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Effects of cathode open area and relative humidity on the performance of air-breathing polymer electrolyte membrane fuel cells

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Abstract

For portable applications, the, characteristics of passive air-breathing PEMFCs were investigated by examining effects of cathode open area and relative humidity on the cell performance. Among the single cells with cathode open area from 52 to 94%, the single cell with the open area of 77% exhibited the highest performance. The cell performance was improved with increasing RH of atmosphere from 20 to 100% in the low current region while lowered in high current region. Those results were related with the mass transport of oxygen from the atmosphere to the catalyst layer and the degree of membrane hydration determining the ionic conductivity of the membrane.

Keywords: PEMFC; Portable fuel cell; Air breathing; Passive feeding; Cathode structure

1. Introduction

The direct methanol fuel cell (DMFC) has attracted considerable attention to replace the battery in portable devices such as cellular phones, PDAs and laptop computers because of its feature of easy fuel supply [1]. However, DMFC has a critical drawback of low power density resulting from the methanol crossover through the membrane and the low reaction rate of methanol oxidation [2]. As an alternative, the polymer electrolyte membrane fuel cell (PEMFC) with a high power density can be considered even though there is still the technical change of hydrogen storage.

Comparing mobile applications and residential power generation for the PEMFC, a portable PEMFC system should be compact and simple since the absolute volume and weight allowed for a mobile power source are limited. Thus, it is necessary to minimize balance of plant (BOP) devices such as pumps, valves and fans [3].

Particularly humidifiers and a water-cooling system are not applicable to portable systems. For that reason, a passive air-breathing PEMFC can be a feasible power source for the portable devices. Although the passive air-breathing PEMFCs have different characteristics from the active air-feeding systems usually applied to fuel cell vehicles and residential power generation systems, the effects of design parameters and operating conditions on the performance of passive air-breathing PEMFCs have not been systematically examined [4–7]. In this study, the characteristics of the air-breathing PEFMC without pump or blower for the air supply to the cathode were investigated by examining the effects of the structure of the cathode current collector and the relative humidity (RH) of air on the cell performance.

2. Experimental

2.1. Cell design

Fig. 1 shows the schematic cell structure for the passive air-breathing PEMFC used in this study. The anode flow field was made of graphite with five-serpentine channels of 1 mm wide and 0.9 mm deep. Polytetrafluoroethylene (PTFE) gaskets were used for gas sealing of both anode and cathode. The cathode current collector was made of 2 mm thick gold-coated copper

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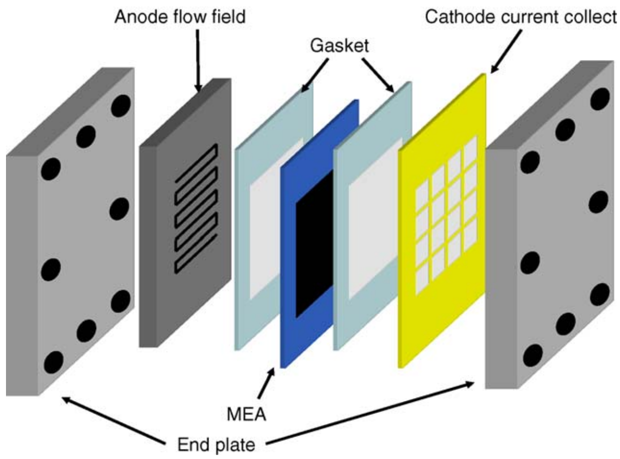

Fig. 1. A schematic structure of the passive air-breathing single cell.

plate. For air-breathing designs, the copper plate was machined to have various open areas with square openings as depicted in Fig. 2 and then coated with gold layer to protect from corrosion. The dimensions of the square openings were 4.5 mm × 4.5 mm, 6.67 mm × 6.67 mm, 11 mm × 11 mm and 24 mm × 24 mm and the total opening areas were 52, 64, 77 and 92%, respectively. The rib width was 2 mm.

