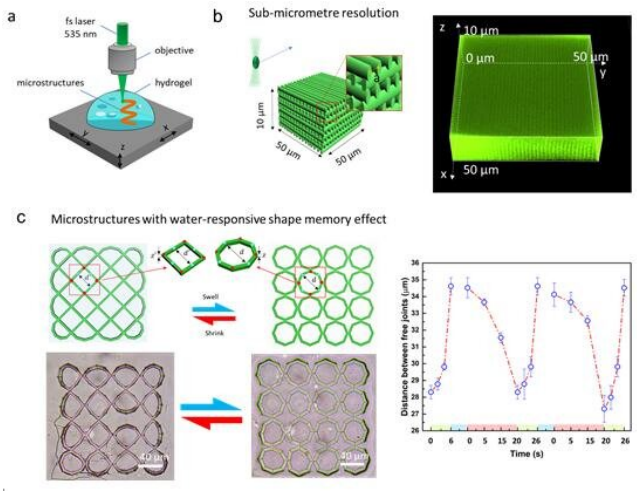
Two-photon polymerization of PEGda hydrogel microstructure

21 January 2021



a, An illustrative image for a typical three-dimensional direct laser writing process. A femoto second later was tightly focused into a photosensitive material (hydrogel in our case). b, Fabrication result of 3D woodpile microstructure. The woodpile structure was imaged under reflective mode in a Nikon confocal microscope, and the 3D feature and the sub-micrometer resolution was clearly demonstrated. c, Fabrication and characterization of a microstructure with water-responsive shape memory effect. When the microenvironment is filled with water, the microstructure will swell into octagons due to its mechanical property. When the water content in the environment drops (evaporates), the octagons will shrink into squares. Due to the robustness of the material, this shape memory effect process can be reversed for several times at micrometer scale. Credit: Haoyi Yu, Haibo Ding, Qiming Zhang, Zhongze Gu, and Min Gu

The fabrication of shape-memory hydrogel scaffolds not only requires biocompatibility, micrometer resolution, high mechanical strength, but also requires a low polymerisation threshold in high-water content environment to incorporate microstructures with biological tissues. Towards this goal, scientists from China and Australia developed a new hydrogel formula that full fills this goal and demonstrated water-responsive structures with a shape-memory effect at a micrometer scale. This work is of importance for the development future reversible microdevices in biomedical engineering.

Three-dimensional (3-D) direct laser writing (DLW) based on two-photon polymerisation (TPP) is an advanced technology for fabricating precise 3-D hydrogel micro- and nanostructures for applications in biomedical engineering. Particularly, the use of visible lasers for the 3-D DLW of hydrogels is advantageous because it enables high fabrication resolution and promotes wound healing. Polyethylene glycol diacrylate (PEGda) has been widely used in TPP fabrication owing to its high biocompatibility. However, the high laser power required in the 3-D DLW of PEGda microstructures using a visible laser in a high-water-content environment limits its applications to only those below the biological laser power safety level.

In a new paper published in *Light Advanced Manufacturing*, a team of scientists, led by Professor Min Gu from from the Centre for Artificial-Intelligence Nanophotonics, University of Shanghai for Science and Technology,and the State Key Laboratory of Bioelectronics, Southeast University, China, and co-workers from the Laboratory of Artificial-Intelligence Nanophotonics, RMIT University, Australia, have developed a formula for a TPP hydrogel based on 2-hydroxy-2-methylpropiophenone (HMPP) and PEGda was developed for the fabrication of 3-D DLW microstructures at a low threshold power (0.1 nJ per laser pulse at a writing speed of 10 ?m·s^{-1}) in a high-water-content environment (up to 79%) using a green laser beam (535 nm).

Based on these outstanding properties of this hydrogel formula, a novel shape-memory microstructure 'octagons to squares' was designed and fabricated in a highwater content environment. Due to the responsive effect of hydrogel to water,

the the microstructure can change its shape along with the water content change in the micro-environment. Besides, the microstructure also demonstrated a very robust reversibility. The hydrogel formula and the shape-memory microstructure can support various kinds of applications in biomedical engineering. These scientists summarize the principle that the new photosensitive material is developed upon:

"PEGda is a very typical hydrogel materials and have been widely used in numerous applications in biomedical engineering, due to its high biocompatibility and nontoxicity to biological tissues. The photo initiator: 2-hydroxy-2-methylpropiophenone (HMPP) is one kind of very commonly used photo-initiator for single photon ultra-violet light lithgraphy but has not been used for visible light sources (green) in TPP based on 3-D DLW. We chose this material because it can satisfy the needs for future 3-D DLW: sub-micrometer fabrication resolution; strong mechanical stability; high polymerization ratio in high water content environment, which will reduce the laser threshold power needed for TPP fabrication; and supports visible light wavelength as the working laser source."

"The presented material can be used to fabricate various microstructures using 3-D DLW with a low power. And it will be used in a wide range of application scenarios, for instance, we can fabricate microstructures with biological tissue on site, and then control shapes of the microstructure using the shape-memory effect. This breakthrough could open a new venue for future reversible microstructures in controlling biological tissues and would be a useful platform for scientists to study the behaviors and functions of biological tissues." the scientists forecast.

More information: Haoyi Yu et al, Three-Dimensional Direct Laser Writing of PEGda Hydrogel Microstructures with Low Threshold Power using a Green Laser Beam, *Light: Advanced Manufacturing* (2021). DOI: 10.37188/lam.2021.003

Provided by Chinese Academy of Sciences