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What Makes Aromatic Polyamide Membranes Superior: New Insights into Ion Transport and Membrane Structure

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Abstract

Polyamide composites are instrumental to modern desalination technology; however, reasons for the superior performance of polyamide membranes have been unclear. Models usually view membranes as an array of charged nanopores, however, observed discrepancies and inconsistencies call for more insights. Here ion conductance in polyamide membranes was analyzed using electrochemical impedance spectroscopy, focusing on the effects of salt type, concentration, and pH, which are compared with the conductance obtained for a dense linear polyamide Nomex® of similar superficial thickness. The results rule out the common view of polyamide membranes as a homogeneous or nanopore array and indicate that they essentially behave as thin films of Nomex. The salt exclusion in both materials is so strong that uptake of protons (rather than sodium) dominates membrane conductivity yielding a similar concentration-dependence. However, the conductivity of polyamide membranes is much higher and equivalent to sub-10 nm Nomex films. These findings are explained by the sponge-like structure of polyamide, containing voids separated by thin polymer films, which can be adequately modeled as 3D random resistor network. This unique structure, combining very dense (hence highly selective) and extremely thin (hence reasonably permeable) films supported within a ~100 nm porous layer is what enables exceptional performance of polyamide membranes.