

# Characteristics of DMFC Using High Porous Active Carbon as an Uncatalysed Diffusion Layer in Anode Electrode

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(Received 4 January 2000; accepted 1 June 2000)

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## Abstract

Performance of direct methanol fuel cell using high porous active carbon as an uncatalysed diffusion layer in anode (composite electrode) has been evaluated. Effects of porous active carbon in anode were investigated by galvanostatic method and Fourier Transform Infrared spectroscopy. The single cell was operated with 2.5 M methanol at temperature of 80-120°C and showed performance of 210-510 mA/cm<sup>2</sup> at 0.4V. By replacing conventional electrode with composite electrode, the increment of 90 mA/cm<sup>2</sup> in current density was obtained at 90°C and 0.4V. The potential decay of the single cell was about 14.5% for 20 days operation.

**Keywords :** Direct Methanol Fuel Cell, Activated Carbon, Composite Electrode, I-V Characteristics

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## 1. Introduction

Direct methanol fuel cells (DMFC) using polymer electrolyte membrane are promising candidate for application of portable power sources and electric vehicle because they do not require any fuel processing equipment and can be operated at low temperature of 60°C-130°C [1-3].

Considerable efforts have recently been made in the field of DMFC electrocatalysis [4, 5]. Systems consideration for whole fuel cell units requires a certain advanced stage in fuel cell electrocatalysis and preparation of membrane and electrode assembly (MEA) to improve cell performance. Gas flow distribution is also important.

To prepare high performance electrode in DMFC, pretreatment conditions, morphology and structure of catalyst, and operating conditions of the DMFC have been studied [6-8]. The key to cell construction is the MEA that lies at the center of the single cell system. Optimization of the MEA can improve the overall energy efficiency of the fuel cell by changing not only the design of the mechanical framework but also the electrode types whether the electrode has an uncatalysed porous diffusion layer in anode (composite electrode) or not (conventional electrode). In the DMFC system, mixed methanol solution with water is used as anode fuel for producing proton by the oxidation of methanol. A hydrophilic high porous carbon as an uncatalysed diffusion layer in the anode could extend the retention time of fuel at the anode side by the rich adsorption of the fuel into the micropore of the carbon, and could increase the contact area between the fuel and catalyst layer.

In this study, the characteristics of direct methanol fuel cell using high porous active carbon as an uncatalysed diffusion layer in anode (composite electrode) have been investigated.

Effects of porous active carbon in anode were evaluated by galvanostatic method and Fourier Transform Infrared (FT-IR) spectroscopy. I-V characteristics of direct methanol fuel cell were tested with single cell test apparatus at various operating conditions.

## 2. Experimental

### 2.1. Characteristics of composite electrode

Characteristics of composite electrode were analyzed with FT-IR spectrometer (JASCO Co.) and with half-cell test by using Potentiostat/Galvanostat (M283, EG&G Co.). Half-cell test was carried out in an air-sealed glass that had three separate compartments for the working, counter, and reference electrode. Active carbon coated on 60%Pt-Ru/C (3 mg/cm<sup>2</sup>) supported on carbon cloth (E-tek Inc.) was used for working electrodes having geometric area of 0.64 cm<sup>2</sup>. Platinum gauze (99.999%) was used as the counter electrode. A reversible hydrogen electrode (RHE) was used for the reference electrode. Galvanostatic polarization was performed by using Potentiostat/Galvanostat controlled by IBM PC in 0.5 M H<sub>2</sub>SO<sub>4</sub> and 1 M CH<sub>3</sub>OH at constant temperature of 30°C.

