3D printing for porous membrane integrated miniaturized fluidic devices

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Abstract:

3D printing for integrating porous materials into fluidic devices has evolved into a new fabrication technique to implement functionalities like selective membranes to adsorbents, stationary phases, catalysts, and cell scaffolds-related materials. However, the lack of ability to control and alter the structural (pore morphology and porosity) and chemical properties of the 3D printed porous separation materials is still a challenge. Here DLP 3D printing combines with polymerization induced phase separation has been used to directly 3D print submicron and nanoporous (<1 μm) membranes. The effects printing parameters such as Individual layer thickness, exposure time, number of layers have been studied to fine control the morphology (pore features) and bulk (porosity, density) characteristics enabling the pore sizes from 100 nm to 1 μm. Finally, the fluidic devices developed using a print-pause-print approach have been used for electrokinetic DNA extraction. Furthermore, a novel technique for simultaneous printing dense and porous structures with finely controlled porous features in all three dimensions using a single hybrid ink has been presented. Grayscale digital light projection (G-DLP) 3D printing of a hybrid polymerization induced phase separation (PIPS) ink is introduced to print hierarchical porous structures. The structural properties of the printed material can be controlled from effectively dense to a porous material with interconnected pores up to 250 nm within an individual print layer using a single ink. Heterostructures with physically dense areas are formed contiguous to intrinsically porous domains (porosity 23%) within a single layer by using greyscale masks. Materials with skeletal densities spanning from 1.01 to 1.21 g cm^{-3} were found to allow for highly controlled wicking rates from complete diffusion blockage up to 4.5 mm h^{-1}, and the novel functionally integrated fluidic devices were applied for elemental metal sensing of iron for soil. This approach demonstrates a single-step fabrication of functionally graded porous materials (FGM) within a single layer, which can act as tunable membranes or adsorbents for environmental and healthcare applications.

Keywords: 3D printing, Porous membranes, DNA extraction, Functionally graded porous materials