

Novel method for precise 3D nanofabrication

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Nanostereolithography improves the strength and spatial resolution of fabricated 2D and 3D microstructures.

Two-photon photopolymerization (TPP) uses near-IR laser pulses to sculpt photosensitive materials. It is an effective technique for fabricating the 2D and 3D micrometer-scale polymeric and ceramic structures found in optical and electronic microdevices. In particular, TPP offers numerous advantages over conventional MEMS (microelectrochemical systems) fabrication processes, which tend to be time-consuming and highly complicated. Nevertheless, despite the powerful merits of TPP for 3D microfabrication, some fundamental issues still remain to be resolved. Chief among them is improving the spatial resolution and strength of TPP-generated microstructures.

To this end, the Nanophotonic Materials Laboratory at Hannam University, in collaboration with the Laboratory for Computer-Aided Net Shape Manufacturing and Laser Science Research at the Korea Advanced Institute of Science and Technology (KAIST) in Korea, recently reported a TPP-based nanostereolithography (NSL) technique for making 3D microstructures in the submicrometer range required for MEMS devices. To demonstrate the potential of the approach, we have, for the first time, succeeded in producing an artistic microstatue with ultraprecise spatial resolution.^{1,2}

We began by developing highly efficient two-photon absorption (TPA) photosensitizers and matrix materials, together with novel mechanical approaches and optical setups.^{3,4} For example, by employing TPA active dyes and computer-aided design (CAD) systems, we successively increased the spatial resolution of microfabrication to below 100nm.^{5,6} We also introduced an effective method for reproducing 3D nano- and microstructures in a single step using a multilayered stamp via TPP.⁷ In addition, we synthesized efficient two-photon absorbing materials based on phenylene vinylene, phenylene ethynylene, and

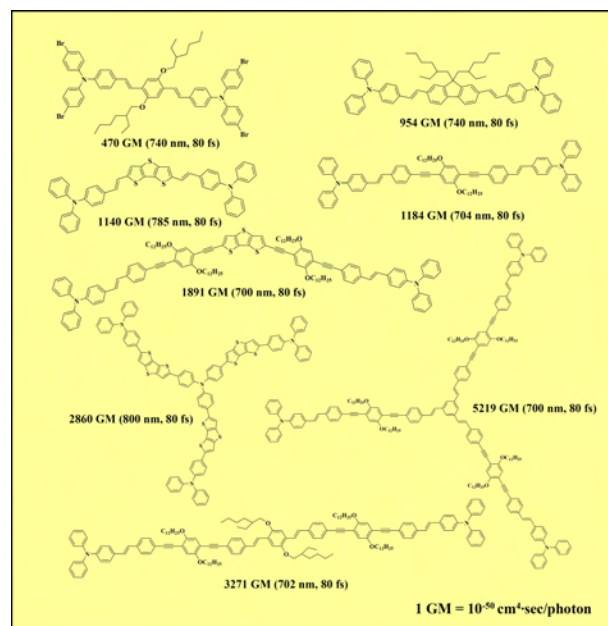


Figure 1. Examples of efficient two-photon absorbing materials.

fluorene and dithienothiophene moieties as TPP photosensitizers (see Figure 1). We also reported a series of original schemes for improving NSL, including its efficiency, fabrication strength and rate of throughput.¹⁻⁸

We constructed a novel femtosecond-laser system—see Figure 2(a)—which uses a mode-locked titanium-sapphire laser as a light source. The laser beam is scanned along the focal plane using a galvano-mirror set with a resolution of approximately 1.2nm per step and along the vertical axis using a piezoelectric stage. The beam is closely focused by means of an objective lens with a high numerical aperture.

To create a 3D microstructure with NSL, the overall CAD model is first arranged into slices. The laser then reproduces the first of these slices in the photosensitive material by scanning along it. After moving the location of the beam spot along the z axis using the piezoelectric stage, the next slice is scanned and

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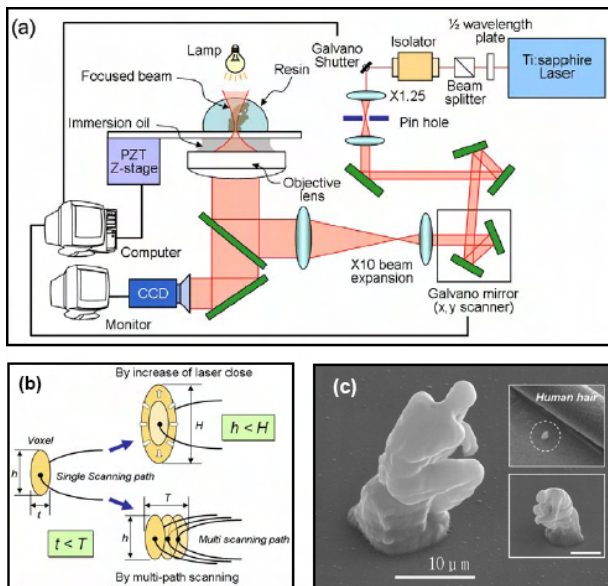


Figure 2. (a) Laser setup for fabrication. (b) Schematic illustration of the difference between two approaches for greater contour thickness: increasing the laser dose and multipath scanning. (c) Scanning electron microscope image of 'The Thinker' made by nanostereolithography. PZT: Piezoelectric transducer. Ti: Titanium.

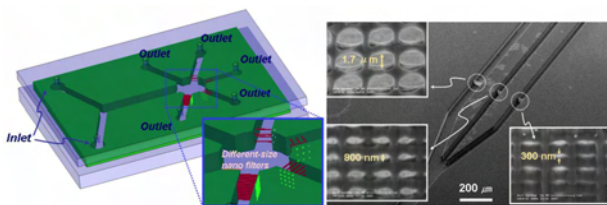


Figure 3. Schematic diagram of designed 'smart channel' structure. Some functional 3D microstructures are included within the channel.

added onto the previous slice. This process is repeated until the whole shape of the 3D structure is reproduced in the photosensitive material.

The main drawback of this process is that 3D pattern deformations can be caused by surface tension during the developing process. One way to prevent this from occurring is to thicken the contours of the 3D microstructures by increasing the laser power (P) and exposure time (t) of the TPP: see Figure 2(c). However, this method is not suitable for ultraprecise creation of complicated 3D microstructures due to large voxels (volume element). As an alternative approach, we have reported a new method for preventing 3D pattern collapse without losing resolution, termed multipath scanning. This involves reinforcing the 3D microstructures via a contour scanning method.¹

Figure 3 shows a smart channel containing highly functional 3D microstructures that were successfully fabricated by NSL. By controlling their shapes and dimensions, these structures can be used as either filters or mixers. Similar smart channels could serve a variety of applications in the fields of biological MEMS and chemically resistant microfluidics.

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