The Electrical Properties of Aluminum Bipolar Plate for PEM Fuel Cell System

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(Received September 8 2004, Accepted October 15 2004)

In this work, we present the electrochemical properties of Al bipolar plate, which can be researched for the application of PEMFC system. Bulk resistance of the plate was measured with a four-point probe method. The electrical conductivity of noble metal coated Al plate was 4.40 x 10^4 S/cm. On the other hand, the electrical interfacial resistance of the noble metal coated Al plate valued at 0.15 mΩ-cm^2 and that of graphite was 0.26 mΩ-cm^2 under the holding pressure of 140 N/cm^2 at the applied current of 5 A. And the performance of Al bipolar plate for PEMFC was evaluated at various conditions. The single cell performance was more than 0.43 W/cm^2 (0.47 W/g) for noble metal coated Al bipolar plate at 50 ℃ under atmospheric pressure in external humidified hydrogen and oxygen condition. As the present results, we could show the results that the noble metal coated Al bipolar plates were favorable in the aspect of electrical properties compared with those of the commercialized resin-impregnated graphite plates.

Keywords : Bipolar plate, PEMFC, Corrosion, Tafel plot, Surface treatment, Conductivity

1. INTRODUCTION

The PEMFC (Polymer Electrolyte Membrane Fuel Cells) are the most promising power sources in the near future for mobile, stationary and portable applications. They offer the potential of compactness, lightweight, high power density and low temperature operation. A first market introduction of portable will be seen in the near future, however there are still issues to work on before fuel cell mobile system will have a big market share. One of the important issues in this context is the availability of low cost bipolar plates. Bipolar plates based on carbon materials have been the main focus of the development activities so far. These materials will fulfill all requirements in the near future. Nevertheless, further cost reduction and increase of power density is beneficial for fuel cell technology. Bipolar plate based on polymer composites offer a high potential to reduce costs and enhance power density.

PEMFCs are efficient, environmentally, and friendly electrical power generators. In order to become commercially viable, it is widely accepted that PEMFC stacks have to be cheaper, lighter, and more compact. An important component of the stack cost and volume is the bipolar plate. These plates separate individual cells of the fuel cell stack and also provide anode and cathode gas to the fuel cell.

Bipolar plate requires several properties to achieve the desired fuel cell stack performance that are electrical conductivity, gas tightness, chemical stability, light-weight and mechanical strength to withstand clamping forces. Also, an optimal bipolar plate should be low-cost and easily manufactured.

Bipolar plates in PEMFCs have typically been made of polymer resin impregnated graphite. However, they are very expensive and it is difficult to machine the gas flow field channels providing gas distribution for the streams. It is considered that the alternative materials to graphite are metals, carbon-carbon composites, and carbon-polymer composites. Therefore, several kinds of composite plates for PEM fuel cells are currently under development to reduce cost, stack volume and weight. In the case of polymer composites remain the problems of progress in the electrical conductivity to be solved.

Generally, PEM fuel cell overall reaction is follow

Anode reaction : $2H_2$ (g) → $4H^+$ + $4e^-$
Cathode reaction : O_2 (g) + $4H^+$ + $4e^-$ → $2H_2O$ (ℓ)
Overall reaction : $2H_2$ (g) + O_2 (g) → $2H_2O$ (ℓ)

In this paper, test results of bipolar plate materials concerning electrochemical properties are presented. Based on the measurements of resistivity and cell performance, the investigated bipolar plates appeared to be proper for that of PEMFC.

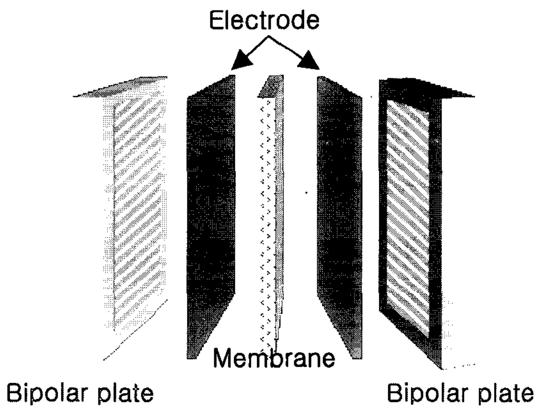

Fig. 1. The structure of PEM fuel cell.

