One of the important factors determining the lifetime of polymer electrolyte membrane fuel cells (PEMFCs) is membrane degradation and failure. The lack of effective mitigation methods is largely due to the currently very limited understanding of the underlying mechanisms for mechanical and chemical degradations of fuel cell membranes.

In order to understand membrane degradation in fuel cells, two different experimental approaches were developed; one is fuel cell testing under open circuit voltage (OCV) with bi-layer configuration of the membrane electrode assemblies (MEAs) and this other is a modified gas phase Fenton’s test. Accelerated degradation tests for polymer electrolyte membrane (PEM) fuel cells are frequently conducted under open circuit voltage (OCV) conditions at low relative humidity (RH) and high temperature. With the bi-layer MEA technique, it was found that membrane degradation is highly localized across thickness direction of the membrane and qualitatively correlated with location of platinum (Pt) band through mechanical testing, Infrared (IR) spectroscopy, fluoride emission, scanning electron microscopy (SEM), transmission electron microscopy (TEM), and energy dispersive spectroscopy (EDS) measurement.

One of the critical experimental observations is that mechanical behavior of membranes subjected to degradation via Fenton’s reaction exhibit completely different behavior with that of membranes from the OCV testing. This result led us to believe that other critical factors such as mechanical stress may affect on membrane degradation and therefore, a modified gas phase Fenton’s test setup was developed to test the hypothesis. Interestingly, the results showed that mechanical stress directly accelerates the degradation rate of ionomer membranes, implying that the rate constant for the degradation reaction is a function of mechanical stress in addition to commonly known factors such as temperature and humidity.

Membrane degradation induced by mechanical stress necessitates the prediction of the stress distribution in the membrane under various conditions. One of research focuses was on the developing micromechanism-inspired constitutive model for ionomer membranes. The model is the basis for stress analysis, and is based on a hyperelastic model with reptation-inspired viscous flow rule and multiplicative decomposition of viscoelastic and plastic deformation gradient. Finally, evaluation of the membrane degradation requires a fuel cell model since the degradation occurs under fuel cell operating conditions. The fuel cell model included structural mechanics models and multiphysics models which represents other phenomena such as gas and water transport, charge conservation, electrochemical reactions, and energy conservation. The combined model was developed to investigate the effect of compression on fuel cell performance and membrane stress distribution.

Major: Mechanical Engineering

Educational Career:
Bachelor’s of Mechanical Engineering, BS, 1998, Hongik University, Seoul, Korea
Master's of Mechanical and Aerospace Engineering, MS, 2005, Seoul National University, Seoul, Korea

Committee in Charge:
Xinyu Huang, Chair, MMAE
James M. Fenton, FSEC, MMAE
Quanfang Chen, MMAE
Nina Orlovskaya, MMAE
Alfons Schulte, Physics

Approved for distribution by Xinyu Huang, Committee Chair, on February 16, 2010.
The public is welcome to attend.