Salt Permeation Mechanisms Through Inkjet Printed Charge Mosaic Membranes

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Abstract

Charge mosaic membranes are capable of separating dissolved salts from neutral molecules of comparable size. The ability of these membranes to facilitate the transport of the charged species is due to their unique microstructure, which consists of distinct positively-charged and negatively-charged domains that traverse the membrane thickness. Recently, we developed a method for producing charge mosaic membranes in a scalable manner by inkjet printing composite polymeric inks onto a structural template. Namely, mosaic patterns consisting of positively-charged, poly(diallyldimethylammonium chloride) and negatively-charged, poly(sodium 4-styrene sulfonate) domains were printed on polycarbonate track-etched (PCTE) membranes using a commercial inkjet printer. When tested in pressure-driven piezodialysis experiments, the charge mosaic membranes fabricated using this robust, reliable, and rapid method were able to enrich the concentration of potassium chloride in the permeate solution relative to the feed solution.

In order to guide the design and optimization of these charge mosaic membranes, a fundamental understanding of the salt permeation mechanisms through them is still needed. In this regard, inkjet printing is an attractive method for fabricating charge patterned membranes because it allows for facile control over the patterned membrane microstructure. This microstructure, in turn affects membrane performance. As such, in this study, we utilize inkjet printing to produce charge patterned membranes of varied composition (i.e., positively-charged, mosaic patterned, and negatively-charged) and quantify the salt permeability of the three membranes in diffusion cell experiments. The permeabilities of the membranes are characterized as a function of salt identity; potassium chloride (KCl), magnesium chloride ($MgCl_2$), potassium sulfate (Na_2SO_4), and magnesium sulfate ($MgSO_4$) are selected as solutes because they comprise of ions that cover a representative range of valence numbers. Additionally, the permeabilities of the membranes are quantified as a function of feed solution concentration. A simple theoretical framework capable of describing the trends in salt permeability through the charged membranes as a function of salt identity and concentration is detailed. Inkjet printing offers a straightforward and scalable route toward the design and fabrication of charge mosaic membranes that could find use in the myriad applications that rely on the rapid transport of charge solutes. Moreover, it enables the generation of fundamental insights regarding the mechanisms governing transport through charge-patterned membranes.