FABRICATION AND CHARACTERIZATION OF OPAQUE 3D MICROSTRUCTURES

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3D laser direct writing has been employed as a technology of rapidly increasing importance [1], finding its applications in various fields, especially in micro-optics [2], with a growing demand for transparent and opaque three dimensional microstructures, where opaque microelements play essential roles, especially for stray light suppression, beam blocking and beam absorption. While Two Photon Polymerization (TPP) enables the fabrication of complex, high resolution free-form 3D structures [3], the construction of opaque microstructures remains challenging, due to the strong absorption of opaque photoresists in the UV to near-infrared spectral regime [4]. Moreover, most of the previous demonstrations of opaque microstructures have been achieved using organic photoresists, which limit the mechanical and thermal performance of the fabricated components [4,5].

In this work, truly opaque and inorganic microstructures are fabricated using a hybrid organic-inorganic photoresist as the precursor material [6], providing a viable alternative to organic precursors, with improved chemical inertness and mechanical robustness. The hybrid resist is optically transparent during fabrication, enabling efficient photopolymerization, which turns opaque only after thermal post-processing. Using femtosecond laser-based TPP, the smallest feature size of 755 nm was achieved with the hybrid resist. The fabricated structures were subjected to pyrolysis at 1400^{o}C, in an inert nitrogen atmosphere to remove the organic fraction of the structures, yielding opaque and ceramic microstructures, including solid cubes of dimensions 80 x 80 x 30 μm^3 as shown in Fig 1b.

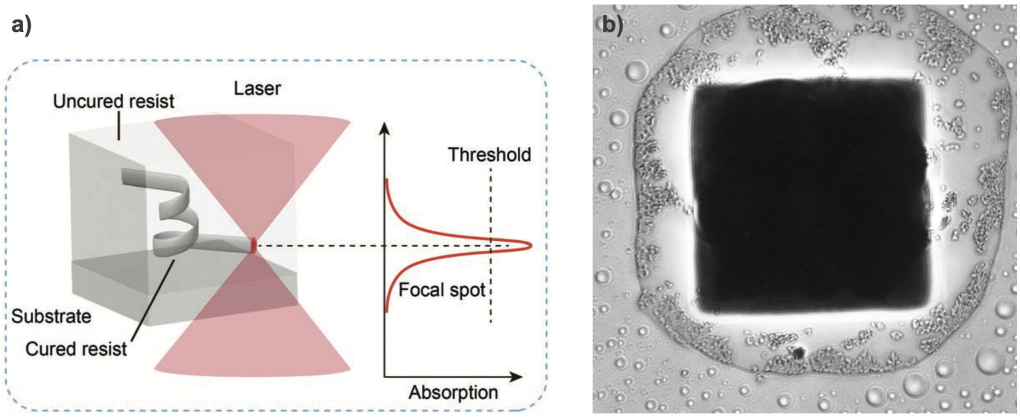

Fig. 1. (a) Process of two photon polymerization, adopted from [3]. (b) Opaque microstructure experimentally observed under transmission microscope

Systematic optimization of laser parameters was performed through the fabrication of an array of test structures, with varying laser power and scanning velocity, enabling the construction of robust free-form microstructures with sub-micrometer feature sizes. Post pyrolysis characterization of structures confirmed the formation of opaque and inorganic microstructures which were further analyzed for opaqueness, surface roughness, structure composition, and shrinkage behavior. These results demonstrate a versatile route for producing opaque and ceramic microstructures using the hybrid organic-inorganic precursor, combined with the high geometric freedom and resolution provided by TPP. They also highlight the potential applications of such structures especially in micro-optics, which require opaque and thermally stable microcomponents such as apertures, beam blockers and absorbers at the microscale.

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