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The influence of the liquid water interaction between channel, GDL and CL on cell performance

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Oxygen transport phenomena in porous media and /or channels (Ch.) in polymer electrolyte fuel cells (PEMFCs) is one of the most dominant phenomena to realize high current density operation for cost reduction of fuel cell electric vehicles (FCEVs). At the same time, it is widely known that the oxygen transport phenomena is strongly affected by liquid water behavior in Ch. and its interaction with liquid water inside porous media, such as gas diffusion layers (GDLs) and catalyst layers (CLs) (1). So far, significant research have been carried out to understand the liquid water behavior in Ch., however the relationship between the liquid water behavior and the cell performance have not been fully understood (2, 3).

In this study, coupled cell performance evaluation, liquid water visualization by neutron radiography (NRG) method and numerical modeling based on multi mixture (M2) model(4) were performed to investigate the role of the surface properties of bipolar plates (BPPs) on the liquid water behavior and cell performance.

Cell performances were evaluated with two types of BPPs. One was hydrophobic and the other was hydrophilic. Carbon papers without PTFE treatment were utilized through these analyses. Membrane electrode assemblies (MEAs) were fabricated with catalyst coated membrane (CCM) and GDLs without MPLs. Operating conditions are summarized in Table 1.

NRG was carried out to evaluate water distribution in MEAs at a current density under in-situ condition. Parameters for NRG were same with R. S. Fu et al(5).

Additionally, numerical analysis was conducted for deeply understanding the effect of liquid water interaction between that in Ch. and MEAs on cell performance. In this study, new models were implemented into M2 model(3, 4) which can account for micro oxygen transport resistance near Pt surface, r , which was implemented in Butler-Volmer equation like equation (1) (see T. Shiomi et al.(6) for detail), the effect of the interaction between liquid water in Ch. and GDLs and influence of porosity distribution of GDLs and/or a gap between GDL/ CL.

$$j=\frac{A\cdot C_{O_2\_bulk}}{4F\cdot C_{O_2\_ref}}\left(\frac{4C_{O_2\_ref}F\cdot v.r.f(1-s)^n}{4C_{O_2\_ref}F\cdot v.r.f(1-s)^n+A\cdot r}\right) \quad (1)$$

$$A=-a\,i_0\cdot\exp\left(-\frac{\alpha_c F}{RT}\eta\right) \quad (2)$$

The liquid water interaction at the interface between Ch./GDL was given as a coverage ratio which was calculated based on an assumption of liquid water shape in Ch. The influence of porosity distribution and/or gap between GDL/CL was described as bi-layer which has different permeability derived by Carman-Kozeny equation(7). Figure 1 shows the comparison of numerical and experimental results on liquid water distribution in cathode. As a reference, image of a numerical result without bi-layer model is also shown. Without bi-layer model, there was a discrepancy between numerical and experimental results in liquid water distribution. There is no peak near CCM in GDL. This indicates, liquid water distribution in MEA was strongly affected by porosity distribution and/or gap between GDL/CL, as a result liquid water saturation in CL dramatically increased. So in order to keep saturation in CL lower, it is necessary to reduce porosity distribution and/or gap between GDL/CL. At the same time, it can be understood that wettability of BPPs also affected saturation in MEA.

Table 1. Operating conditions

Cell temperature [K]	333.15
Relative humidity [%]	100
Inlet pressure [kPa_abs.]	200
Gas flow rate [L/m]	2
Gas species	H_2/Air

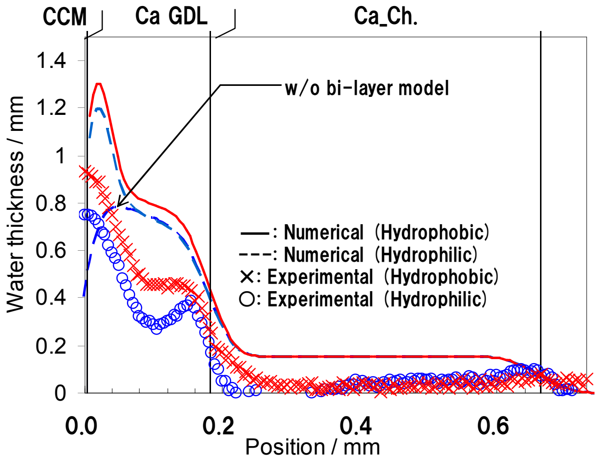

Figure 1. Comparison of numerical and experimental results on liquid water distribution in MEAs.

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