3D Graytone Printing for Thermo-Mechanical and Optical Applications

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Micro-actuators are of rising interest for their potential applications to microsurgery and micro-robotics [1,2]. We designed two different thermoelastic metamaterial devices, shown in Fig. 1, which provide fundamental mechanical rotation and translation. Our design is based on thermally actuated bilayers. The coupled materials exhibit distinct thermal expansion coefficients and Young's modulus. We use direct laser-writing (DLW) lithography based on two-photon absorption to fabricate the metamaterial structure, using a femtosecond pulsed laser. Samples are built from a single material (Ip-Dip resin) using single-step lithography. However, each part of the bilayer was exposed to a different laser power. We printed the less expansive component with a laser power of 10 mW and the highest expansive component with a laser power of 9 mW. The power combination is selected by taking into account the shape and stability of the structure. The engineered structures show good repeatability and perform in accordance with the theoretical design.

Although, realizing free-form and transformation optical components, volume holograms, point-to-point photonic wire-bonding between photonic components, and integrated photonics circuits [3, 4] in general has significantly gained momentum through 3D additive fabrication based on two-photon polymerization. In this work, we realized connection topologies for efficient signal distribution using fractal-branching as well as spatial-filtering according to Haar-filters [3] fabricating waveguides with a polymer-core without cladding, i.e., with a large refractive index difference.

Moreover, we developed a new technology for additive fabrication of integrated 3D step-index photonic waveguides [5] by combining high-resolution direct-laser writing with one photon blanket polymerization, shown in Fig. 2, which accelerates fabrication ten-fold. We achieve low propagation losses of -1.36 dB/mm, close to cm-scale integrated circuits and demonstrate single-mode waveguides and splitters.

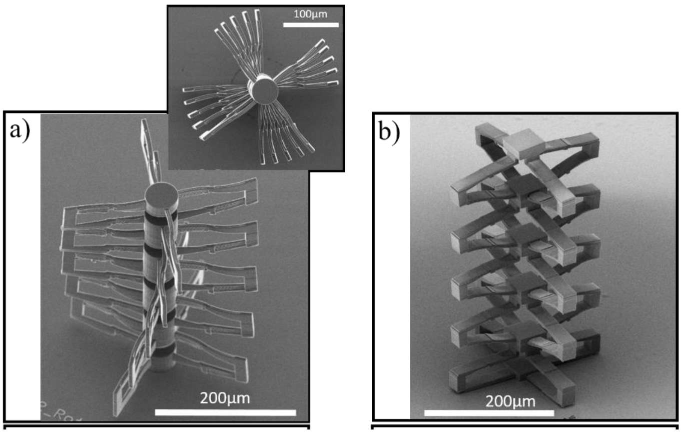

Figure 1: Scanning electron microscopy (SEM) of the polymer lattices fabricated by DLW for rotational (a) and translational (b) structures.

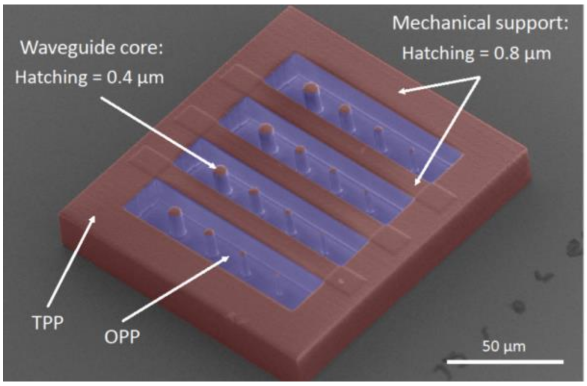

Figure 2: Combining one-photon polymerization (**OPP**) and **TPP** (shown at right) in order to accelerate the fabrication of large photonic circuits, while simultaneously improving the performance of the waveguides.

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