Effect of Through-plane Polytetrafluoroethylene Distribution in a Gas Diffusion Layer on a Polymer Electrolyte Unitized Reversible Fuel Cell

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1. Introduction

Polymer electrolyte fuel cells and electrolyzers are essentially the same device, working in the opposite direction. Unitized reversible fuel cells (URFCs) combine the functionality of a fuel cell (FC) and electrolyzer (Ely) in one unitized device. URFCs have the potential to be simpler and more compact to construct, compared to the traditional systems with separate electrolyzers and fuel cells (two separate units). A URFC with hydrogen storage can be compared to a secondary battery. The advantage compared to secondary batteries is the capability storing large quantities of energy (in the form of hydrogen) without self-discharge and the existence of oxygen as side-products.

An important component in a polymer electrolyte-based URFC is the gas diffusion layer (GDL), which plays vital roles in water management and reactant distribution during both fuel cell and electrolysis operation modes, because mass transfer phenomena occur across the GDL. In the field of proton exchange membrane fuel cell (PEMFC), several works have focused on the through-plane PTFE distribution in the GDL of carbon material, and reported that the distribution directly depends on the treatment process.

In our current study, we examined the effect of different drying conditions of PTFE dispersion on PTFE distribution in Ti-felt GDL by using scanning electron microscopy (SEM)-based energy dispersive X-ray spectroscopy (EDS) imaging. We expected the drying process under vacuum pressure to yield a more uniform through-plane PTFE distribution than that under atmospheric pressure. Our goal was to verify the relationship between the through-plane distribution of PTFE in a Titanium-felt GDL and the URFC performance.

2. Experimental

A single cell of URFC with 27 cm^2 active area is used for the experiments. The cathode bipolar plate is manufactured from titanium but anode bipolar plate is carbon material. The MEA is placed between the flow fields of both bipolar plates. The MEA used here was developed through collaboration between Takasago Thermal Engineering Co. and Daiki Ataka Engineering Co. The carbon paper GDL (Toray) treated with 10% PTFE was used at the hydrogen side. Various titanium (Ti)-felts were used as the oxygen side GDL. All the samples used here had the same fiber diameter (20 μm), porosity (0.75), and thickness (300 μm). To investigate the effect of drying condition, we prepared three different types of Ti-felt GDL; not treated with PTFE (T0), treated with PTFE dried under atmospheric pressure (T1), and treated with PTFE dried under vacuum pressure (T2).

3. Results and discussion

Figure 1 shows the through-plane distributions of porosity (ε) and the PTFE fraction (f_{PTFE}) calculated from the EDS maps for PTFE treated samples; PTFE dried atmospheric condition and vacuum condition. The PTFE distribution in T2 (vacuum-dried) significantly differed (Fig. 1(b)) from that in T1 (Fig. 1(a)). Due to the vacuum drying, capillary pressure had no effect on the agglomeration mechanism of PTFE, and thus the PTFE was distributed more evenly throughout the bulk.

Figure 2 shows the *i*-*V* characteristics of fuel cell mode of URFC with the same cell set-ups as in Fig. 1. In the case of fuel cell operation, we could observe positive effect of the even distribution of PTFE through the Ti-felt GDL when the humidification temperature of gases was the same as the cell temperature.

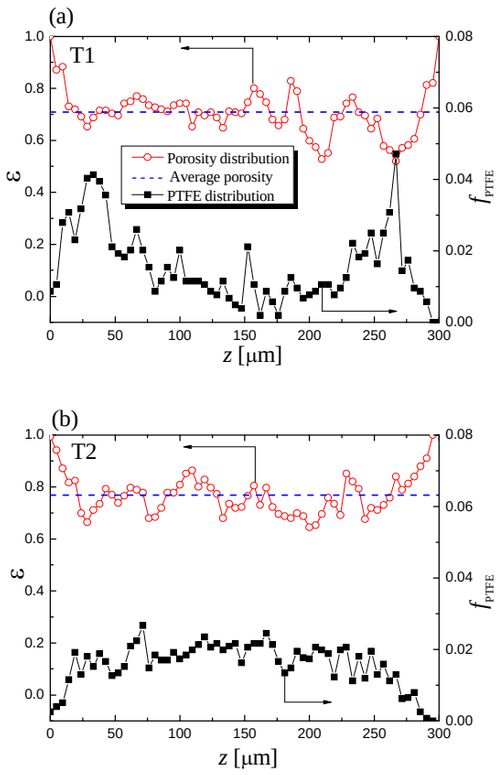

Figure 1. Porosity (ε) and normalized PTFE fraction (f_{PTFE}) distributions along the through-plane position (*z*) for PTFE-treated Ti-felt samples of T1 (a) and T2 (b).

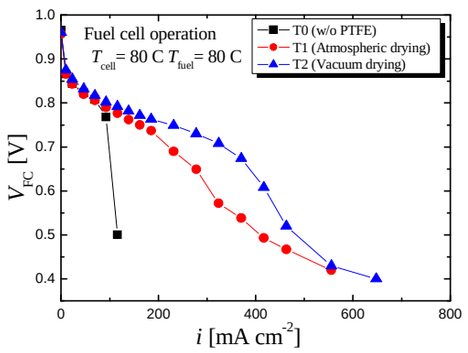

Figure 2. Current density (*i*) - voltage (*V*) characteristics during fuel cell operation mode for four different URFC set-ups at fuel humidification temperature (T_{fuel}) of 80°C, cell temperature (T_{cell}) of 80°C, and fully wet condition (RH = 100%).