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High-Resolution Top-Down SLA of Viscous Functional Polymers for Active Biomedical Micro-Devices

Antun Jakob Marić[1]

[1] Faculty of Mechanical Engineering and Naval Architecture, University of Zagreb, Croatia. antun@3dtech.hr

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Extended Abstract

Abstract

Additive manufacturing of functional polymer micro-devices is limited by the constraints of conventional vat photopolymerization systems, particularly when processing highly viscous resins and fabricating thin-walled, compliant architectures. Common challenges—including unstable recoating, layer misalignment, and separation-induced deformation—can compromise geometric fidelity and, for active materials such as shape-memory polymers (SMPs), alter the functional response defined by the as-printed microstructure. This work presents a novel top-down stereolithography (SLA) platform designed to overcome these mechano-manufacturing limitations through printer architecture and process control. The system integrates a newly developed viscosity-independent resin alignment mechanism with a programmable high-resolution light unit, enabling repeatable layer formation and sub-10 μm XY resolution across a wide range of resin rheologies. This configuration allows stable fabrication of thin-walled, architected micro-devices that are difficult or impossible to manufacture using standard bottom-up SLA configurations. A fully integrated digital workflow provides precise control over exposure history, layer thickness, and curing profiles. Process performance was evaluated by fabricating shape-memory polymer (SMP) micro-stents and representative micro-architected test structures. The results demonstrate improved dimensional fidelity, reduced interlayer variability, and consistent functional activation at the device scale. The study highlights the strong coupling between printer design, process-induced constraints, and the manufacturability and functional

reliability of active polymer micro-devices. The presented platform extends the applicability of SLA to viscous functional materials, providing a scalable manufacturing route for next-generation biomedical micro-devices whose performance is governed by architected mechanics.

Keywords:

Additive manufacturing Top-down stereolithography Shape-memory polymers Micro-architected structures