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PROCEEDINGS

Developing Two-Wavelength Digital Light Processing-Based Vat Photopolymerization for Multi-Material/High-Resolution 3D Printing

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ABSTRACT

Vat photopolymerization (VPP) among other additive manufacturing (AM) processes have a great potential to rapidly print complex 3D components out of a matrix of photo-curable resin. Current VPP processes utilize single-wavelength light exposure, imposing limitations on print speed and throughput, especially in multi-material AM. This is attributed to delays in material switch-over mechanisms. Additionally, the resolution of conventional single-wavelength VPP is constrained by over-curing. Despite ongoing efforts and progress in VPP, there remains a need for effective approaches to address these persistent issues.

In this work, we report our development of two-wavelength digital light processing-based VPP processes, denoted as $VPP_{2\lambda}$. Generally, the $VPP_{2\lambda}$ process involves concurrent light irradiation at two different wavelengths, inducing distinct photochemical reactions. This allows for spatial modulation of material processing, achieving localized composition and properties. Our research lab is investigating two types of $VPP_{2\lambda}$ processes tailored for two critical application scenarios: 1) rapid, continuous, and complexly architected multi-material VPP; and 2) high-accuracy, high-resolution precision VPP. The first process, specifically designed for multi-material (Mm) AM, is referred to as two-wavelength selective VPP ($MmVPP_{2\lambda}$). $MmVPP_{2\lambda}$ employs two-wavelength light patterns to selectively cure different material components at different locations within each layer. This enables the continuous construction of real 3D multi-material parts without the need to change vats. The second process, termed photoinhibition-aided $VPP_{2\lambda}$ ($PinVPP_{2\lambda}$), utilizes two-wavelength exposure masks for initiating and inhibiting polymerization. $PinVPP_{2\lambda}$ is designed to address both vertical and lateral over-curing issues, thereby enhancing not only print speed but also three-dimensional accuracy, resolution, and precision.

This work presents fundamental and experimental research aimed at establishing the feasibility and enhancing the performance of the $MmVPP_{2\lambda}$ and $PinVPP_{2\lambda}$ processes. Physics-based data-driven modeling methods [1; 2] and an instrumented platform for in-situ monitoring [3; 4] of these emerging VPP processes have been developed. These tools offer spatiotemporally resolved insights into the unique and more complex process dynamics arising from the two-wavelength irradiance and the concurrent occurrence of two distinct reactions, along with their interactions. The new $VPP_{2\lambda}$ process-structure-property relations are quantified using machine learning techniques applied to data from model simulations, in-situ monitoring, and ex-situ characterizations. Our preliminary results [5] demonstrate the potential advantage of the futuristic multi-wavelength VPP printing. This research is poised not only to advance VPP AM but also to contribute to the development and application of photochemistry and polymers. Furthermore, it holds promise for novel applications in multi-material 3D printing, including metamaterials, soft robots, and flexible electronics.

KEYWORDS

Vat photopolymerization; wavelength selective; photo inhibition; digital light processing; multi-material 3D printing; over-curing

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Xiayun Zhao has a pending patent with US Application No.: 17/437,343. International Application No.: PCT/US20/21727. The reported photoinhibition aided vat photopolymerization-based additive manufacturing systems and methods along with some of the sdiscussions have been filed within the pending patent above.

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