Developing a novel three-dimensional printing approach for polyamide-based thin-film composite membranes by electrospray technique

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Abstract:

Increased water scarcity requires improved membranes for desalination and water reuse. Three-dimensional (3D) printing has the potential to fabricate next-generation membranes with customized architectures, morphologies, and water/solute selectivity. However, the current state-of-the-art printed polyamide (PA)-based thin film composite (TFC) membranes by the electrospray technique have only adopted layer-by-layer fabrication. The stochastic reaction between monomer microdroplets in the electrospray process has left the production of lateral features uncontrollable and the membrane formation mechanisms uncertain. In our study, we propose a novel approach to printing the PA thin films using the electrospray technique. We found that, by modifying the ultrafiltration substrate with polydopamine, the substrate can be better wetted, leaving a more uniform aqueous film on the substrate surface. Taking advantage of this phenomenon, trimesoyl chloride (TMC) in the organic phase was electrosprayed onto the m-phenylenediamine imbibed aqueous phase on the surface of the modified substrate. With this approach, PA-based TFC membranes with NaCl rejection of 97% and water permeance of ~1 $L \cdot m^{-2} \cdot h^{-1} \cdot bar^{-1}$ can be printed using only one scan, which has not been achieved by previous studies. We further studied the effect of electrospray distance on the printed membrane performance. Changing the electrospray distance can result in different electrohydrodynamics of the TMC solution, which can affect the PA morphology and performance. It was also found that when electrospray distance was at 1 cm, PA stripe patterns can be produced due to the use of the jet regime in the cone-jet mode of the electrospray. The width of PA stripes showed a linear relationship to the electrospray flowrate of the TMC solution. At a constant 5 mL/h TMC flowrate, the separation performance of the printed membranes can be tuned by changing the overlapping ratio (i.e., changing the nozzle moving speed) of the PA stripes. Our approach, for the first time, has demonstrated the use of the electrospray technique to produce lateral PA membrane features with tunable separation performance.

Keywords: electrospray technique, 3D printing, polyamide-based thin-film composite membranes, patterned membrane