Effect of perforation structure of cathode GDL on liquid water removal in PEFC

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Polymer electrolyte fuel cell (PEFC) is the most promising power source for automotive and portable applications due to its high power density and low operating temperature. However, there are several technical problems to be solved in order to achieve practicability and popularization. Above all, "water flooding" is a critical issue for high performance operation. When the open pores in cathode catalyst layer (CL) and gas diffusion layer (GDL) are filled with much liquid water, oxygen transport to active reaction sites is blocked. To alleviate this issue, it is essential to design the optimum electrode structure for promotion of water removal on cathode side.

In the previous studies, several researchers have proposed the penetration hole structure of cathode GDL to promote liquid water removal and prevent water flooding [1-3]. Alink et al. revealed that the perforated GDL structure beneficially enhances the in-plane water transport toward the holes in the cathode GDL, because the laser perforation process creates the hydrophilic region around the holes [2]. On the other hand, according to Manahan et al., the loss of hydrophobicity in the perforation regions due to the laser processing unfortunately promotes liquid water accumulation and causes local flooding [3]. As mentioned above, the influences of perforation structure and its hydrophilization of cathode GDL on liquid water behavior and flooding phenomenon have not yet been fully elucidated.

In this study, the dynamic behavior of water droplets in the cathode channel of an operating PEFC is optically visualized using a high-resolution digital CCD camera, and the effect of various perforation structures of cathode GDL on the liquid water transport and cell performance is investigated. To evaluate the influence of hydrophilization of penetration hole on the water behavior within the GDL, the perforation machining of the GDL is carried out by two different methods of electric discharge machining (EDM) and micro-drilling technique. The EDM method removes PTFE coating from the sidewall of penetration hole due to its high-temperature processing. In contrast, the micro-drilling technique maintains the hydrophobic sidewall.

Fig. 1 shows the schematic diagram of the transparent fuel cell used in this experiment. A catalyst coated membrane (CCM, PEM: Nafion-115) on which platinum particles (0.5 mg/cm^2) are loaded is sandwiched between two PTFE-proofed GDLs (Toray, TGP-H-120). The active electrode area of the cell is 5.0 cm^2. The structure of gas flow filed is a two-pass serpentine flow channel. The width, depth, and length of flow channel are 1.0 mm, 1.0 mm, and 107 mm, respectively. To directly observe the dynamic behavior of water droplets in the cathode flow field during operation, a quartz glass is inserted between the cathode current collector and separator. Fig. 2 presents the schematic drawing of the position of the penetration holes along the cathode flow field. For promotion of water removal, seventy perforation holes are installed at even intervals throughout the cathode flow field. The diameter of the holes machined by EDM and micro-drilling is 300 μm. The operating temperature and current density of the experimental cell are 45°C and 0.2 A/cm^2. Fully humidified hydrogen and air are supplied to the anode and cathode channels at the stoichiometry of 10 and 20, respectively.

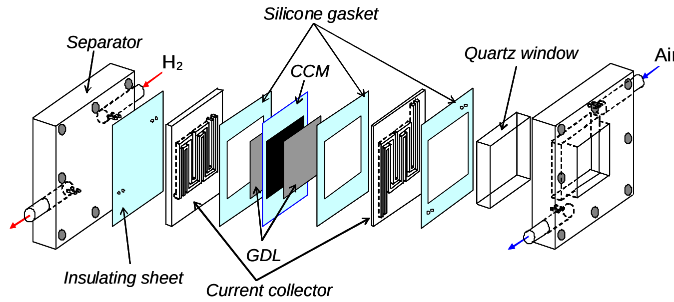

Fig. 1 Schematic diagram of transparent fuel cell.

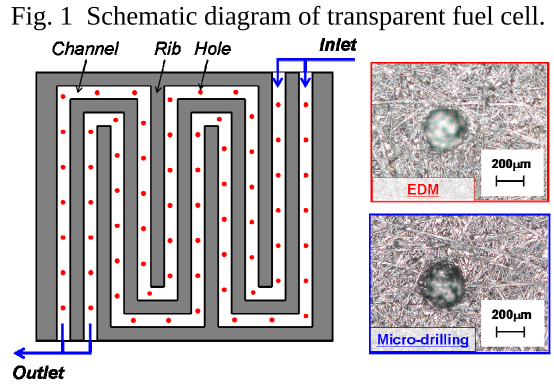

Fig. 2 Schematic of the position of the penetration holes along the cathode flow field.

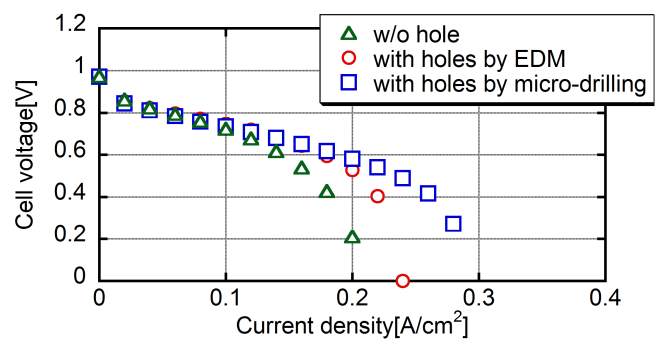

Fig. 3 IV characteristics for three different cathode GDL structures: (1) w/o hole, (2) with holes by EDM, (3) with holes by micro-drilling.

Fig. 3 shows the IV characteristics for three different cathode GDL structures: (1) w/o hole, (2) with holes machined by EDM, (3) with holes by micro-drilling. The IV measurement was conducted after the constant-current operation at 0.2 A/cm^2. In the case without hole, when the current density increases over 0.1 A/cm^2, the cell voltage rapidly decreases due to the concentration overpotential. At high current density, excessive liquid water is accumulated in the cathode CL and GDL, and oxygen cannot be sufficiently supplied to the reaction sites. On the other hand, in two cases with the perforation hole, the limiting current density is improved by the promotional effect of water removal. Furthermore, the limiting current density in the case of micro-drilling is higher than that in the case of EDM. These results indicate that the perforation structure of cathode GDL promotes liquid water removal and effectively alleviate water flooding. However, the EDM method tends to cause the liquid water accumulation inside the holes because this method hydrophilizes the sidewall of penetration hole. The hydrophobic perforation structure machined by the micro-drilling technique is the most effective in removing liquid water from the cathode GDL, and enhances the cell performance.

References

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