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"Experimental study of PEMFC conditioning methods"

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Abstract

The conditioning procedure of polymer electrolyte membrane fuel cell (PEMFC) requires to acquire its maximum performance and promote commercialization of fuel cell society. Depending on the conditioning method, this procedure terminates in various time. To analyze the effect and time required for conditioning, commonly used procedures involving constant current (0.25A/cm^2) and constant voltage (0.6V) and new method which suggested in this study were adopted to experiments and optimize most effective conditioning methods. The best performance was reached by new conditioning method called Cathode Oxygen Depletion (COD) during 2hours, but 4hours and 21hours for CC and CV, respectively. As that results, COD conditioning method proceeded remarkably fast, and most of the conditioning process was finished within just few hours. It could be concluded that the MEA activation procedure had a significant effect on the MEA durability and reduction hydrogen gas required for conditioning.

Keywords: Polymer electrolyte membrane fuel cell; Cathode oxygen depletion; conditioning

1. Introduction

The worldwide effort for the reduction of greenhouse gas emissions by fossil fuels has generated Eco-friendly devices which capable of replacing internal combustion engines. Among the commonly used Eco-friendly devices, the Polymer electrolyte membrane fuel cell (PEMFC) is highly demanded as zero-emission energy conversion devices. Typically, the PEMFC is used for portable power and transportation due to their compactness, simple-structure and sustainability. For an active electrochemical reaction of PEMFC, a part in which reaction gas, hydrogen ions and electrolyte can coexist is required. This part is called as triple-phase boundary (TPB), and it is important to secure TPB as much as possible during operating the fuel cell. The procedure so-called break-in/conditioning /activation is essential to acquire TPB expansion which described in Figure 1, leading to maximize PEMFC performance. However, using inappropriate conditioning methods can result in unnecessary hydrogen consumption and conditioning time. It is the main assignment to optimize effective conditioning method.

There are hypothetical theories usually mentioned during conditioning procedure are i) Conditioning expands passage of the reactants to reach the catalyst[1]. ii) Membrane of PEMFC is initially dry, hindering the cell performance until the membranes are hydrated during the conditioning[2]. iii) The continuous activity of hydrogen ions and electrons is secured by improving the ion conductivity. Most theories are lack of direct experimental support or concrete experimental validation A systematic investigation of conditioning and its theories about mechanism is still required[3].

The conditioning procedures are classified to two strategies: on-line and off-line conditioning methods. The traditional conditioning methods are as follows. On-line techniques explored include current control[4,5], potential control[7,8,], temperature control[9-11], hydrogen pumping[12], CO stripping[13], and air braking[14]. Off-line methods include electrochemical conditioning of the MEA and steaming or boiling the electrode[15]. In this study, we suggested state-of-the-art conditioning method called Cathode oxygen

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depletion (COD) that is controlled the air-supplying and shortened time to reach maximum MEA performance remarkably. To verify the effect of COD, the commonly used conditioning methods were chosen and compared each performance.

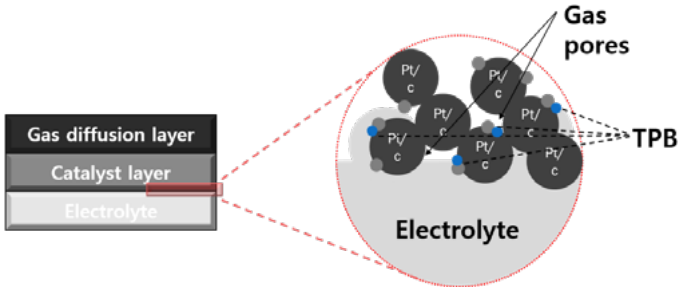

Fig. 1. Schematic of Triple-Phase Boundary (TPB)

2. Experimental

2.1 Description of Experiment equipment set-up

The PEMFC had an active area of 25cm^2. The entire conditioning methods were carried out using Vinatech Co. membrane-electrode-assembly. The Pt loading on the anode and cathode electrodes was 0.4mg/cm^2. The cell was assembled between two graphite plates with serpentine flow channel, current collectors coated with copper and fastened under constant pressure. After assembly, cell was connected to electrode load (PLZ664WA, Kikusui). The heating rods were used to maintain experiment operating temperature. Air and hydrogen gas were humidified and then controlled using mass flow controller (SEHWA Hightech). The flow rate of hydrogen and air were 100 and 200 mL/min, respectively. Experiment equipment diagram was described in Figure 2.

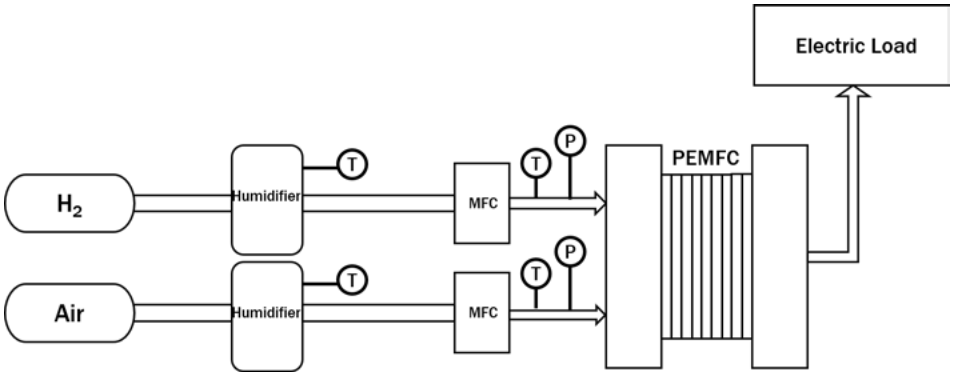

Fig. 2. Schematic of Experiment equipment

2.2 Performance measurement

The conditioned MEA performance was measured in galvanostatic mode and characterized by polarization curve. The applied conditions were maintained at 65℃ under relative humidity (RH) of 100%. For the polarization curve, the electric load was connected to PEMFC. The voltage from 0.9V to 0.1V was hold for 5 minutes at each voltage step. Power density was calculated from the current and applied voltage.

