Single-digit-micron-resolution Continuous Liquid Interface Production (CLIP) 3D Print Technology

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Continuous Liquid Interface Printing (CLIP) 3D print technology is a promising additive manufacturing technique for manufacturing high-resolution micro-architectures with rapid print speed and phenomenal print quality which is suitable for a wide range of applications, including translational medicine applications, microneedles, optics, micro electro mechanical systems (MEMS), and microelectronics. Here, we present the development of a single-digit-micron-resolution 3D printer using the CLIP technology. The custom 3D printer hardware consists of projection optics components, an oxygen permeable window with a resin vat, a high-precision vertical translation stage that translates the build platform, and a real-time projection monitoring sub-system for focusing and monitoring the UV projection. Moreover, the control of the printing process is managed by a C++-based custom software application. With the abovementioned components, we have built a printer with projection pixel sizes of 3.7 and 1.5 µm. Amongst the high-resolution 3D printing technologies, it is generally difficult to achieve a high printing resolution while maintaining a high-print speed. Therefore, we have assessed the 3D CLIP printing performance regarding its print resolution and speed. With a sample design, the printing time difference between the custom CLIP-based 3D printer and a commercial two photon polymerization (TPP) printer was strikingly around 105 and this significantly highlights the print speed and ultimately the scalability of the CLIP technology. 2D patterns including lines and holes were designed to characterize and understand the high-resolution printability of our single-digit-micron-resolution CLIP 3D printer. The designed length scales of tested line patterns range from 135 to 4.5 µm. It is observed that the print accuracy of the line patterns is optimal at length scales at or above 6 µm, with the print dimension degrading below this value. The designed length scale of tested hole patterns ranges from 45 µm to 18 µm. It is observed that the print accuracy of the hole patterns is optimal at 22.5 µm and it degrades when printing at a smaller length scale shown qualitatively and quantitatively. Taken together, the single-digit-micron-resolution 3D CLIP printer was achieved with design for projection optics system, an in-line focusing system, and a software-controlled printing process and its print performance showed significantly fast print compared to other high-resolution printers while maintaining the high-resolution capability.

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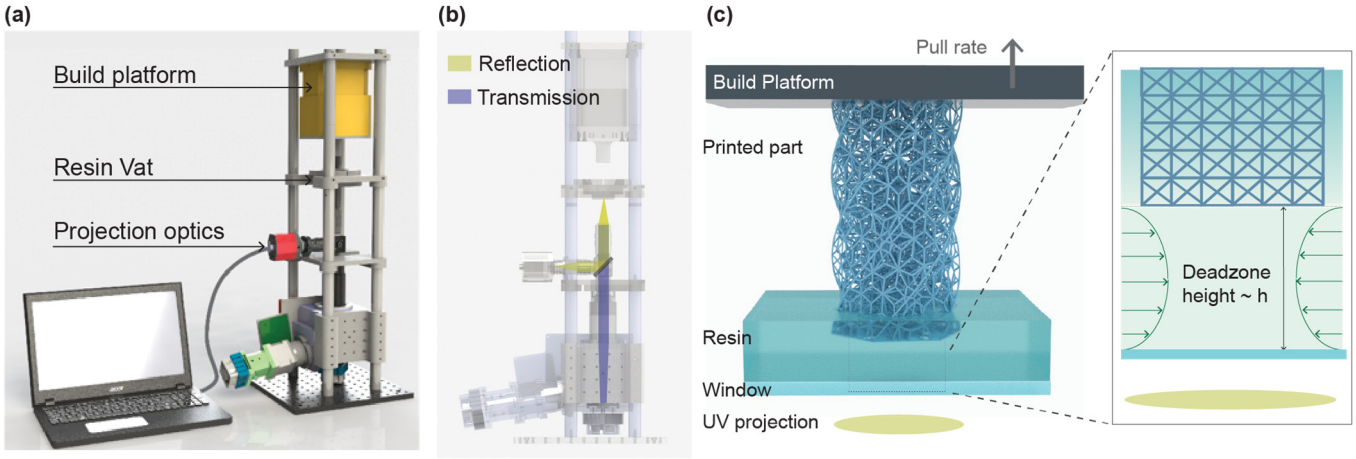

Fig. 1 Single-digit-micron-resolution continuous liquid interface production (CLIP)-based 3D printer (a) Schematic of the single-digit-micron-resolution CLIP-based 3D printer, (b) Projection optics system includes a UV camera and a computer for real-time monitoring of the projected images and enabling the focal plane fine-adjustment, and (c) CLIP process contains an oxygen-permeable window; the permeated oxygen forms a thin layer of dead-zone above the window, where photopolymerization is inhibited. The dead-zone allows a continuous 3D print