The Delicate Interplay Between Light, Interfaces and Design: The Complex Dance that Allows 3D Printing to Scale to Manufacturing

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Abstract
The production of polymeric products relies largely on age-old molding techniques. In this talk, I will describe a breakthrough in additive manufacturing—3D printing—referred to as Continuous Liquid Interface Production (CLIP) technology (*Science* **2015**). CLIP, and its recently introduced cousin injection CLIP (iCLIP; *Science Advances* **2022;** *PNAS* **2024**), embody a convergence of advances in software, hardware, and materials to bring the digital revolution to the design and manufacturing of polymeric products. CLIP uses software-controlled chemistry to produce commercial quality parts rapidly and at scale by capitalizing on the principle of oxygen-inhibited photopolymerization to generate a continual liquid interface of uncured resin between a forming part and a printer's exposure window. Instead of printing layer-by-layer, this allows layerless parts to 'grow' from a pool of resin, formed by light. Compatible with a wide range of polymers, CLIP opens major opportunities for innovative products across diverse industries. Previously unmakeable products are already manufactured at scale with CLIP, including the large-scale production of running shoes by Adidas (Futurecraft 4D); mass-customized football helmets by Riddell; the world's first FDA-approved 3D printed dentures; and numerous parts in automotive, consumer electronics, and medicine. At Stanford, we are pursuing new advances including digital therapeutic devices, new multi-material printing approaches, and the design of a high-resolution printer to advance technologies in the microelectronics, electrodes for batteries and electrocatalysis, intradermal drug/vaccine delivery, and pain-free, minimally-invasive approaches for interstitial fluid sampling to enable low-cost liquid biopsies.