2. EXPERIMENTAL

Al was used as the raw material of bipolar plates. The bipolar plate had a thickness less than 3 mm and an active area ranging 25-240 cm^2. The gas flow field with a channel structure was fabricated onto bipolar plate by CNC machining, and then noble metals Pd-Ni (0.5-1.0 μm) were coated on the surface of Al bipolar plate by electroplating to prevent corrosion and/or apply electrical conductivity. The Al plate shape is showed in Fig. 2.

The bulk resistance of the plate was measured using a four-point probe. On the other hand, the electrical interfacial resistance measurements were conducted by measuring the potential between the plates and the gas diffusion media of carbon cloth in a single cell structure, which was roughly modified with a typical unit arrangement in PEMFC, under the various holding pressures of 140, 200 and 300 N/cm^2 at the applied current of 5 A. The corrosion rate was measured with the Tafel method by EG&G 273A potentio/galvanostat. The performance of the single cells with an active area of 240 cm^2 was evaluated at various conditions.

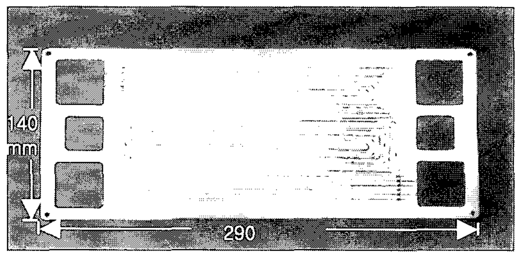

Fig. 2. Pd-Ni coated Aluminum bipolar plates (active area 240 cm^2).

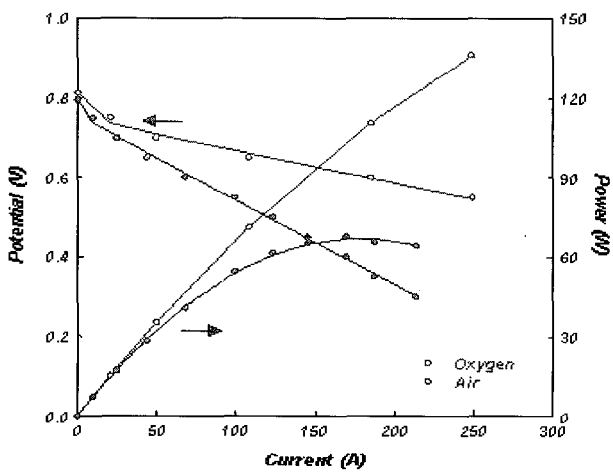

Fig. 3. Pd-Ni coated Al bipolar plates using of 240 cm^2.

3. RESULTS AND DISCUSSION

In this work, processes for making up the flow fields as well as preparation of bipolar plates for PEMFC, which consisted of new materials, was studied. It was found that Al was favorable in terms of its electrical and physical properties compared with conventional resin-impregnated graphite block. The gas flow fields were fabricated by injection molding onto these bipolar plates. The thickness of these bipolar plates is less than 3 mm. Pd-Ni (0.5-1.0 m) was coated on the surface of metal bipolar plates. Figure 2 shows the coated bipolar plates used in this study. The Pd-Ni coated Al bipolar plate has an active area of 240 cm^2, respectively.

The Bulk resistance of the plate was measured with a four-point probe method. The electrical conductivity of polymer composite plate was $4.40x10^3$ S/cm ($2.27x10^{-4}$ Ω -cm), respectively. It is considered that the plate in this work possess very superior electrical conductivity due to noble metal coating on the surface of substrate, since the target value in US DOE is set up over 100 S/cm.

The results of electrical interfacial resistance measurement under various holding pressures at the applied current of 5 A were shown in Table 1. The values of electrical interfacial resistance tend to decrease in accordance with increasing the holding pressures regardless of plate materials. The electric interfacial resistance of the Pd-Ni/Al plate was valued at 0.15 mΩ -cm^2 and that of graphite was 0.26 mΩ -cm^2 under the holding pressure of 140 N/cm^2 at the applied current of 5 A. As considering these results in all aspects, in the case of Pd-Ni/Al plate electrical properties remain to be improved as a subject in the future.

Table 1. Electrical interfacial resistance under various holding pressures at applied current of 5 A.

