High Performance Electrode Fabrication for Direct Methanol Fuel Cells

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INTRODUCTION

Although a direct methanol fuel cell (DMFC) shows much lower power density than hydrogen proton exchange membrane fuel cell (PEMFC), it has been extensively studied due to its simple peripheries compared to those of PEMFC. Achieving high anode and cathode kinetics from a membrane electrode assembly (MEA), which is amenable to mass production, is one of good strategies to reduce methanol crossover through the membrane.

EXPERIMENTAL

A commercial 20 wt.% FEP wet-proofed Toray 090 carbon paper (E-Tek) was used as a diffusion electrode substrate material. A microporous layer consisting of carbon black (Cabot, Vulcan XC72R) and PTFE (Dupont, TFE30) was coated on one side of the carbon paper by tape casting method and sintered for 15 min at 360 ^{o}C.

A 5 wt. % Nafion solution (Aldrich, EW 1100) was reacted with diluted sodium hydroxide solution resulting to Na+ form of Nafion, mixed with a polar organic solvent and then boiled to evaporate all the alcoholic solvents, resulting to a solvent-substituted Nafion solution.

A slurry of catalyst layer was prepared by dispersing unsupported Pt-Ru black (Alfa Aesar, Pt:Ru = 1:1 atomic ratio) for the anode or supported Pt (E-Tek, 40 wt.% Pt on Vulcan XC72R) for the cathode into the solvent-substituted Nafion solution, coated on the microporous layer-formed electrode by tape casting, cured in an atmospheric oven, protonated in 0.1 M sulfuric acid and then dried again in the oven.

After trimming the catalyzed electrodes for both anode and cathode, these were positioned on two sides of a pre-cleaned Nafion 112 and hot-pressed to form a membrane electrode assembly (MEA). The MEA (active area, 5 cm^2) was installed into single cell hardware (Electrochem. Inc), fed with 1 or 2 M diluted methanol by a peristaltic pump to an anodic inlet and with breathable-grade air to a cathodic inlet, and its power performance was evaluated by a PC-controlled Arbin BT+4.

RESULTS AND DISCUSSION

In an effort to optimize the degree of compression, MEA was subjected to two different kinds of compression by using two incompressible PTFE gaskets of different thickness, 100 and 200 μm. In the highly compressed MEA case the electrode facing with ribs of flowfield experienced approximately 66 % of thickness reduction, whereas a mildly compressed MEA was subjected to 33 % of thickness reduction of its electrode.

The effect of cell compression on the polarization characteristics of MEA is shown in Fig. 1. The highly compressed one showed a much lower transport limiting current than the mildly compressed one. As a result of measuring anode overpotential separately and observing the cross sectional morphology of MEA by SEM, it was found that a mechanically damaged cathode gas diffusion electrode due to the high cell compression is more prone to water flooding and hence leads to a decreases in the utilization of cathodic catalyst layer. That is, the mass transport limited current densities are caused by cathode flooding.

Changes in polarization characteristics of MEA with methanol molarity and cell temperature are shown in Fig. 2. In the low current regime, 2 M MeOH-fed MEA showed a lower cell voltage than that of 1 M due to excessive fuel crossover. As the mass transport of methanol to the anode catalyst layer dominates a reaction rate in the high current regime, the 2 M MeOH-fed MEA showed higher performance reaching to 0.21 W/cm^2 at 0.3 V.

Based on the anode overpotential measured separately using a hydrogen-fed cathode, it was found that the mass transport limited current is due to MeOH transport on the anode at 1 M but shifts to the cathode flooding at 2 M for 90^{o}C. But for 60^{o}C, the transport-limited current is still caused by the anode even at 2 M.

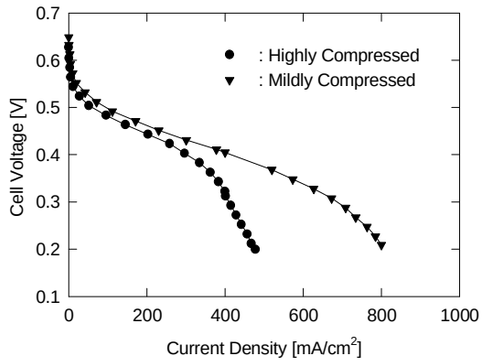

Fig. 1 Effect of cell compression on the polarization characteristics of MEA at 90 ^{o}C in 2 M MeOH, consisting of 4 mg/cm^2 Pt-Ru black-loaded anode, 1.5 mg/cm^2 carbon-supported Pt-loaded cathode and Nafion 112.

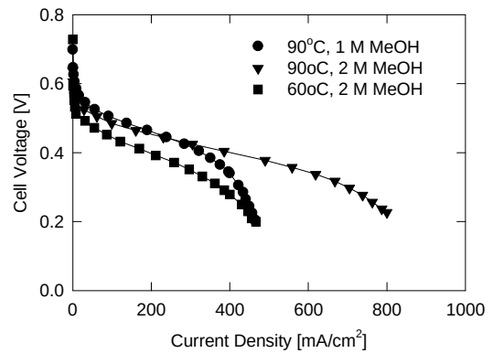

Fig. 2 Effect of methanol concentration and cell temperature on the polarization characteristics of MEA, consisting of 4 mg/cm^2 Pt-Ru black-loaded anode, 1.5 mg/cm^2 carbon-supported Pt-loaded cathode and Nafion 112.