Modeling the Behavior of a Polymer Electrolyte Membrane Within a Fuel Cell Using COMSOL

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Abstract

In recent years, scientists have taken great interest in the development of renewable and alternative energy sources. One viable alternative to non-renewable fossil fuels is the fuel cell, which produces electricity via a simple chemical reaction using hydrogen and oxygen gases with little or no pollution as the only by-products formed are heat and water. A special class of FC i.e. Proton Exchange Membrane Fuel Cell (PEMFC) has been investigated during the present study. Membrane is a very important part of a PEMFC as most ohmic losses occurs here and limits the maximum operating temperature, causes fuel cross over effect, and increase electrochemical kinetics losses resulting in reduced fuel efficiency and cathode catalyst poisoning. Therefore there is a need of an accurate modeling of the membranes to study the overall physical and electrical behavior of real Fuel Cells. In this project Poly (1-vinylimidazole) or PVIM polymer membrane has been modeled and its performance has been investigated by studying its conductivity, heat flow, and weight loss at various temperatures and compositions. Modeling has been done using simulation software, COMSOL Multiphysics 4.2a, which allows the application of various physics interfaces to the model and facilitates all the necessary steps needed to ensure that the model is as realistic as possible.

Reference

1. Adzakpa, K. P., K. Agbossou, Y. Dubè, M. Dostie, M. Fournier, and A. Poulin. “PEM Fuel Cells Modeling and Analysis Through Current and Voltage Transient Behaviours.” IEEE Transactions on Energy Conversion, Vol. 23, No. 2, 2008: 581-591.
2. Alotto, Piergiorgio, Massimo Guarnieri, and Federico Moro. “A Fully Coupled Three-dimesional Dynamic Model of Polymeric Membranes for Fuel.” COMSOL Conference. Milan, 2009.
3. COMSOL. “Mass Transport Analysis of a High Temperature PEM Fuel Cell.” Solved with COMSOL Multiphysics 4.2, 2011: 1-31.
4. COMSOL. “Species Transport in the Gas Diffusion layers of a PEM.” Solved with COMSOL Multiphysics 4.2, 2011: 1-30.
5. Friede, Wolfgang, Stéphane Raël, and Bernard Davat. “Mathematical Model and Characterization of the Transient Behavior of a PEM Fuel Cell.” IEEE Transactions on Power Electronics, Vol. 19, No. 5, 2004: 1234 – 1241.
6. Jia, J., Q. Li, Y. Wang, Y. T. Cham, and M. Han. “Modeling and Dynamic Characteristic Simulation of a Proton Exchange Membrane Fuel Cell.” IEEE Transactions on Energy Conversion, Vol. 24, No. 1, 2009: 283-291.
7. Jingzhou Zhonghe Chemical. “Poly (1-vinylimidazole).” 2010. jzzhchem.com (accessed October 2, 2011).
8. Nice, Karim, and Jonathan Strickland. “How Fuel Cells Work.” How Stuff Works. http://auto.howstuffworks.com/fuel-efficiency/alternative-fuels/fuel-cell.htm (accessed September 6, 2011).
9. Pasricha, Sandip, and Steven R. Shaw. “A Dynamic PEM Fuel Cell Model.” IEEE Transactions on Energy Conversion, Vol. 21, No. 2, 2006: 484-490.
10. Perma Pure LLC. “Nafion: Physical and Chemical Properties.” Perma Pure. http://www.permapure.com/tech-notes/key-concepts/nafion-physical-and-chemical-properties/ (accessed September 30, 2011).
11. “What is Nafion®?” Perma Pure. http://www.permapure.com/industry/enviro/technology/ (accessed September 30, 2011).
12. Siegel, C., G. Bandlamudi, and A. Heizel. “Modeling Polybenzimidazole/Phosphoric Acid Membrane Behaviour in a HTPEM Fuel Cell.” COMSOL Conference. Hannover, 2008.
13. Siegel, C., G. Bandlamudi, N. van der Schoot, and A. Heinzel. “Large Scale 3-D Flow Distribution Analysis in HTPEM Fuel Cells.” COMSOL Conference. Milan, 2009.
Smithsonian Institution. “Fuel Cell Basics.” American History. 2008. 14. http://americanhistory.si.edu/fuelcells/basics.htm (accessed September 6, 2011).
15. Spiegel, Colleen. PEM Fuel Cell Modeling and Simulation Using Matlab. Elsevier Inc., 2008.
16. Stewart, K.A, and H.P.S Missan. “Nano-composite Ternary Acid-Base Blend Based Polymer Electrolyte Membranes.” ECS Transactions, 2010: 17-27.
17. University of Cambridge. “Center for Research in Electrochemical Science and Technology.” Electrochemistry Group Fuel Cell. cheng.cam.ac.uk (accessed October 2, 2011).