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Short communication

A novel method for the preparation of a PEMFC water management layer

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Abstract

A novel rolling method for the preparation of the water management layer (WML) of a PEMFC was developed. In this method, the WML was prepared without dependence on the carbon paper substrate. The obtained WML was in a filmed state. The thickness, PTFE content and sintering condition of the rolled WML film were investigated. The MEA with the WML film exhibited a more stable performance than the MEA without the WML during a long running period. The water management ability of the WML film was confirmed.

Keywords: Water management layer; Rolling method; PEMFC

1. Introduction

Proton exchange membrane fuel cells (PEMFCs) have attracted a great deal of attention due to various kinds of advantages [1]. Great improvements have been made in the preparation methods of their membrane electrode assemblies (MEAs) in the past decades [2,3]. The so called water management layer (WML) [4] or gas diffusion layer (GDL) [5] is a sublayer which is located between carbon paper and catalyst layer, and is mainly composed of carbon and PTFE. Brushing [5] or spraying [6] methods were employed in traditional preparation process for the WML; Yu et al. [7] reported a method, in which carbon and PTFE were dry-deposited on carbon paper first and then its surface was flattened by rolling. However, the reported methods for preparing the WML were all dependent on the carbon paper substrate. In this work, the WML film was prepared by a rolling method without carbon paper. It is rational that this method is expected to bring significant convenience in the preparation of MEAs, because the inconvenience and complexity caused by the fragility of the carbon paper can be avoided.

2. Experimental

Ethanol was added to Vulcan XC-72, and then PTFE emulsion (60 wt%) was slowly dropped into the suspension with magnetic agitation. After stirring for 15 min, the suspension was slowly heated (about 50 °C) until the PTFE was coagulated, and then filtered. The obtained mixture was transformed into a film by an adjustable two-roll-shaft roller with a rolling rate of 30 rpm at room temperature. The film was rolled repeatedly in order to achieve enough toughness and then was sintered. The Pt/C catalyst (20 wt% Pt from Johnson Mattey Corp.), de-ionized water and isopropyl were mixed in an ultrasonic stirrer for 15 min, and then 5 wt% Nafion solution (Aldrich Chem.) was added to the mixture, with a weight ratio of 1:3 between the dry Nafion and the Pt/C. Having been stirred for 30 min, the "ink" formed was dried at 50 °C in vacuum, until it became a porridge-like mixture [8]. The "porridge" was then smeared on two pieces of 2 cm × 2 cm of the WML film. The Pt loading was set to 0.4 mg cm^{-2}. The two pieces of electrodes so obtained were dried in air at room temperature, and then hot-pressed with a Nafion1135 membrane (Dupont Corp.) at 0.3 MPa and 140 °C for 60 s. After two pieces of carbon paper were fixed onto the two sides of the two pieces of the WML film, an MEA was obtained. The MEA was mounted in a single cell with stainless steel end plates and graphite collector plates, which was designed with

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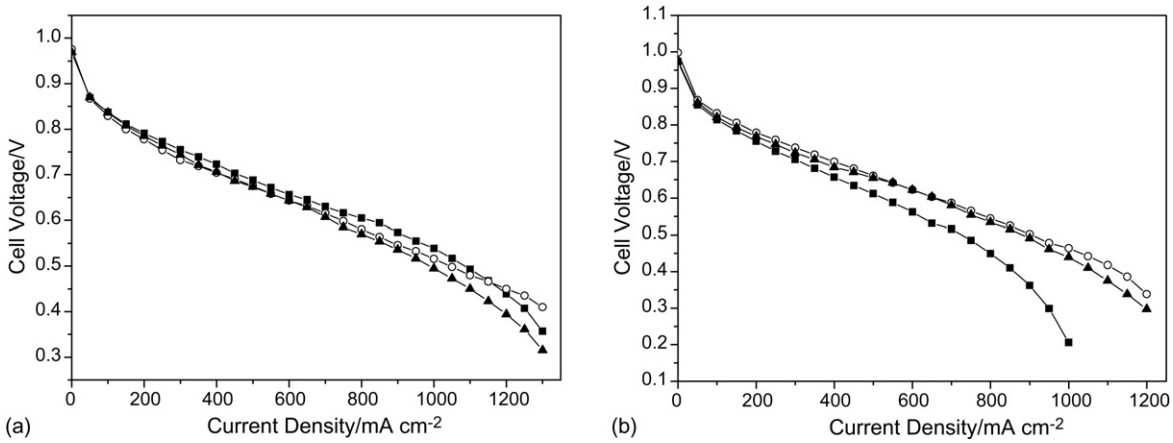