2.3 Conditioning procedures

The three kinds of conditioning methods were conducted in this study: Constant voltage, Constant current and Cathode Oxygen Depletion. Each method is explained below.

(a) Constant voltage. The cell is operated under constant voltage at 0.6V for 4h.
(b) Constant current. The cell is operated under constant current at 0.25A/cm^2 for 21h
(c) Cathode Oxygen Depletion. (i) Constant voltage Open circuit voltage (OCV) operation for 15~20s. (ii) Air supplied off and wait until voltage drops. (iii) Air supplied on and voltage maintains at 0.2V for 30s.

3. Results and discussion

3.1. Polarization curves of MEAs on conditioning methods

The comparison of Polarization curves after conditioning for 2h is shown in Figure 3(a). As can be seen, the OCV of COD, CV and CC has similar value due to experiment condition of temperature and gas partial pressure is equivalent. The current densities at 0.6V of COD, CV and CC are 1.0588 A/cm^2, 0.914A/cm^2 and 0.7632A/cm^2, respectively. We aimed that when the current density reaches above 1.0A/cm^2 at 0.6V, conditioning procedure terminates. According to the performance of COD achieves target value after 2h conditioning, activation using COD is sufficient only 2 hours. However, the performances of CV and CC do not reach aimed current density at 0.6V, it is difficult to finish conditioning within 2 hours.

Figure 3(b) describes the comparison of current density at 0.6V depending on conditioning time. It shows that a rapid performance increase within a short time using COD method. Also, the COD conditioning has its peak performance after 2 hours and maintains steady state as time passes. In case of CV, the performance achieves above 1.0A/cm^2 within 4hours and has steady state after 4hours. On the other hand, performance using CC increases slowly and the target performance does not reach over time.

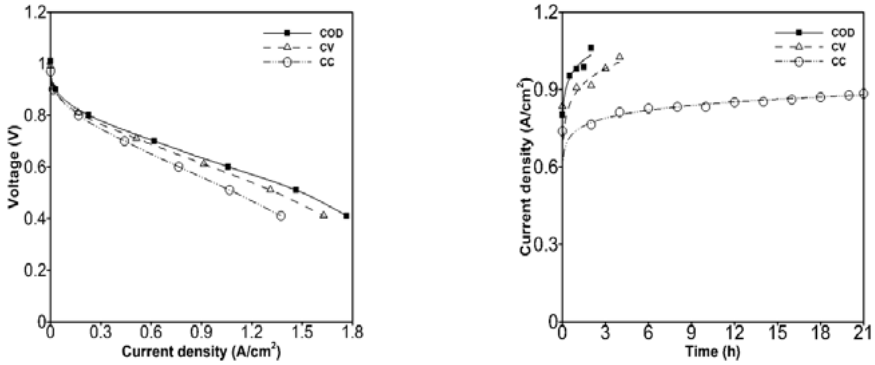

Fig. 3 (a) Polarization curve after 2h of conditioning procedures (b) Current density at 0.6V depending on conditioning time.

3.2. Final performance of conditioning by different procedures

Figure 4 presents the performance of all MEAs after finishing the conditioning procedures. The results show that current densities using COD, CV and CC are 2.062A/cm^2, 2.0308 A/cm^2 and 1.9256 A/cm^2, respectively. Using COD method can acquire highest performance of MEA within only 2hours. Because cod accelerates the catalyst penetration into membrane which is the component of TPB. Then, the MEA performance by CV method obtain second highest performance within 4hours. However, the performance CC has lowest performance and does not reach peak performance of MEA. This result indicates by the fact that amount of produced water in the MEA is insufficient, because it is operated at low current density; therefor the MEA can not be hydrated enough, leading to be unable to achieve aimed performance. Comparatively, investigation

of the conditioning cells shows that COD conditioning procedure is an effective method for conditioning and shorten conditioning time significantly.

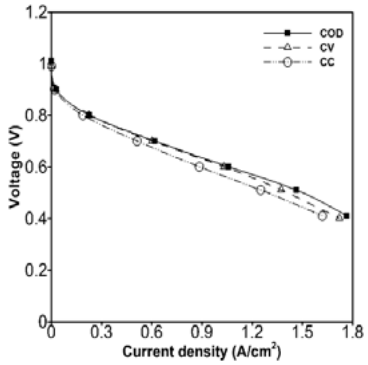

Fig. 4. Polarization curve after end of conditioning procedures

4. Conclusion

The performance of MEA subjected to a new conditioning method: Cathode Oxygen Depletion. Also, the effect of MEA using COD method by comparing commonly used conditioning methods, involving Constant current and Constant voltage. The time required to condition MEA using the COD procedure to reach maximum performance is 2 hours, comparing to 4 hours for CV and 21hours for CC. The results demonstrated that activating by COD conditioning is the most time-effective and secures economics of Fuel cell society.

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