Characterization of Gas Diffusion Layers for PEMFCs

Minkmas V. Williams, Eric Begg, Leonard J. Bonville, H. Russell Kunz, James M. Fenton

Department of Chemical Engineering
University of Connecticut
Storrs, CT 06269

Proton exchange membrane fuel cells (PEMFCs) are comprised of a proton-conductive membrane which has cathode catalyst layer on one side and anode catalyst layer on the other side, sandwiched between two gas diffusion layers. Gas diffusion layers serve as current collectors that allow ready access of the fuel and oxidant to anode and cathode catalyst surfaces, respectively. Therefore, the requirements of an ideal gas diffusion layer are several, including diffusing the gaseous reactants effectively into the catalyst layers, having high in-plane and through-plane electronic conductivity, having uniform surface for good electrical contact, and having proper hydrophobicity for water management in each application. Property characterization of commercial or manufactured gas diffusion layers is critical for optimization of PEMFC performance and understanding the functional mechanisms of gas diffusion layers.

A gas diffusion layer contains a mixture of carbon black powder, hydrophobic dispersion agent, and solvents, applied onto carbon paper or woven carbon cloth substrates (both have macro-pores), to form a uniform thin micro-porous layer on top of the macro-porous layer of the substrates. Gas diffusion layers are manufactured using Toray papers as the macro-porous substrate [1]. Commercial and manufactured gas diffusion layers are characterized and compared with different methods in accordance with the four requirements above. Gurley number was measured to determine the gas permeability through diffusion layers [2]. A direct correlation between this number and the diffusion characteristics would not be expected because the Gurley number involves viscous flow, while the diffusion layer performance is more dependent on diffusion. Therefore, the porosity and pore size distribution of diffusion layers are also characterized using mercury porosimetry. An example of the pore size distribution of a manufactured gas diffusion layer, and bare Toray paper, are compared in Figure 1. Electronic conductivity, both in-plane and through-plane, is measured under real PEMFC operating load of 20-100 kPa. Ideal fraction of hydrophobic pores required is dependent on the PEMFC operating conditions. Two operating temperatures, the typical PEMFC operating temperatures (70-80 °C) and the elevated operating temperatures (100-120 °C) were studied. The fraction of hydrophobic pores is determined using decane, which fills both hydrophobic and hydrophillic pores, and water which fills only hydrophillic pores [3].

All parameters of commercial and manufactured gas diffusion layers are characterized and correlated with cathode limiting current, which represents the maximum current limited by oxygen diffusion. The limiting current is determined after correcting for losses from ionic resistance in the membrane and in the cathode catalyst layer. By comparing all the critical parameters of gas diffusion layers with limiting current and diffusion properties, the optimization of diffusion layers for PEMFC performance can be obtained and the functional mechanisms of diffusion layers can be understood.

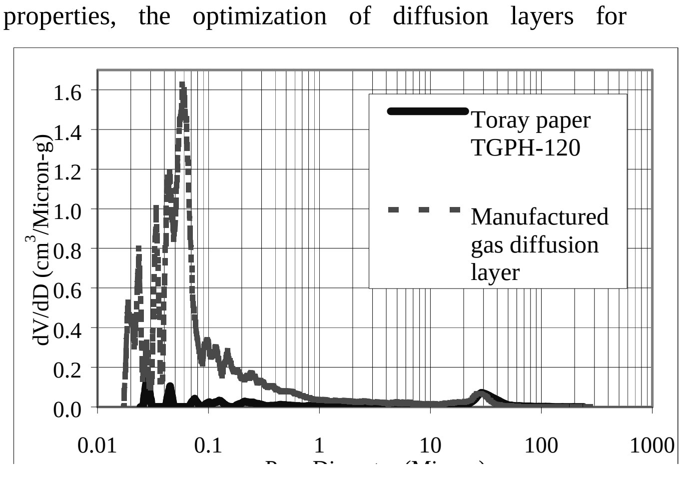

Figure 1. Pore size distribution curves

References

1. M. Vatanatham, Y.Song, L. Bonville, H.R. Kunz, J.Fenton, A. Smirnova, X.Wang, Electrochemical Society Extended Abstract 02-1, Abstract#29 (2002)

2. B. Mueller, T. Zawodzinski, J. Bauman, F. Uribe and S. Gottesfeld, Electrochemical Society Proceedings Volume 98-27, P.1 (1998)

3. H. Dohle, H. Schmitz, T. Bewer, J. Mergel, D. Stolten, J. Power Sources, 106, P.313 (2002)