selleri[1], L. Romoli[1], A. Fortunato[2], A. Cucinotta[1]

[1]University of Parma, Department of Engineering and Architecture, Parco Area delle Scienze 181/A, 43124 Parma, Italy
[2]University of Bologna, Department of Industrial Engineering, Viale Risorgimento 181/A, 40136 Bologna, Italy
*[*seyyedhossein.mckee@unipr.it](mailto:seyyedhossein.mckee@unipr.it)*

Fabrication of 3D microstructures by two-photon polymerization is reported. This process exploits femtosecond laser pulses and a photo resist transparent at the laser wavelength (515 nm) that absorbs two photons at high intensity to polymerize.

Keywords: Two-photon polymerization, femtosecond laser pulses

1. Introduction

The optimal use of time and resources, together with increased product functionality and customization, are amongst the primary reasons motivating companies to move towards the downsizing of components via 3D printing microfabrication. Two-photon polymerization (2PP), a revolutionary novel microfabrication technology, has therefore gained much attention in terms of research due to its promising potential as a 3D printing technique for achieving resolution beyond the diffraction limit [1]. 2PP is based on the non-linear two-photon absorption (2PA) process whereby femtosecond pulses are tightly focused into a very small volume of photosensitive material that triggers polymerization to fabricate arbitrarily, complex micro- and nanoscale structures. This technique demonstrates great promise for the fabrication of 3D photonic crystals, micro-optical components and biomedical devices such as microneedles for drug delivery [2].

2. Experimental Setup and Discussion

Our laboratory has recently been equipped with an ultrashort pulsed laser for microfabrication via 2PP without the need for cleanroom facilities. A schematic representation of the experimental setup is shown in Fig. 1(a). The femtosecond laser has the ability to generate pulses of duration 80 fs, pulse energy 70 nJ and peak power 100 kW. The repetition rate and operating wavelength are 76 MHz and 1030 nm, with the latter frequency doubled to 515 nm with a pulse energy of 25 nJ. The laser beam is tightly focused with 10-100× objectives to a spot size ranging from approximately 10 µm to 1 µm. The fabrication process starts with the production of a 3D computer model of the desired object using CAD software, which is saved in the stereolithography file format (STL). The STL file is then sliced and hatched with an open-source 3D slicing engine and subsequently imported into the laser micromachining software, which is responsible for programming the laser path within the volume of the photosensitive material (photo resist). The first step in the material preparation process is placing a drop of E-Shell300 on a glass substrate mounted on 2D stages for positioning and movement of the material in the *x*- and *y*- directions. E-Shell300 is a dimethacrylate-based liquid photo resist with viscosity of 339.8MPa·s, mainly designed for the fabrication of biomedical devices such as hearing aids [3]. Although the velocity of the moving the mechanical stages is low, they exhibit a high precision of approximately 1 µm. The 10-100× objectives (0.25-1.45 numerical aperture) are mounted on a mechanical *z*-stage with the same precision and are used to focus the green laser beam within the preloaded photo resist. The obtained result is polymerization of the material, namely transformation from a liquid to solid state via polymerization, along the path followed by the moving focused laser beam. The process allows fabrication of complex 3D structures beyond the diffraction limit. The next step after obtaining the desired microstructure is immersing the sample in isopropyl alcohol (2-propanol) to remove unsolidified photo resist, leading to emergence of the desired microstructure on the glass substrate.

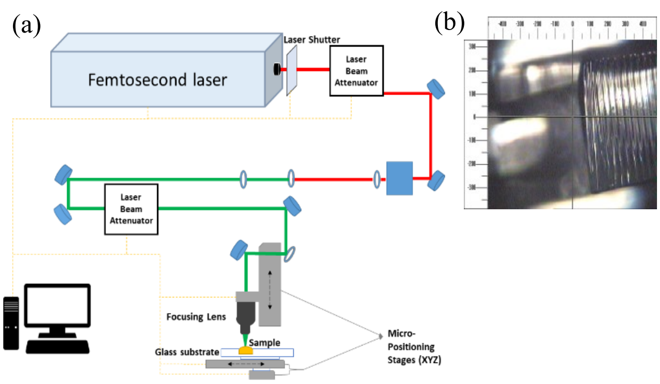

Fig. 1. (a) Schematic of setup for 2PP microfabrication with green laser beam and (b) a simple structure fabricated by usine two-photon polymerization technique.

3. Conclusion

The purpose of this paper is to introduce two-photon polymerization as a state-of-the-art microfabrication technique and to describe the steps that need to be taken in order to produce desirable microscale structures. More insight will be given within the presentation.

References

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