A Novel 3D-Printing Methodology of Inverse Opals from Free-Standing Crystalline Structures for Next-Generation Optical Sensing

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Inverse opals (IOs) are currently limited to planar, discrete patterns. Although they boast extraordinary applications, knowledge of their properties on a 3D scale is limited and no methods exist to print IOs directly from free-standing, crystalline templates. In this project, we developed of a novel 3D printing methodology for inverse opal structures from crystalline templates. Using direct-write free-form assembly, factors involving assembly, infiltration, cross-linking, and etching were explored to print inverse opal features and retain template structures. A novel vacuum infiltration technique was created to enhance silk infiltration in crystalline templates, and a novel methanol vapor cross-linking method was developed to maximize structural retention in cross-linking. The intermediate printing techniques were applied in parallel with optimized parameters to create fully-infiltrated, free-standing 3D inverse opal structures. Optical and SEM images were taken after each printing stage to analyze target factors such as structural retention, feature homogeneity, and crystalline arrangements. Optimized structures were functionalized into heavy metal cation sensors using fluorescence-quenching mechanisms, providing the first demonstration of inverse opal printing and functionalization on a 3D scale. Successful functionalization reveals that the structure can be used to detect hundreds of other contaminants in water with respect to doping material. The results reveal a promising path to incorporate the technique into a breadth of applications including drug release platforms, biosensors, and energy storing devices.

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