Understanding Conduction and Anisotropy in Nanostructured Soft Materials using Multi-Modal NMR

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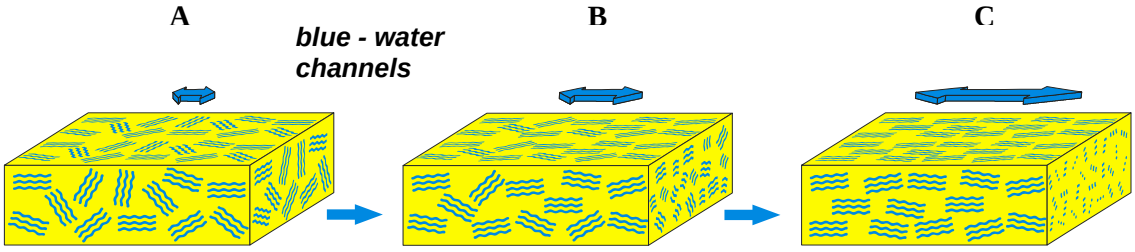
A wide variety of the materials we encounter exhibit average molecular alignment that leads to striking properties. Ion-containing polymers represent a class of nanostructured soft materials that often show such alignment, with resulting effects on ion and small molecule transport. Our lab uses NMR microimaging, diffusometry, and spectroscopy to quantitatively characterize soft material behaviors such as orientational order, weak intermolecular associations, and molecular diffusion. Such information allows development of fundamental models for morphology, dynamics, and transport, and enables improved material design and performance in applications such as fuel cells, reverse-osmosis water purification systems, and LC optical switches.

^{2}H NMR spectroscopy and multi-axis NMR diffusometry provide a unique combination to relate material anisotropy and transport of mobile species such as water and ions.[1,2,3] We will present ^{2}H spectroscopy and diffusion studies of water and ions in the 1-20 nm hydrophilic channels of ionomer membranes that have varying composition and degrees of alignment. In drawn Nafion © membranes, we find a linear relationship between diffusion anisotropy and material orientational order parameter measured from ^{2}H NMR, thus establishing new constraints on the hydrophilic channel structure in Nafion. This striking relationship of transport to material alignment parallels theories of thermotropic liquid crystals, and demonstrates that the local conducting channel and defect structures in these membranes are unaffected by macroscopic deformation. We will further present progress toward understanding mobile ion aggregates inside ionomers using various NMR techniques and a range of sample compositions.[4]

We will also discuss the general utility of NMR in morphology and transport studies of oriented soft materials, especially regarding the probing of different length and time scales, and different symmetries of order.



Hydrophilic channel alignment models for uniaxially drawn membranes. Arrows indicate draw direction. (A) Undrawn (B) Draw ratio 2:1 (C) Draw ratio 4:1.

References:

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