Relationship of Diffusion of Water to Performance of Reverse Osmosis Desalination Membranes

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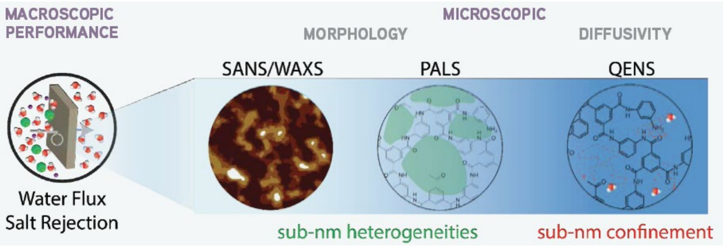
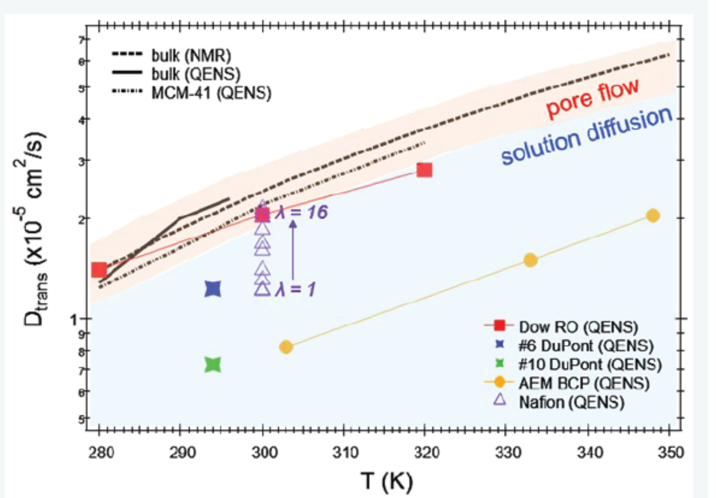
The scarcity of clean water is a world-wide crisis that threatens the environment and endangers human life. In recent years membrane-based desalination has proven to be an impactful approach for expanding access to fresh water. These reverse osmosis (RO) membranes typically have a thin crosslinked polyamide layer that selectively passes water while excluding dissolved salt. The primary mechanism for the complex water transport through these membranes is unresolved, especially in light of seemingly contradictory results regarding the correlation between crosslink density and water permeance. Specifically, membranes with lower crosslink density show an increase in salt passage but a decrease in water flow through the membrane even though the membranes swell considerably.

To resolve this paradox, researchers from the University of Michigan, Grand Valley State University, Dupont, and NIST performed quasi-elastic neutron scattering (QENS) measurements on HFBR to parameterize the motion of the water through membranes with different characteristics. The results show that water diffuses slowly in the membrane with the lowest crosslink density (#10) due, in part, to a higher concentration of polar free amines that interact with the water and impede its mobility. In contrast, the water easily diffuses through "pores" that are formed due to steric hindrance in the membrane with the highest density and highest salt rejection (#6). A comparison of these two membranes to other constructs validates the conclusion that a higher concentration of free amines leads to increased water impedance. Overall, this investigation reveals unexpected characteristics responsible for the highest performance in RO membranes.

V.J. Witherspoon, K. Ito, C.M. Snyder, M. Tyagi, T.B. Martin, P.A. Beaucage, R.C. Nieuwendaal, R.S. Vallery, D.W. Gidley, J.D. Wilbur,D. Welsh, C.M. Stafford, and C.L. Soles, Journal of Membrane Science **678**, 121670 (2023). DOI: 10.1016/j.memsci.2023.121670d





Translational diffusion coefficients of water measured by QENS in various environments, including DuPont membranes #6 and #10, a different PA membrane from Dow, and AEM membrane, and Nafion as a function of hydration in comparison to diffusion coefficients of water in bulk and porous MCM-41 substrates, as well to bulk water.