Controlling Membrane Morphology to Improve Performance

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Motivation

The microstructure, or morphology, of membranes determines properties including transport, rejection, and fouling resistance. However, this morphology is not well understood. Design of next-generation membranes requires understanding connections among chemistry, morphology, and transport.

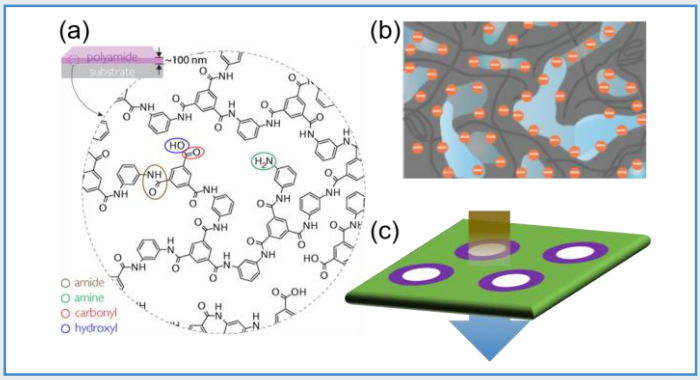

Fig. 1. *Membrane morphologies can vary from (a) dense[1] to (b) phase-separated to (c) discrete nanopores.*

Technological Challenges

Polymer-based membranes are used for water treatment and other applications. However, polymers are often disordered and change dynamically in water or other realistic environmental conditions. Polymers are composed predominantly of light elements, e.g. carbon, making it challenging to probe specific chemical components. Energy-tunable X-rays provide sensitivity to specific elements, and can reveal chemical bonding information and spatial information related to membrane morphology.

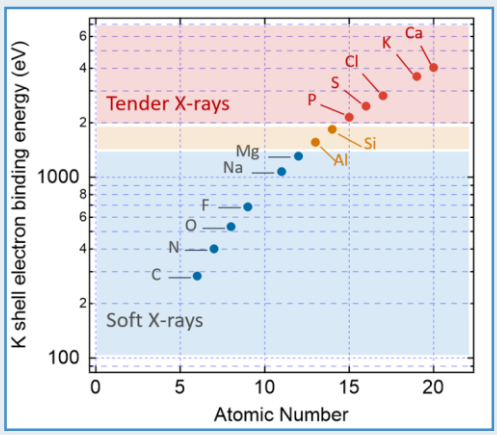

Fig. 2. *Elemental sensitivity of energy-tunable X-rays.*

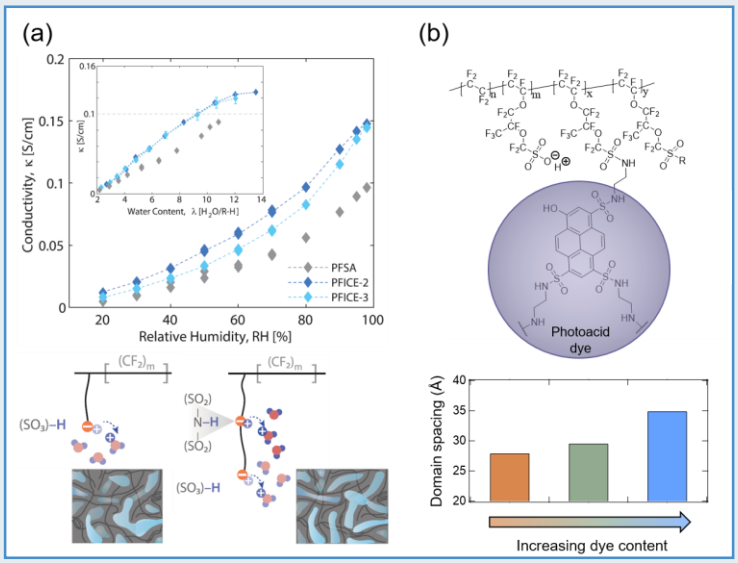

Fig. 3. *(a) Multi-acid side-chain ionomers show improved conductivity (blue data points) and a more ordered morphology.[2] (b) Domain spacing of dye-modified ionomers for solar-driven desalination can be tuned with dye content.[3]*

Research

Ion-conducting polymers (ionomers), are promising for solar-driven desalination and other applications. These materials form a phase-separated morphology (***Fig. 1b***) that defines the pathways for ion transport. X-ray characterization reveals that ionomers with multiple acidic groups on the side-chains exhibit more ordered membrane morphologies[2] (***Fig. 3a***) resulting in significant improvement of ion conductivity.

Ionomers can be functionalized with photoacid dyes to produce light-driven ion-pumping systems for solar-driven desalination. Attachment of these dyes systematically alters phase-separated morphology[3] (***Fig 3b***). Overall, understanding membrane morphology from molecular origins will enable design of next-generation membrane materials.

References

1. D. F. Sunday et al. *Phys. Rev. Mater*. **2018**, *2*, 032601(R).
2. G. M. Su et al. *J. Am. Chem. Soc*. **2019**, *141*, 13547.
3. G. M. Su et al. *ACS Macro Lett*. **2019**, *8*, 1353.

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