Compensating for distortions in architected microstructures 3D printed by two-photon polymerization

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Abstract

Two-photon polymerization (2PP) is an additive manufacturing technique exploiting two-photon-absorption-induced photo-polymerization to fabricate three-dimensional complex geometries at the micrometric scale. Applications span various fields from photonics to bio-scaffolds to microrobotics. Unfortunately, even when using ultra-low-shrinkage polymeric resins, distortions occur, which compromises the dimensional fidelity and expected performance of the printed structures. In nano-mechanics, this lack of fidelity results in discrepancies between experimental results and numerical simulations and, so far, the most widely adopted workaround entails consideration of the distorted geometry rather than the intended one as an input for simulation. This work aims at compensating for such distortions so that the printed objects match the initially intended geometries. Hence, the physical sources of the distortions arising in 2PP 3D-printed structures are carefully examined. A primary distortion (due to a refractive index mismatch between the immersion medium of the objective and the polymeric resin) causes an overall stretching, whereas a secondary distortion (related to a saturating voxel growth during hatching and slicing) leads to an additional thickness on individual features within a structure. Two prints are thus devised to evaluate the stretching factor and saturated voxel height, and a straightforward technique is proposed to pre-compensate for distortions in the initial design of a structure. Finally, this methodology is shown to successfully eliminate all distortions in complex structures such as lattices and triply periodic minimal surfaces (TPMS).

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