3D Printing of Microstructured Metallic Thin-Films

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Metal deposition is crucial to semiconductor manufacturing of electronic and optical devices. Traditionally, physical vapor deposition (PVD) is widely used to produce simple patterned metal film; however, PVD requires a long time due to its vacuum deposition nature. In comparison, additive manufacturing (AM) can significantly lower production time and cost. Yet, current AM metal deposition techniques require high-temperature metal powder fusion and therefore are not compatible with all processes. Previously, we have developed a polymer-assisted photochemical deposition (PPD), which prints continuous metal structures directly out of aqueous precursors under programmed ultraviolet (UV) illuminations in ambient conditions. Here, metal-printing precursor solutions are made from metal salt, reducing agent, and a ligand-rich polymer. Under UV illumination, the metal salt is reduced to into metal nanoparticles (NPs) in solution, and the polymer acts as a binding agent to attach the metal NPs and bring them to the substrate. Uniquely, by adjusting the patterns and doses of the digital light projector (DLP), micrometer-scale structures have been successfully produced[1,2].

To further improve the printing uniformity and resolution, we have built a new optical setup to correct lens distortion issues. The system is designed to have a theoretical magnification of 0.09, allowing us to use stronger objectives (20x or 100x) for finer print resolution. To test the printing resolution, we first exposed and developed photoresist with a microstructured stripe pattern. Further, a layer of PPD-printed silver film (~20 nm thick) was deposited on top of the photoresist patterns. Then, the photoresist was stripped away, leaving printed silver structures on the substrate. The deposited geometries have shown print resolutions of 0.6 – 1.6 um/px utilizing a 10x objective at a deposition rate of 0.5 - 1 nm/min. We expect to demonstrate the feasibility of our new optical setup to produce micrometer-scale metal geometries with a variety of shapes for color display.

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(1) 1 Zhi Zhao *, Jing Bai, Yu Yao, and Chao Wang*, "Printing Continuous Metal Structures via Polymer-Assisted Photochemical Deposition," *Materials Today,* vol. 37, pp. 10-17, 2020.

(2) Shinhyuk Choi, Zhi Zhao, Jiawei Zuo, Hossain Mansur Resalat Faruque, Yu Yao, and Chao Wang*, "Structural color printing via polymer-assisted photochemical deposition," *Light: Science & Application*, vol. 11, pp. 84, 2022.

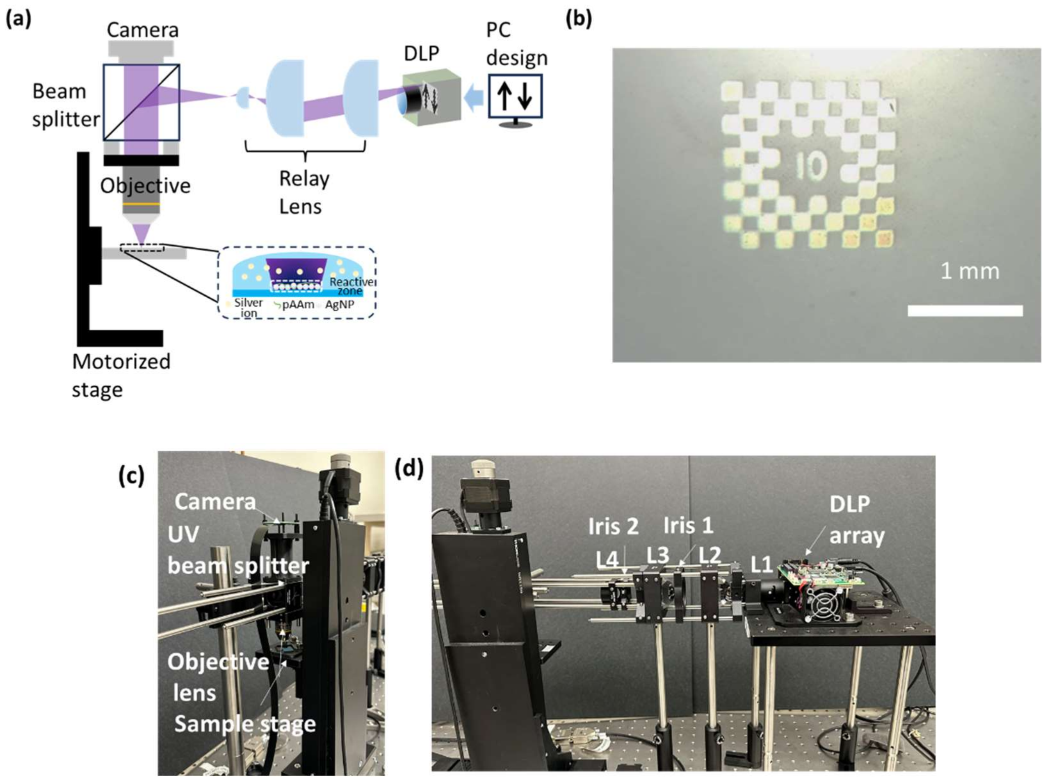

Figure 1 – Printing setup and optical light path. (a) Optical light path from digital light projector (DLP) through relay lenses to beam splitter and objective. (b) Silver print example demonstrating complexity on borosilicate substrate. (c-d) Optical image of printing setup.

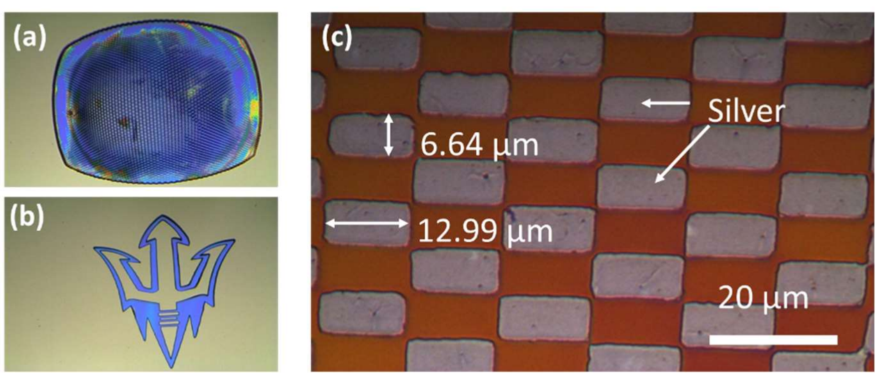

Figure 2 – Optical images of printed patterns. (a-b) Patterns in photoresist after exposure from DLP setup. (c) Silver microstructures of checkerboard design after photoresist stripping on silicon substrate. Overall print area: ~600 um in height and ~900 um in width.