Functional Two-Photon Multi-Materials 3D-Printing of Lateral Micro-Optics

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This study utilizes two-photon polymerization (2PP) and in situ material exchange[1] being ideal for complex micro-optics and lens systems with a wide range of optical characteristics[2]. The technology is highly beneficial for applications that require smooth integration of several materials. The technology provides accurate alignment, fast printing of multiple materials, the ability to work with different substrates, and improved 3D specifications. This enhances the process of additive rapid prototyping and small-scale production. During prior studies, the utilization of 2PP 3D laser printing showcased the reliable production of microlenses with exceptionally smooth surfaces (< 10 nm RMS) and complex geometries. Multi-material systems improve the performance of broadband optical lenses, affecting factors such as focus size beam scanning ability, and performance for non-central illumination. Our current work introduces an innovative method for lateral multi-material microlens printing. Leveraging a novel printhead concept, the open-fluidic system allows lateral lens orientation and in-situ material exchange on large-area substrates (Figure 1a). Lateral microlenses, distinct from vertical counterparts, offer unique advantages for optics and photonics integration. This approach seamlessly integrates microlenses into final products like PCB chips and fiber optics, showcasing its impact on advanced optical integration.

We employed a pre-existing optic design consisting of three components (Figure 1b).[3] The peripheral lenslets were made from customized PETA printing material, while the central lenslets was made from dye doped PETA. The utilization of conventional Dip-in Laser Lithography (DiLL) technology (Nanoscribe), in conjunction with our printhead (HETEROMERGE), facilitated instantaneous modifications to the material throughout the writing procedure. The central lenslet was printed first, while the peripheral lenslets were printed following the material exchange. For high exchange efficiency, the material flow was orthogonal to the optical axis. The technology allows for exact control of polymerization via the writing parameters. One PGMEA development step was done for the complete lens stack. It was then characterized by different methods, including optical, fluorescence, and scanning electron microscopy (SEM) imaging (Figure 1c). In conclusion, we demonstrated the versatility of printing optics using a novel in-situ material exchange within commercial 2PP 3D printing system.

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[1] R. Kirchner, Y. Yu, M. H. Wong, S. Toukabri, and J. Knorr, in *Proc. SPIE PC12412, 2023*, PC1241206
[2] M. Schmid, S. Thiele, R. Kirchner, and H. Giessen (submittted)
[3] https://www.thorlabs.de/thorproduct.cfm?partnumber=TRH064-010-A

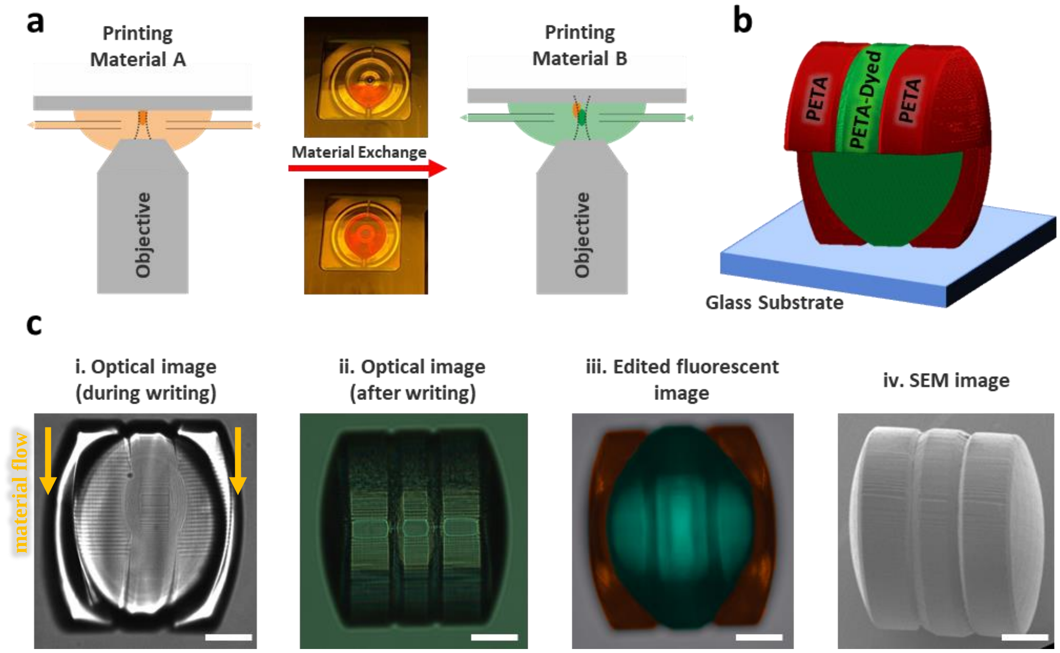

Figure 1. Illustration of the fabrication of lateral microlenses using various materials in a single-print process. a) Schematic representation of in-situ material exchange through the HETEROMERGE printhead during writing, b) Schematic depicting the microlens comprising three lens components (lenslets), c) Characterization of the final prototype including (i) optical image during writing along with material flow indications, (ii) optical microscopy image, (iii) fluorescent microscopy of different lens components under different filters, and (iv) Scanning Electron Microscopy (SEM) image. Scale bar 50µm.