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A Novel Method for Preparing PEMFC Catalytic Layers

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A novel PEMFC catalytic layer was fabricated by a Nafion-pyrolyzed method, which demonstrated a high performance with a maximum power density of 0.82 W/cm^2 on an electrode prepared by this method. The effects of the heat-treatment temperature and Nafion content in the catalyst layer on performance were studied.

Proton exchange membrane fuel cells (PEMFCs) are attracting extensive attention due to their high efficiency and low pollution. Many efforts have been made over two decades to increase Pt utilization. Raistrick[1] and other researchers[2,3] prepared a Nafion impregnated PTFE-bonded electrode (designated as a PTFE-bonded electrode hereafter) in which the contact between Pt and the electrolyte is not efficient and Pt utilization is low. Wilson[4] developed a thin hydrophilic electrode by spreading the catalyst ink of Nafion and Pt/C onto a Nafion membrane. Uchida[5] and other researchers[6–8] prepared a Nafion-bonded electrode using Nafion as a binder. Both the thin hydrophilic electrode and the Nafion-bonded electrode are prone to flooding due to a lack of hydrophobic materials. In this paper, a novel method to prepare a catalytic layer is introduced. Not only ionic and electronic contacts are guaranteed, but also flooding is avoided in this electrode.

As shown in Fig. 1, the performance of the Nafion-pyrolyzed electrode, at a maximum power density of 0.82 W/cm^2, is higher than that of a PTFE-bonded electrode with a maximum power density of 0.54 W/cm^2. In the PTFE-bonded electrode, Pt/C and PTFE are mixed and a Nafion solution is sprayed onto the surface of the electrode. The three-phase reaction zone cannot be extended effectively because Nafion does not penetrate into the catalytic layer and contact Pt particles sufficiently. Therefore, the utilization of Pt is low, which leads to its inferior performance. In the Nafion-pyrolyzed electrode, Pt/C and the Nafion solution are mixed thoroughly, so more Pt particles are active, and Pt utilization is increased. Additionally, in the electrode heat-treated above 280 °C, a part of the Nafion in the catalytic layer must have pyrolyzed and lost sulfonic acid groups,[9] and acted as hydrophobic materials in the electrode as PTFE does in the PTFE-bonded electrode. Therefore, the Nafion-pyrolyzed electrode not only guarantees ionic and electronic contacts, but also provides the passage of gases and avoids flooding, improving the utilization of Pt and the performance of the electrode.

Figure 2 demonstrates that the performance of the electrodes varies with the heat-treating temperature during preparation, and that the electrode heat-treated at 320 °C shows the best performance. On one hand, when the temperature is below 320 °C, only a small portion of the Nafion pyrolyzes and loses sulfonic acid groups. So the passage of gases is not sufficient, and the resistance of the mass transfer is large. On the other hand, if the temperature is increased to 340 °C, too much Nafion pyrolyzes. This leads to a decrease of the three-phase reaction zone and an increase of the resistance of ionic conductivity.

As can be seen from Fig. 3, the performance of the electrode containing 15 wt % Nafion in the catalyst layer is almost the same as that of the electrode containing 7 wt % Nafion. This can be explained by the promotion and suppression effects for changing Nafion content. The proton conductivity is enhanced with the increase in Nafion, while the resistance to diffusion (gases and water) is also increased. In the case of 7 wt % Nafion content, gas diffusion is sufficient, but proton conductivity is low, is contrary to the 15 wt % Nafion content. When the Nafion percentage increases up to 30 wt %, the performance of the electrode decreases dramatically. The reason may be gas diffusion is not sufficient due to excessive Nafion blocked some passages of the electrode.