2.2. Preparation of membrane electrode assembly (MEA)

A perflurosulfonic acid (PFSA) membrane (NRE-211, DuPont) was used as the electrolyte. The catalyst powder (40 wt.% Pt/C, E-Tek), Nafion solution (5 wt.%, EW = 1100, DuPont) and *iso*-propyl alcohol were mixed to prepare the catalyst ink. The total amount of Nafion ionomer in the electrodes was 33 wt.% of the catalyst weight. Then, the prepared catalyst inks were sprayed on the gas diffusion layer (wet proofing dry 20 wt.% of PTFE, Toray) with a platinum loading of 0.4 mg cm^{-2} for both anode and cathode. The membrane-electrode assembly (MEA) was prepared by placing the above electrodes on both sides of the pretreated Nafion membrane, followed by hot pressing at 140 °C and 100 atm for 90 s. The effective electrode area was 25 cm^2.

2.3. Measurement of cell performance impedance

To measure cell performance, dry hydrogen (99.9%) was used for the anode fuel and the flow rate was fixed at 100 mL min^{-1}. To maintain temperature and relative humidity of the surrounding atmosphere, all experiments were conducted in a controlled temperature and humidity chamber. Relative humidity in the chamber was changed from 20 to 100% at 35 °C. Before all measurements, single cells were pre-activated for 1 h at 100 mA cm^{-2} to eliminate effects of self humidification on ionic conductivity of the membrane. Polarization curves were measured with increasing current by 20 mA cm^{-2}. Each step was kept for 1 min to stabilize the cell voltage. Polarization resistance of the single cells was evaluated by measuring ac impedance of the cell with the air electrode as the working electrode and the hydrogen electrode as the reference and counter electrode. IM6 (ZAHNER) was used for the impedance measurement and the

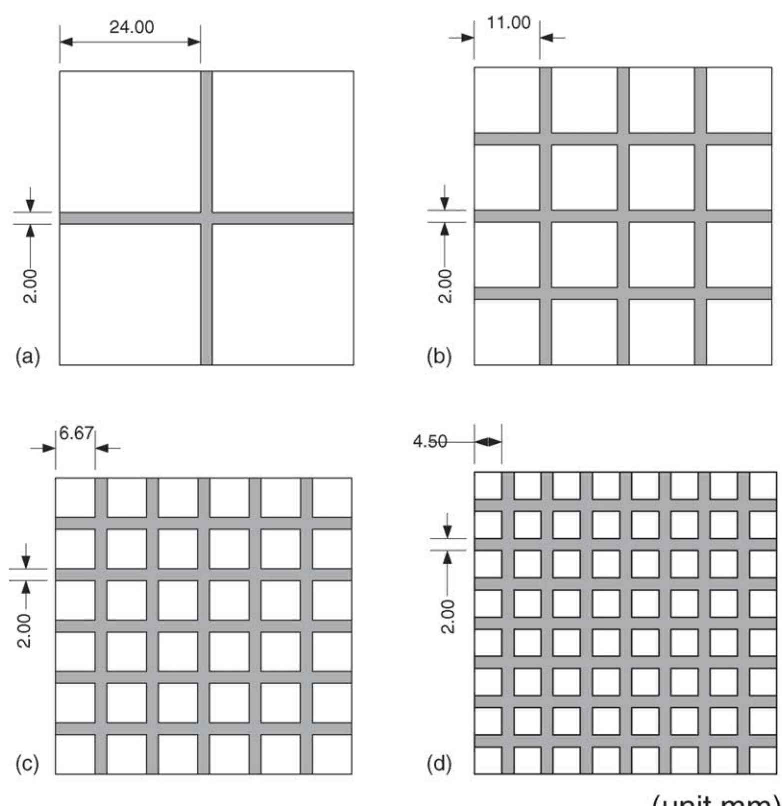

Fig. 2. Design of cathode current collectors with different open area: (a) 92%, (b) 77%, (c) 64% and (d) 52%.