### 2.2. Preparation of electrode and MEA

Anode reaction of DMFC using liquid methanol occurs on the two-phase interface of methanol and solid catalyst layer. To improve reaction efficiency of methanol in anode, a higher methanol adsorption will be necessary in the electrode diffusion layer. Active carbon or active carbon fiber, which have high surface area with hydrophilic groups such as carboxyl and phenol groups, could be considered as an uncatalysed diffusion layer in anode. In this study, active

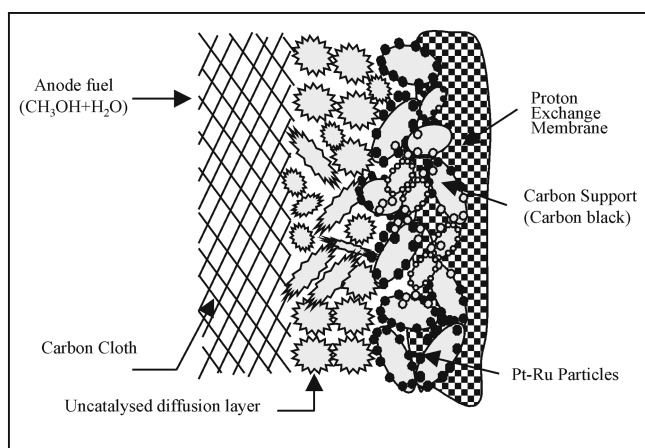


Fig. 1. Schematic representation of Nafion impregnated carbon composite electrode having an uncatalysed diffusion layer in anode between carbon cloth and catalyst layer.

carbon powder having surface area of  $1500 \text{ m}^2/\text{g}$  (Kuraray chemical co.) was used as an uncatalysed diffusion layer material.

The schematic representation of anode part of DMFC is shown in Fig. 1. Carbon cloth was used as a supporting material of the electrode. An uncatalysed diffusion layer was prepared by coating  $3 \text{ mg}/\text{cm}^2$  of mixed active carbon powder with 5% of Nafion solution on the carbon cloth. 60%Pt-Ru/C ( $3.0 \text{ mgPt}/\text{cm}^2$ ) and 60%Pt/C ( $3.0 \text{ mgPt}/\text{cm}^2$ ) powder were used as anode and cathode catalysts, respectively. An uncatalysed diffusion layer was located between carbon cloth and anode catalyst layer.

Membrane and electrode assembly (MEA) with Nafion 117 (Dupont) electrolyte was fabricated by hot pressing at  $120^\circ\text{C}$  and  $100 \text{ kg}/\text{cm}^2$  for 120s after applying about  $0.6 \text{ mg}/\text{cm}^2$  of 5% Nafion solution (900 equivalent weight, Aldrich) onto the surface of anode and cathode electrode.

### 2.3. Performance test of single cell

MEA was loaded into a single cell test fixture. The single cell fixture was composed of two copper current collector end plates and two graphite plates serial flow channel patterns allowing the passage of the mixed methanol to the anode and oxygen to the cathode. The single cell was connected to a fuel cell test station with an electrode load. An active electrode area of  $7.25 \text{ cm}^2$  was evaluated at the temperature of  $80^\circ\text{C}$ - $120^\circ\text{C}$ . The methanol concentration of 2.5 M with the flow rate of  $10 \text{ ml}/\text{min}$  and pure oxygen with the flow rate of  $300 \text{ ml}/\text{min}$  was supplied to the anode and the cathode, respectively. The mixed methanol was supplied to the anode through a peristaltic pump and a vaporizer maintained at same temperature of the cell. Oxygen was fed to the cathode at 2 atm.

## 3. Results and Discussion

Fig. 2 shows galvanostatic polarization of composite and

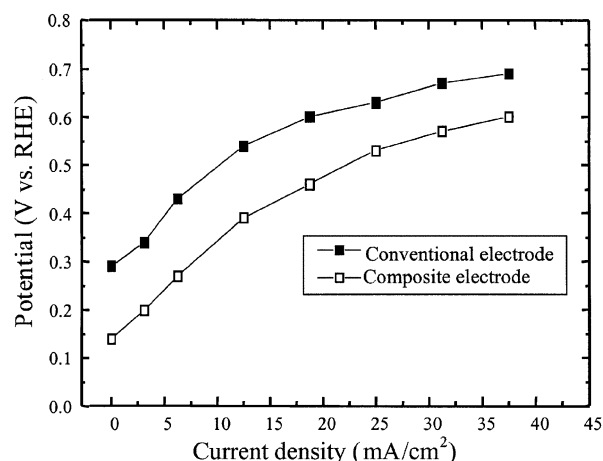


Fig. 2. Galvanostatic polarization of composite and conventional electrodes in  $0.5 \text{ M H}_2\text{SO}_4 + 1 \text{ M CH}_3\text{OH}$  solution at  $30^\circ\text{C}$ .

