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Performance Analysis of Polymer Electrolyte Membrane Fuel Cell with Magneto-Aerodynamic Effects

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Extended Abstract

Polymer electrolyte membrane fuel cells (PEMFCs) are promising candidates for portable devices such as drones and vehicles owing to their low operating temperature and high efficiency [1]. However, PEMFCs face commercialization challenges, because oxygen reduction reaction (ORR)-related losses account for 51% of the total performance loss at the cathode [2]. To address these challenges, numerous studies have focused on enhancing ORR performance by improving catalytic activity [3], membrane [4], and flow channel structures [5]. Despite these efforts, there are still limitations in ORR performance improvement. Therefore, it is necessary to apply novel methods to overcome these bottlenecks.

In this study, we propose a method to enhance the ORR performance of PEMFCs by applying magnetic fields (MFs). The performance of MF-applied PEMFCs (MF-PEMFCs) was compared to that of PEMFCs under various operating conditions. The experiment was conducted with a unit cell consisting of an active area of 9 cm^2 and membrane electrode assemblies (MEAs) fabricated by the catalyst coating method. The Pt loading on the anode and cathode was 0.2 mg_{pt} cm^{-2}. The polymer membrane and gas diffusion layer were Nafion 211 and Sigracet 39BB, respectively. Permanent magnets were placed on the end plate, parallel to the surface of the MEAs. For 0.7 V, the current increase of MF-PEMFCs compared to PEMFCs was performed at MF densities ranging from 0 to 260 mT, cell temperatures (T_{cell}) of 40 and 80 °C, and relative humidity (RH) ranging from 40 to 80%. The results showed that the ORR-related performance of MF-PEMFCs was significantly improved compared with that of PEMFCs. The current increase was 11.3% at a MF density of 260 mT, T_{cell} of 40 °C, and RH of 80%. This was because the oxygen concentration rate at the surface of the triple-phase boundary increased with enhanced kinetics of oxygen resulting from the magneto-aerodynamic effects of MF densities. Additionally, the humidification of membrane surfaces in MF-PEMFCs was more uniform than that in PEMFCs owing to the improved mobility of humidified oxygen. Moreover, the current increase in MF-PEMFCs compared to PEMFCs at T_{cell} of 40 °C was more substantial than that at T_{cell} of 80 °C, because the MF-alignment in the permanent magnets became more uniform at lower temperatures. Therefore, it is recommended to operate under low-temperature and high-humidity conditions to achieve maximum performance of MF-PEMFCs.

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