Name(s)

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Project Number

S0613

Project Title

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

Abstract

Objectives

Inverse opals (IOs) are currently limited to planar, discrete patterns. Although they boast promising applications, knowledge of their properties on a 3D scale is limited and no methods exist to print IOs directly from free-standing, crystalline templates. The three main objectives of this research are: 1) Characterize and study key factors related to the five-step 3D printing methodology for silk IOs; 2) Apply this understanding to novel techniques that enhance cross-linking and infiltration; 3) Functionalize optimized 3D IO structures into metal cation sensors to demonstrate biosensing applications.

Methods

Direct-write free-form assembly was used to assemble crystalline templates. Mechanical motors positioned with optical cameras controlled a lowering, heat-substrate stage. An upper syringe platform dispensed the colloidal solution onto a silicon wafer. The crystalline templates were infiltrated in various silk-water solutions, cross-linked in methanol, and etched in toluene in aluminum pans under a fume hood. A dessicator was used to facilitate vacuum infiltration and methanol vapor cross-linking. Optical and SEM images were taken after each printing stage to analyze target properties such as structural retention, feature homogeneity, and crystalline arrangements. After quantum dot doping, the functionalized towers were exposed to toxic copper chloride-water drops to observe fluorescent detection.

Results

Optimal parameters in assembly, infiltration, cross-linking, and etching were determined. 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 optimized structures displayed target properties, and the doped structures successfully detected copper chloride at toxic levels in water.

Conclusions

We have extended IO applications into practical, 3D scales by developing a method to print directly from arbitrary 3D crystalline structures. The developed techniques can be applied to basic materials science research for cross-linking fragile materials and enhancing infiltration. The results reveal a promising path to incorporate the printing methodology into a breadth of scientific fields. Successful functionalization reveals that the structure can be used to detect hundreds of other contaminants in water with respective doping.

Summary Statement

I developed a novel 3D printing methodology for inverse opals, features with extraordinary applications in biology, chemistry, mechanics, and demonstrated a new form of optical sensing using these structures through functionalization.

Help Received

Mr. Alvin Tan at the MIT Mechanosynthesis group trained me on using equipment, operating optical microscopes, and performing basic material science procedures such as spin-coating. He took scanning electron microscope images for me, answered questions, and assisted in interpreting results.