Investigation of liquid water accumulation in operating PEM fuel cells with/without MPL and its effect on cell performance

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Water management is an important issue in proton exchange membrane fuel cells (PEMFCs). The membrane needs sufficient humidification in order to act as proton conductor. On the other hand, the excess of liquid water generated from the reaction could accumulate in the membrane electrode assembly (MEA) and hinder the transport of gas to the reaction sites in catalyst layer (CL), which deteriorates the cell performance. It is necessary to understand the behaviors of liquid water in the MEA in order to design a better fuel cell. Recently, several techniques have been developed to observe the liquid water accumulation in the MEA [1]. However, the liquid water distribution in the MEA and its effect on the cell performance, especially at high current density operation, is not clearly known. This study presents the investigation of liquid water distribution in the MEA with/without MPL by using soft-X-ray radiography and its effect on the fuel cell performance.

The visualization of liquid water in the operating PEMFCs was performed by using laboratory-based soft X-ray microscope system (Tohken, TUX-3110FC). We used a thin-film of tungsten on diamond window as the target material for generating X-ray with the photon energy of 8.4–10 keV. The X-ray tube voltage was set at 18 kV. The catalyst-coated membrane (CCM) was fabricated using a transfer printing method. The CL with Pt loading of 0.36 mg Pt cm^{-2} was decaled on to the perfluorinated sulfonic acid membrane (Nafion® EC NRE 212, 50 μm-thick) by hot pressing. An active area of the MEAs was 0.10 cm^2 (0.8 mm x 12 mm). SGL 24BC and SGL 24BA were used as gas diffusion layer (GDL) with and without micro porous layer (MPL). The channel width and depth were 1.0 and 0.5 mm. The rib-to-channel ratio was 1. Hydrogen and oxygen gases were used at a flow rate of 50 sccm. The bubbler and cell temperature was set at 65 °C and 63 °C, respectively.

Fig. 1 shows the polarization curve of the fuel cells with and without MPL. There was no big difference in the cell voltage at low current density up to 0.2 A/cm^2. However, as the current density increased above 0.2 A/cm^2, the voltage of the cell with MPL was significant higher than that of the cell without MPL, which is consistent with the results in previous reports [2].

In order to observe the liquid water accumulation across wide area of the cell, the visualization was performed at low magnification in this study. Fig. 2 shows the original image at open circuit voltage (OCV) and the water distribution in the cell with SGL 24BA. The CCM, GDL, channels, and the rib area were identified. The liquid water thickness was calculated by using the image at OCV conditions and the image at water saturation as the reference. For the GDL without MPL (24BA), the liquid water accumulation was observed at the interface of CL and GDL, and in the GDL. Liquid water was visualized only under the rib at low current densities. However, the liquid water accumulation at the interface of CL and GDL under the channel was also observed as shown in Fig. 2 (b) when the current density was increased.

Fig. 3 shows the original image and water distribution in the cell with MPL. The liquid water was observed to be accumulated at the boundary of MPL and GDL and in the GDL under the rib in case of GDL with MPL. From this result, it is cleared that the liquid water accumulation in the MEA with and without MPL is different. The water accumulation at the interface of CL and GDL could have large impact on deterioration of the cell voltage in the MEA without MPL. In case of the MEA with MPL, the MPL could reduce the water accumulation at the interface of CL and MPL and enhance the cell performance. The water accumulation distribution in the MEA with MPL in several gas flow rate conditions and their effects on cell performance will also be presented.

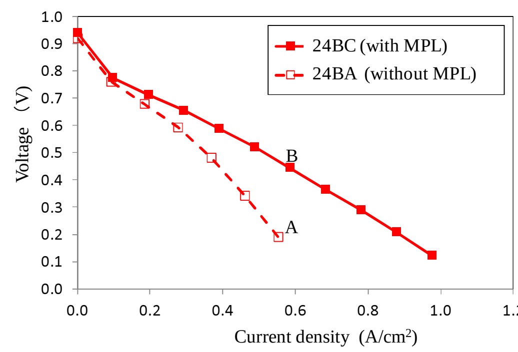

FIG. 1. Polarization curve of the fuel cell using 24BA (without MPL) and 24BC (with MPL).

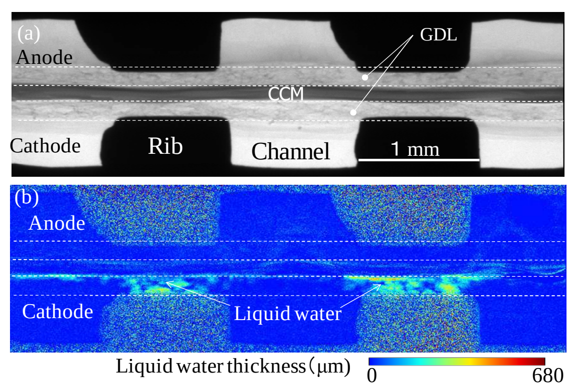

FIG. 2. Original image (a) and liquid water distribution (b) in the MEA with 24BA. (b) represents the liquid water distribution at point A in Fig. 1.

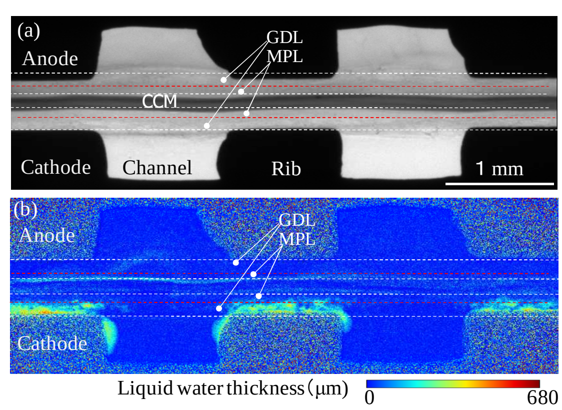

FIG. 3. Original image (a) and liquid water distribution (b) in the MEA with 24BC. (b) represents the liquid water distribution at point B in Fig. 1.

References

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[2] A.Z. Weber, J. Newman, J. Electrochem. Soc. 152 (2005) A677.