Ceramic Vat Photopolymerization: A Multiscale Perspective

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Abstract

Vat photopolymerization (VPP) of ceramics has garnered considerable attention owing to its exceptional capability to fabricate components with intricate and complex geometries. Nevertheless, the pronounced scale-dependent effects in ceramic VPP give rise to a widespread yet poorly understood phenomenon: as-printed green bodies frequently fail to withstand subsequent thermal treatment, i.e., "printable-but-not-sinterable." This dilemma has severely impeded the advancement of ceramic VPP. These issues stem fundamentally from the difficulty in fully understanding and precisely regulating the complex multiphysics coupling phenomena induced by structural features. In single-step processing scenarios, forming quality and precision are governed by the intricate interplay of multiple factors. In multi-stage integrated manufacturing workflows, imperfections originating from upstream processes tend to accumulate and be amplified in subsequent steps. Furthermore, certain geometrical features are inherently incompatible with both shaping and thermal post-processing, rendering the resultant components highly susceptible to warpage, cracking, and loss of dimensional accuracy. This paper reviews multiscale structural forming in ceramic VPP additive manufacturing, focusing on multiphysics coupling mechanisms and their effects on forming quality. To address challenges arising from the long process chain and multiphysics coupling, we propose a holistic process-chain coordination strategy with four-level optimization, guiding the controllable fabrication of high-quality multiscale ceramic components.

Note: Figure translations are in progress. See original paper for figures.