Fig. 1. Polarization curves of MEAs with WML films sintered at different temperatures, $p_{O_2} = 0.30$ MPa, $p_{H_2} = 0.28$ MPa, $T_{cell} = 70\,^{\circ}C$, sintering time: 0.5 h, (■) 150 °C; (◯) 250 °C; (▲) 350 °C. (a) Humidified gases ($T_{O_2} = 85\,^{\circ}C$, $T_{H_2} = 75\,^{\circ}C$) and (b) dry gases ($T_{O_2} = T_{H_2} = 25\,^{\circ}C$).

parallel ribbed channels for gas manifolding. The humidification of the reactant gases was accomplished by diverting the gases through heated water bottles.

3. Results and discussion

3.1. Sintering condition of the WML film

Figs. 1 and 2 show the influence of the sintering factors of the WML film on the performance of the PEMFC. It could be concluded from Fig. 1(a) that the sintering temperature of the WML film did not have a great impact on the performance of the PEMFC with humidified reactant gases. However, if the cell was run with dry gases, the performance of MEA with a WML film sintered at higher temperature (250 and 350 °C) was better, as is shown in Fig. 1(b). Fig. 2 demonstrates the effects of sintering time on cell performance. It could be seen that a too long sintering time (e.g. 60 min) could obviously reduce the performance. Hence, the optimum sintering condition was chosen as 250–350 °C for 15 min.

3.2. Composition parameters of the WML film

Polarization curves of MEAs prepared with WML films with different thickness are shown in Fig. 3. It can be seen that a medium WML film thickness of 90 μm was most favorable for achieving good cell performance, just as in the case with WMLs fabricated by the traditional methods. Fig. 4 illustrates the effects of the PTFE content on the performance of MEAs. The best performance was achieved when the PTFE content was 35 wt%, both higher or lower PTFE contents caused deterioration of cell performance.

Fig. 5 shows the long-time performance of MEAs with and without the WML film at 800 mA cm^{-2}. The thickness of the

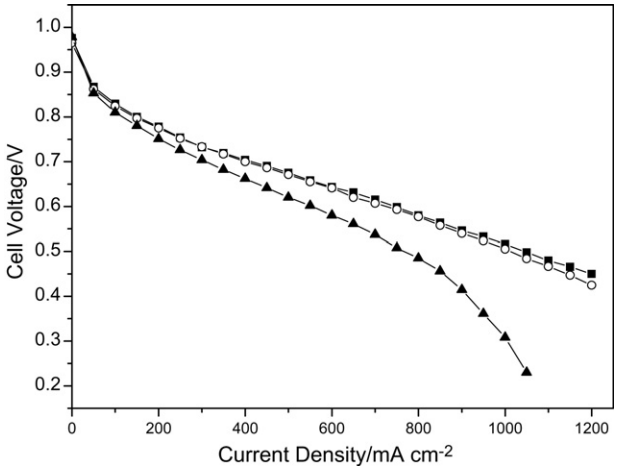

Fig. 2. Polarization curves of MEAs with WML films with different sintering time, $p_{O_2} = 0.30$ MPa, $p_{H_2} = 0.28$ MPa, $T_{cell} = 70\,^{\circ}C$, humidified gases ($T_{O_2} = 85\,^{\circ}C$, $T_{H_2} = 75\,^{\circ}C$), sintering temperature: 270 °C, sintering time: (■) 15 min; (◯) 30 min; (▲) 60 min.

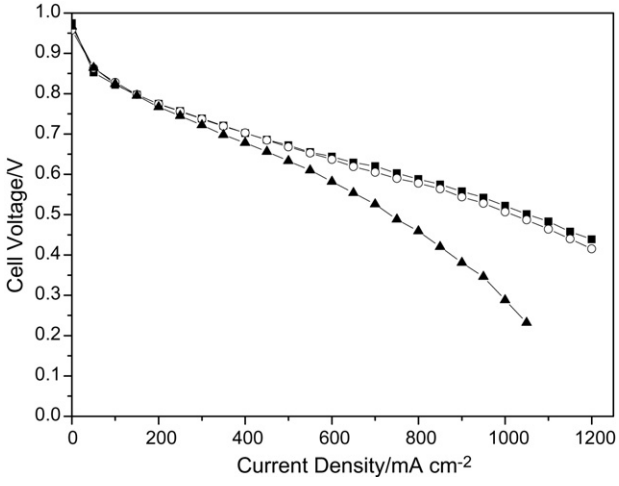

Fig. 3. Polarization curves of MEAs with WML films with different thickness, $p_{O_2} = 0.30$ MPa, $p_{H_2} = 0.28$ MPa, $T_{cell} = 70\,^{\circ}C$, humidified gases ($T_{O_2} = 85\,^{\circ}C$, $T_{H_2} = 75\,^{\circ}C$), PTFE content: 35 wt%, thickness of WML film: (■) 90 μm; (◯) 150 μm; (▲) 50 μm.