The present results demonstrate a novel method to prepare

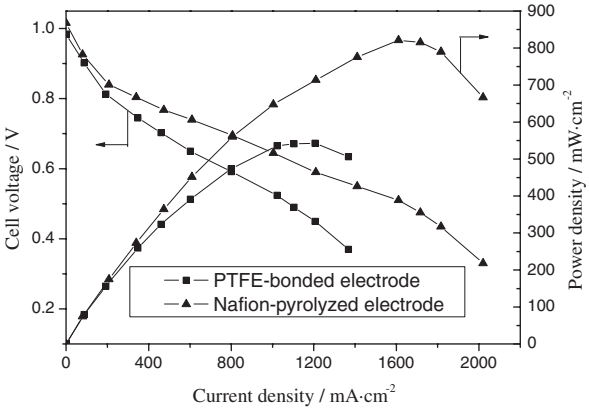

Fig. 1. Performance of MEAs with different electrodes.

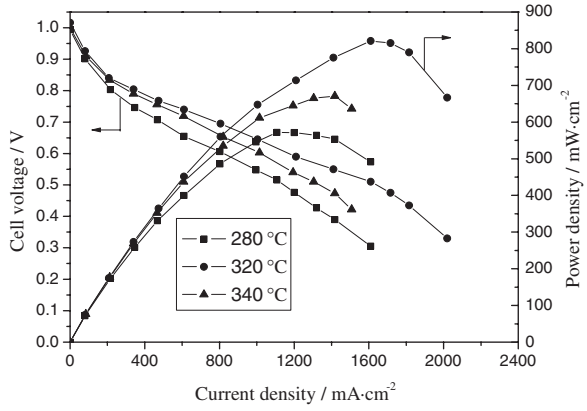

Fig. 2. Effect of heat-treating temperature on the performance of electrodes.

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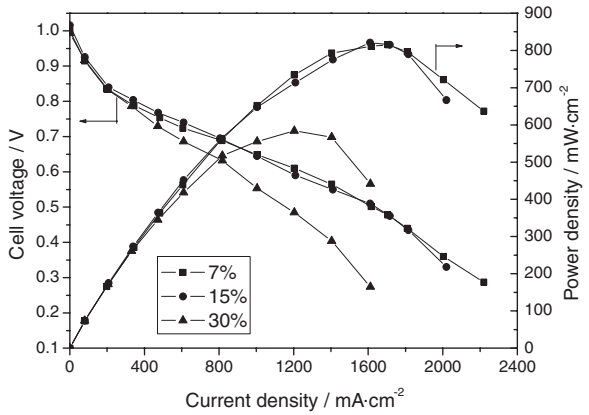

Fig. 3. Effect of Nafion percentage in catalyst layer on the performance of electrodes.

the catalytic layer of a PEMFC. A maximum power density of 0.82 W/cm^2 was achieved on the electrode heat-treated at 320 °C with a Nafion content of 15 wt %.

Experimental

A catalyst ink composed of a Pt/C catalyst, Nafion solution (DuPont), and 2-propanol was spread onto a gas diffusion layer that was prepared by applying a homogeneous mixture of XC-72R carbon and a PTFE emulsion onto a sheet of hydrophobic carbon paper. Then, the electrodes were heat-treated at a temperature from 280 to 340 °C for 1 h under inert gas. After that, a small amount of Nafion solution with a loading of 0.2 mg/cm^2 was sprayed onto the surface of the electrodes. They were then dried at room temperature for 12 h. The electrodes prepared by this novel method are designated as Nafion-pyrolyzed electrodes. An as-prepared electrode was used as a cathode and hot-pressed with an anode together onto a Nafion membrane from both sides to form a membrane electrode assembly (MEA). The loadings of Pt in the cathode and anode are 0.5 and 0.27 mg/cm^2, respectively. A PTFE-bonded electrode, served as a comparison sample, was prepared with the same Pt loading and hot pressed into MEA with the same anode and membrane. MEAs were evaluated in single cells (5 cm^2 of active geometric area) at 80 °C with an external humidification temperature of 85 °C and 90 °C for air and hydrogen, respectively.

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