Manipulating Nanopore Selectivity in Lyotropic Liquid Crystal Polymer Nanofiltration Membranes for the Recovery of Targeted Organic Solutes

With the growing number of industries, there is an increased number of complex aqueous effluent streams in which there are both products and toxins. Membranes offer an energy efficient method to separate these various components, for example, products from toxins. One industrial example is the simultaneous concentration of glucose and removal of furfural from hydrolysis effluents before feeding the stream into a fermentation reactor for the production of 2nd-generation biofuels. However, current membrane fabrication methods limit the control on pore selectivity, especially at the nanopore scale (reverse osmosis and nanofiltration). A novel membrane material that offers an opportunity to manipulate pore character in a controlled fashion is the polymerized, nanoporous, bicontinuous cubic lyotropic liquid crystal (LLC) material recently developed by our research group, which is coated as the active top layer of a thin-film composite (TFC) membrane. This LLC polymer material has three distinct characteristics that enable the resulting TFC membrane to achieve high performance: (1) distinct pores on the size scale of 1 nm, (2) a more uniform pore size distribution due to its liquid crystalline nature, and (3) positively charged pore walls. Anions associate via Coulombic interactions to the positively charged pore walls and can be exchanged upon soaking the fabricated TFC membrane in a salt solution. By placing anions with different physical and chemical characteristics at the nanopore wall, it is possible to manipulate the pore character and effective size and thereby change the selectivity of the membrane. Anion-exchange using organosulfonates of varying bulk causes an increase the rejection of organic solutes in this membrane that is consistent with a reduction of the effective pore size from 1.4 $\pm$ 0.3 nm to 1.00 $\pm$ 0.08 nm. Current research is focused on exploring the degree to which the pore character may be manipulated as well as the possibility of limiting the most selective anion to the pore entrance such that hindrance to water transport is minimized throughout the rest of the pore, thereby increasing the flux. By correlating characterization of the material to observed filtration performance, we are able to contribute to the development of targeted solute selectivity via manipulation of the nanopores in these LLC materials.