	R (mΩ -cm^2) at 5 A		
	140 N cm^{-2}	200 N cm^{-2}	300 N cm^{-2}
Graphite (current)	0.26	0.20	0.16
Au coated aluminum	3.05	3.23	3.17
Pd-Ni coated alumiunm	0.15	0.13	0.10

Table 2. The corrosion test for bipolar plates by Tafel method.

	E_{corr} (mV)	I_{corr}(mA/cm^2)
Au coated aluminum	-320	9.8
Pd-Ni coated alumiunm	-338	1.38
Alumiunm	-628	122

The corrosion rate of the coated plates was valued about in the ranges of 2~10 μA/cm^2. It reveals that anti-corrosion property of the coated plates is superior to aluminum which shows corrosion rate of 122 μA/cm^2. The results of corrosion current density (i_{corr}) and corrosion potential (E_{corr}) were summarized in Table 2. The performance characteristics of the cells with active area of 240 cm^2 were evaluated at various conditions. The single cell performance using a commercial membrane and electrode assembly (MEA) was 0.43 W/cm^2 (0.47 W/g) for Al bipolar plate with that of 240 cm^2 at 50 ℃ under atmospheric pressure in external humidified hydrogen and oxygen condition. The unit cell long-term test was accomplished at 50 ℃ under atmospheric pressure in hydrogen and air condition.

Table 3. The comparison of flexible property for Al plate.

	Yield strength (kg_f/cm^2)	Modulus (kg_f/cm^2)
Graphite	716	102,090
Graphite foil	216	39,259
Pd-Ni / Al	2,354	613,571

Table 4. The comparison of performance used aluminum bipolar plate.

Plate	Performance (kW/kg)
Graphite (current)	o.48
Au coated Aluminum	0.36
Pd-Ni coated Alumiunm	0.47

Figure 4 show life performance test of unit cell using a noble coated Al plate with 240 cm^2 as graphite alternative materials, respectively. As shown in Fig. 4, it is confirmed that polymer composite plate test cell has been operated favorably for 600 hr without degradation of efficiency. Long-run test has been continuously being progressed up to now. In addition, it was shown the plates became to have better performance at high current densities. It might be an affirmative result in fuel cells for automobile, which relies on high current densities.

The single cell performance was 0.43 W/cm^2 for noble metal coated Al bipolar plate with an active area of 240 cm^2. The power density is showed favorable specific power over 0.47 kW/kg used Pd-Ni/Al bipolar plate. Preliminary manufacturing cost of Pd-Ni coated bipolar plate in this laboratory scale was approximately estimated at 15~40 $/kW. It would be possible to reduce cost by constructing optimum process and mass production.

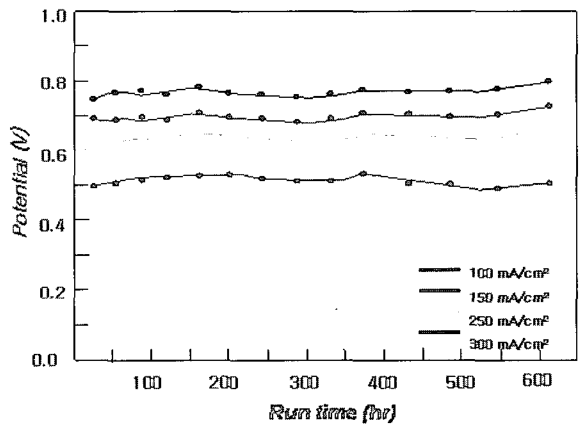

Fig 4. Life performance of unit cell (240 cm^2).

4. CONCLUSION

The Al bipolar plates have been studied for the application of PEM fuel cell. It was found that Al plate show superior electrical conductivity by noble metal coating on its surfaces. The power density was 0.43 W/cm^2 for Al at 50 ℃ under atmospheric pressure in external humidified hydrogen and oxygen condition. It was shown that no visible decrease of efficiency occurred in Pd-Ni coated Al bipolar plate for 600 hr during the unit cell long-run test at 50 ℃ under atmospheric pressure in external humidified hydrogen and air condition.

It is believed that Pd-Ni coated Al is one of the most promising candidate materials for PEM fuel cell bipolar plates with respect to electrical and physical performance characteristics including specific power, mechanical properties and manufacturing cost.

ACKNOWLEDGEMET

This work was supported by Chungbuk National Univertsity Grant in 2004

This work was supported in part by 21st Century COE program "Waseda Univ. Practical Nano-Chemistry" by MEXT.

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