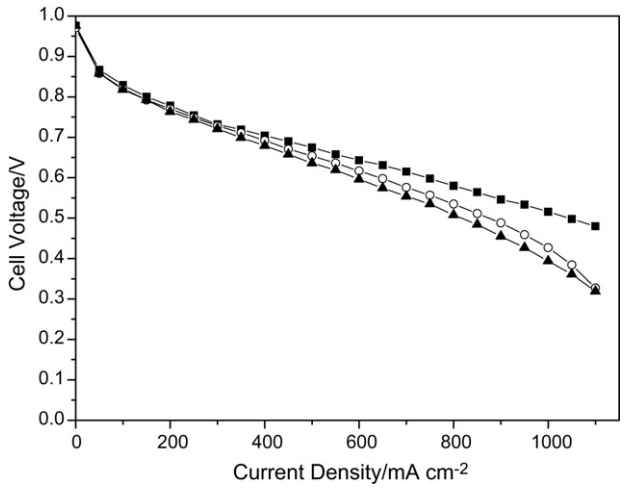

Fig. 4. Polarization curves of MEAs with WML films with different PTFE contents, $p_{O_2} = 0.30$ MPa, $p_{H_2} = 0.28$ MPa, $T_{cell} = 70\,^{\circ}C$, humidified gases ($T_{O_2} = 85\,^{\circ}C$, $T_{H_2} = 75\,^{\circ}C$), film thickness: 90 μm, PTFE content: (■) 35 wt%; (◯) 25 wt%; (▲) 45 wt%.

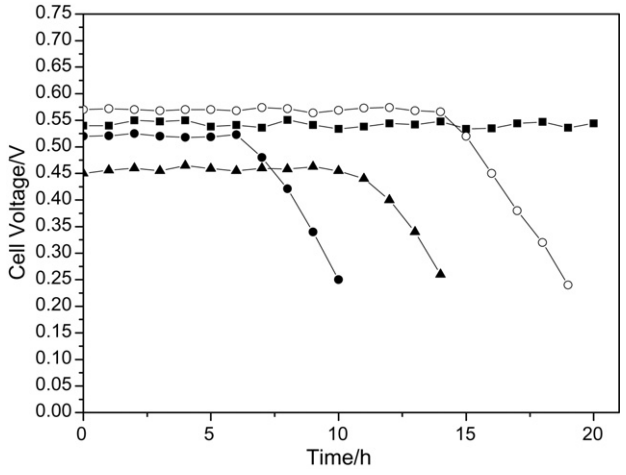

Fig. 5. Cell voltage–time curves of MEAs with and without WML film ($I = 800\,mA\,cm^{-2}$), $p_{O_2} = 0.30$ MPa, $p_{H_2} = 0.28$ MPa, $T_{cell} = 70\,^{\circ}C$, dry gases ($T_{O_2} = T_{H_2} = 25\,^{\circ}C$): with (■) and without (▲) WML film (PTFE content: 35 wt%, film thickness: 90 μm, sintering condition: 270 °C, 15 min); humidified gases ($T_{O_2} = 85\,^{\circ}C$, $T_{H_2} = 75\,^{\circ}C$): with (◯) and without (●) WML.

film was 90 μm and the PTFE content was 35 wt%. A more stable performance was observed when the WML film was applied. The flooding phenomenon was effectively avoided when the cell was run with humidified gases and the decrease of power density was mitigated to a considerable degree when the cell was run with dry gases. This result could be mainly attributed to the water management capability of the WML film.

4. Conclusions

A novel method for the preparation of WML was developed in which a WML film was prepared using a two-roll-shaft roller. The obtained WML film was composed of carbon black and PTFE. The optimum thickness and PTFE content of the WML film were 90 μm and 35 wt% respectively. The experimental results revealed that the performance of the MEA with the WML film was improved when there was no humidification of the reactant gases, and a prolonged operation time of the MEA at high current density was obtained under humidification conditions. Therefore, the water management capability of the WML film was confirmed.

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