Investigation of PEM Fuel Cell Behavior: Swelling and Viscoelastic Properties of Nafion

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Recent work on polymer electrolyte membrane (PEM) fuel cells has demonstrated the importance of membrane mechanical properties and swelling behavior on cell performance. [1,2] Specifically, autohumidified fuel cells operating under certain conditions exhibit two distinct performance levels that correspond to different membrane water content states and depend on prior operating conditions. Cells using aged membranes (>1000 hours operation) oscillate autonomously and regularly between these two performance levels. Furthermore, the responses of fuel cells to step changes in operating parameters are non-linear and subject to numerous dynamic time-scales.

These phenomena indicate that chemical-mechanical coupling plays an important role in governing the behavior of PEM fuel cells. In chemical-mechanical coupling the polymer membrane's mechanical properties (stiffness, Tg, creep behavior, etc) are changed by its water content, which in turn affects the cell performance by altering the internal resistance, which then changes the water production rate, thus changing the membrane water content and mechanical properties.

The impact of chemical-mechanical coupling is especially important for membranes such as Nafion used in fuel cells, as their ionic conductivity and mechanical properties depend strongly on water content. Indeed, mechanical properties and swelling should be considered as integral factors when developing new membranes, improving cell design and creating models.

This talk will present several examples of fuel cell behavior for which mechanical properties and swelling are believed to be responsible and discuss the mechanical properties of membranes that have been determined thus far. Specifically, dependence of Young's Modulus on water content and temperature for Nafion and other fuel cell membranes will be presented, as will dynamic behaviors of Nafion, such as constant-stress creep and swelling.

[1] J. B. Benziger, E. Chia, E. Karnas, J. Moxley, C. Teuscher, and I.G. Kevrekidis, *AIChE Journal* 50 (2004), pp 1889.
[2] J. B. Benziger, E. Chia, J. Moxley, and I.G. Kevrekidis, *Chemical Engineering Science* 60 (2005), pp 1743.