

Water Vapor Exchange Flow Channels to Enhance the Performance of Polymer Electrolyte Fuel Cells Without Cathode Humidification

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The membrane hydration of the polymer electrolyte fuel cell (PEFC) is required to maintain the efficient and stable operation. In general, the inlet gases are humidified for this purpose. However, from the viewpoint of the total efficiency of a PEFC system and the cost, the humidifier should be omitted. In particular, the cathode side is feasible due to the product water. We have thus developed a flow field design having flow channels for water exchange between the cathode and anode to circulate the product water in a cell.

Fig. 1 depicts a schematic illustration of our water vapor exchange structure installed in a cell. The flow fields have triple parallel-serpentine flow channels with water vapor exchange flow channels (Fig. 2). Cathode and anode were assembled in counter-flow configuration. The active area of the MEA (PRIMEA® 5580) was 4.2 cm², while the water vapor exchange area was 1.2 cm². A proton exchange membrane (PEM) without catalyst layers was used for the water vapor exchange part.

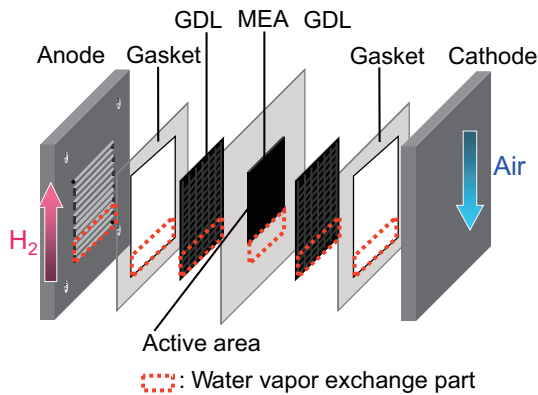


Figure 1: Components of the PEFC with the water vapor exchange channels.

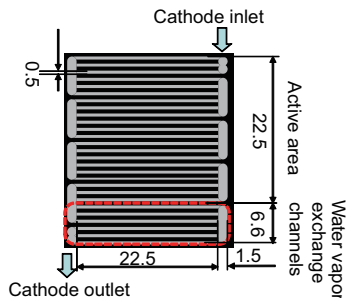


Figure 2: Cathode flow field having the water vapor exchange flow channels.

PEFC performance tests were performed with the cell temperature at 75 °C. Flow rates of the fed gases were controlled using mass flow controllers. Utilization of hydrogen and air at the anode and cathode was set at 60%,

respectively. Relative humidity (RH) of air fed into the cathode was set at 0%, while maintaining a very low RH of 20% at the anode inlet. Back pressure of the fed gases was set to zero. Ohmic loss was measured using current-interruption method.

The anode GDL used at the active area was a commercial carbon paper (SGL SIGRACET® 24BA) without the MPL, which was treated by 5 wt% polytetrafluoroethylene (PTFE) loading to impart hydrophobicity. The cathode GDL used at the active area was a 24BA GDL coated with a hydrophobic MPL. The GDLs used at the water vapor exchange part were a 24BA GDL, a hydrophobic MPL coated GDL and a hydrophilic MPL coated GDL. The hydrophilic MPL consisting of polyvinyl alcohol (PVA) and carbon black was coated on the 24BA GDL with a PVA content of 20 wt%.¹

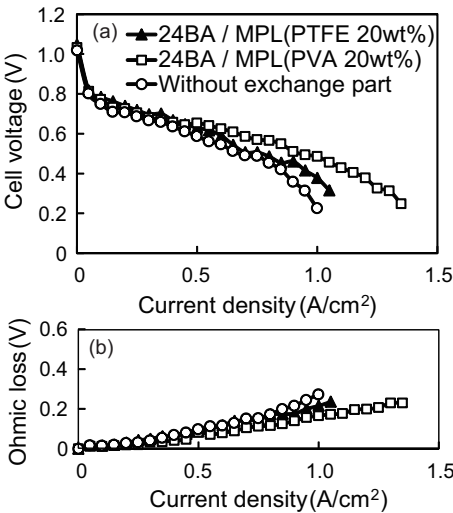


Figure 3: (a) I-V characteristics and (b) ohmic losses for the PEFC at 75 °C.

Fig. 3 shows the influence of the water vapor exchange part on the PEFC performance without cathode humidification. The 24BA GDL without the MPL was used at the anode water exchange area. Either the hydrophobic MPL (PTFE 20 wt%) or the hydrophilic MPL (PVA 20 wt%) coated GDLs were employed at the cathode water exchange part. The ohmic loss when the GDL coated with hydrophilic MPL was employed is lower than that without the water exchange part. However, not so significant enhancement of the PEFC performance is exhibited when using the hydrophobic MPL coated GDL.

This result indicates that the water vapor exchange part with the hydrophilic MPL coated GDL at the cathode is effective for the recovery of the water contained in the cathode downstream gas, which promotes water transport from the cathode to the anode dry gas in the upstream. This is effective to prevent the membrane dehydration, which reduces the ohmic loss, enhancing PEFC performance, as shown in Figure 3. However, in the case of the water vapor exchange part with the hydrophobic MPL coated GDL, the recovery of water in the cathode downstream cannot be enhanced compared to that with the hydrophilic MPL coated GDL, resulting in the membrane dehydration.

Acknowledgments

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References

1. T. Kitahara, H. Nakajima, and K. Mori, *Journal of Power Sources*, **199**, 29 (2012).