A Micro porous Evaporation Plate to Reduce Methanol Crossover in a DMFC

Ruiming Zhang, H. Russell Kunz and James Fenton
Department of Chemical Engineering
University of Connecticut
Storrs, CT 06269

A direct methanol fuel cell (DMFC) uses methanol as a fuel directly without a reformer. Such a fuel cell is very attractive in transportation for reducing harmful emissions, simplifying the fuel cell power plant system, increasing energy efficiency, and using the existing liquid fueling system. It is also a good candidate for portable applications because of its simplicity. Obstacles to commercialization using direct liquid methanol oxidation at a PEM fuel cell anode were studied as early as in the 1980's[1,2]. No system, however, has actually been put into commercial operation due to two major technical issues: slow anode reaction rate and methanol crossover. Some progress has been made on the first issue by using more active anode catalysts to increase the methanol electrochemical oxidation rate. Pt-Ru alloy anode catalysts have been used to reduce the catalyst poisoning of the CO[3-6]. However, for the DMFC system to move forward the methanol crossover issue must be overcome.

Liquid methanol transport from the anode through the membrane into cathode ("methanol crossover") is identified as one of the major efficiency losses in a DMFC[7,8]. Previous studies in methanol crossover reduction have been focused on the development of membranes[9-11] and the optimization of fuel cell operating conditions to feed a very low methanol concentration (~1 M)[12]. However, no membrane with low methanol crossover rate and high ionic conductivity has yet been successfully developed.

The crossover rate using methanol in the vapor phase is much lower than in liquid phase[9]. Vapor feed can be achieved by heating the liquid methanol to elevated temperatures (>100°C). Membranes working at elevated temperatures are under development, but some issues still exist, such as, maintenance of high membrane ionic conductivity and the loss of the cathode reaction efficiency[13]. Additionally, the evaporation of the inlet liquid methanol requires an extra heating system, which may increase the system complexity.

However, methanol vapor feed can also occur at a lower temperature range (<100°C) by separating its vapor from the liquid phase through a porous body. Methanol is a highly volatile chemical with a significant vapor pressure even below the water boiling point (100°C) at ambient pressure. A means of using a micro porous body as a methanol evaporation plate (MEP) to separate the vapor from its liquid phase to reduce the liquid methanol crossover at low temperature range has been developed. A MEP is a carbon plate with a micro porous structure pre-filled with liquid. The liquid flow passes on one side of the plate with pressure P_2 and the gas phase on another side has a higher vapor pressure P_1. Experimental results show that a MEP installed next to the DMFC anode achieves the goal of methanol crossover reduction.

Figure 1 shows the MEP effect on the methanol crossover reduction rate over a wide range of temperature, i.e., from room temperature up to near boiling temperature (100°C). Higher methanol concentration can be used and better DMFC performance is demonstrated with lower catalyst loading and thinner membrane (i.e., 0.4mg/cm^2 Pt on Nafion® 111 membrane) when using a MEP at a DMFC anode. The DMFC achieves higher air utilization at near ambient pressure operations. The performance curve is shown in Figure 2.

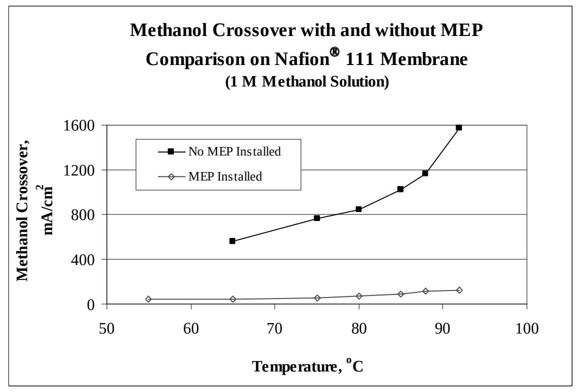

Figure 1 Methanol Crossover Comparison between with and without a MEP

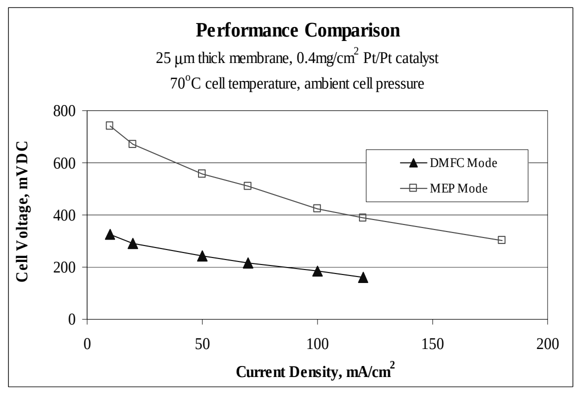

Figure 2 Performance Comparison between with and without a MEP

Reference

1. J. Goodenough, A. Hamnett, B. Kennedy, R. Manohara, and S. Weeks, J. Electroanal. Chem., 240, 133 (1988)
2. M. Watanabe, M. Uchida, and S. Motoo, J. Electroanal. Chem., 209, 151 (1986)
3. M. Verbrugge, J. Electrochem Soc. 136, 417 (1989)
4. Z. Jusys, J. Kaiser, R.J. Behm, Electrochim. Acta 47 (2002) 3693
5. T. J. Schmidt, M. Noeske, H. A. Gasteiger, R. J. Behm, P. Britz, and H. Bönnemann, J. Electrochem. Soc., **145**, 925 (1998)
6. M. Götz and H. Wendt, Electrochim. Acta, **43**, 4367 (1998)
7. S. Lee, K. Park, J. Choi, B. Kwon, and Y. Sung, J. Electrochem. Soc., **149**, A1299 (2002)
8. M. Verbrugge, J. Electrochem Soc. 136, 417 (1989)
9. X. Ren, T. Springer, T. Zawodzinski, and S. Gottesfeld, J. Electrochem Soc. 147, (2) 466-474 (2000)
10. J. Lin, Ph.D. Dissertation, UConn, (2000)
11. L. Hobson, H. Ozu, M. Yamaguchi, and S, Hayase, J. Electrochem Soc. 148, (10) A1185-A1190 (2001)
12. Y. Shi, Ph.D. Dissertation, UConn, (2002)
13. X. Ren, P. Zelenay, S. Thomas, J. Davey and S. Gottesfeld, J. Power Sources 86 (2000) 111-116
14. C. Yang, S. Srinivasan, A. Arico, P. Creti, V. Baglio and V. Antonucci, Electrochemical and Solid-State Letters, 4 (4) A31-A34 (2001)

Key Words: DMFC, fuel cell, direct methanol, methanol evaporation plate, crossover