

Dynamic mechanical response of anion exchange membranes to humidity cycling

Melissa A. Vandiver¹, Benjamin R. Caire¹, Yifan Li²,
Daniel M. Knauss², Andrew M. Herring¹,
and Matthew W. Liberatore¹
Department of Chemical and Biological Engineering¹
and Department of Chemistry and Geochemistry²,
Colorado School of Mines, Golden CO 80401

While robust, well performing proton exchange membranes (PEM) have been developed for fuel cells, these systems are still limited by the high cost of platinum catalyst and limited fuel options. The alkali nature of anion exchange membrane (AEM) fuel cells increases fuel oxidation kinetics allowing options for lower cost catalysts and a variety of fuels¹. AEMs must have a high ionic conductivity, resistance to crossover, and chemical and mechanical stability over the lifetime of the fuel cell¹. Mechanical durability is often the last consideration in membrane development, however mechanical deterioration of the membrane is often the ultimate failure mechanism of a working cell^{2,3}. Variations in humidity in the fuel cell cause dimensional swelling and contraction of the membrane resulting in significant internal stresses. Repeated cycling of humidity can create pinholes and propagate defects that result in the eventual catastrophic failure of the membrane⁴.

In a previous study we investigated the conductivity and tensile properties of a polystyrene-b-poly(vinylbenzyl trimethylammonium) diblock copolymer system and the corresponding homopolymer blend. The tensile properties were tested under dry and saturated gas conditions at 60°C. Water taken up by the polymers at high humidity acted as a plasticizer increasing elasticity of the films, lowering the Young's Modulus (Figure 1). While these polymers had relative high conductivity and a significant response to humidity, the brittleness and development of cracks in the dry state made them impractical for use in fuel cells.

Polymer chemistry was altered by replacing the polystyrene block with polyethylene to reduce brittleness and increase elasticity of the film. Initial testing indicates this polyethylene-b-poly(vinylbenzyl trimethylammonium) (Figure 2) has improved elongation and elasticity. This polymer will be subjected to dynamical mechanical testing with temperature and humidity cycling. The dynamic response of the polymer membrane to sorption and desorption will describe the hygrothermal stresses experienced by the membrane in a working fuel cell.

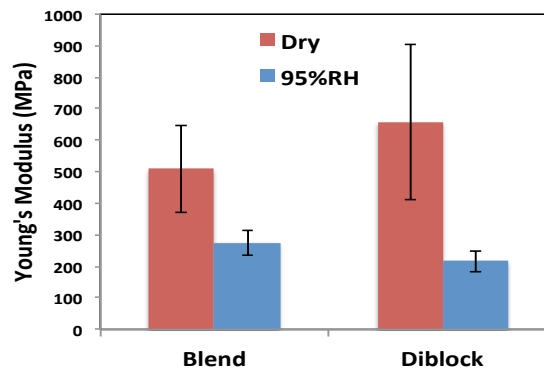


Figure 1: Film elasticity under dry and saturated conditions, 60°C. The Young's Modulus decreased with hydration due to water acting as a plasticizer.

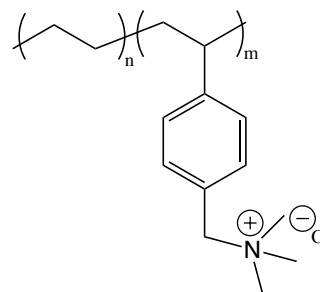


Figure 2: Chemical structure of the polyethylene-b-poly(vinylbenzyl trimethylammonium) AEM.

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References

1. Varcoe, J. R.; Slade, R. C. T. *Fuel Cells* **2005**, *5*, 187–200.
2. Borup, R.; Meyers, J.; Pivovar, B.; Kim, Y. S.; Mukundan, R.; Garland, N.; Myers, D.; Wilson, M.; Garzon, F.; Wood, D.; Zelenay, P.; More, K.; Stroh, K.; Zawodzinski, T.; Boncella, J.; McGrath, J. E.; Inaba, M.; Miyatake, K.; Hori, M.; Ota, K.; Ogumi, Z.; Miyata, S.; Nishikata, A.; Siroma, Z.; Uchimoto, Y.; Yasuda, K.; Kimijima, K.-I.; Iwashita, N. *Chem. Rev.* **2007**, *107*, 3904–3951.
3. Patil, Y. P.; Jarrett, W. L.; Mauritz, K. A. *J Membrane Sci* **2010**, *356*, 7–13.
4. Huang, X.; Solasi, R.; Zou, Y.; Feshler, M.; Reifsnider, K.; Condit, D.; Burlatsky, S.; Madden, T. *J Polym Sci Pol Phys* **2006**, *44*, 2346–2357.