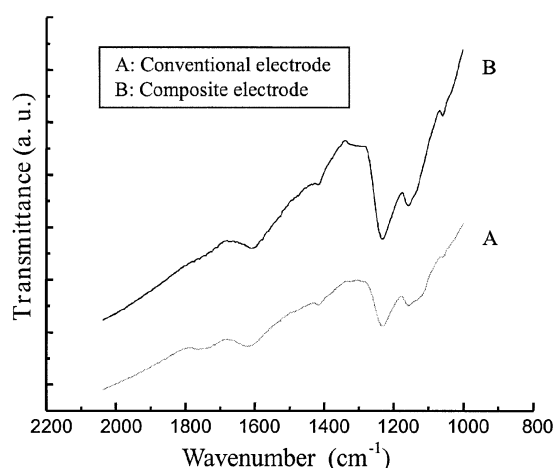


Fig. 3. FT-IR spectra of composite and conventional electrodes.

conventional electrode in  $0.5 \text{ M H}_2\text{SO}_4 + 1 \text{ M CH}_3\text{OH}$  solution at  $30^\circ\text{C}$ . As shown in the Fig. 2, electrode potential was increased with the increasing of current density. At constant current density of  $25 \text{ mA}/\text{cm}^2$ , electrode potential of composite electrode is shown about  $0.5 \text{ V}$  vs. RHE. To compare this potential with that of conventional electrode, the electrode potential of  $0.1 \text{ V}$  vs. RHE was decreased.

FT-IR spectra of the electrode material are shown in Fig. 3. As shown in the Fig. 3, bands at  $1000$ - $1200 \text{ cm}^{-1}$  were attributed to either carboxyl or phenol groups. Another band at  $1600 \text{ cm}^{-1}$  was attributed to aromatic ring systems. The intensity of IR bands at  $1000$ - $1200 \text{ cm}^{-1}$  and  $1600 \text{ cm}^{-1}$  of composite electrode were higher than that of conventional electrode. From the results of Fig. 2 and Fig. 3, the performance of composite electrode was attributed to the increase of hydrophilic groups, such as carboxyl and phenol groups, in high porous active carbon.

Fig. 4 represents the I-V characteristics of DMFC single cell using composite electrode at the operating temperature of  $80^\circ\text{C}$ - $120^\circ\text{C}$ . As shown in Fig. 4, at potential of  $0.4 \text{ V}$ , the current densities are in the range of  $210 \text{ mA}/\text{cm}^2$  to  $510 \text{ mA}/\text{cm}^2$ .

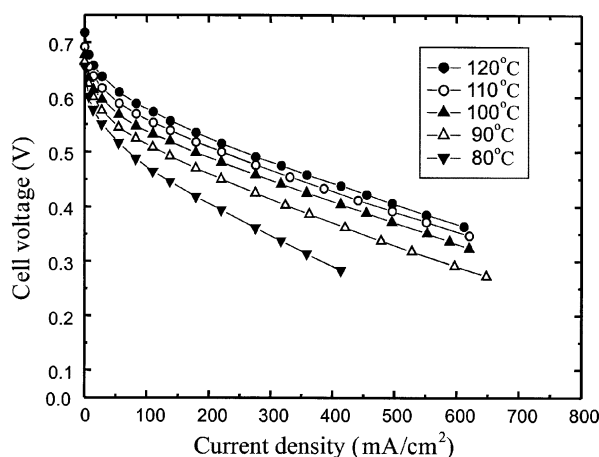


Fig. 4. I-V characteristics of a DMFC single cell at temperature of 80-120°C: anode, 60%Pt-Ru/C (3.0 mgPt/cm<sup>2</sup>), 2.5 M methanol at 9 ml/min; cathode, 60%Pt/C (3 mgPt/cm<sup>2</sup>), 2 kg/cm<sup>2</sup> O<sub>2</sub> at 300 ml/min.

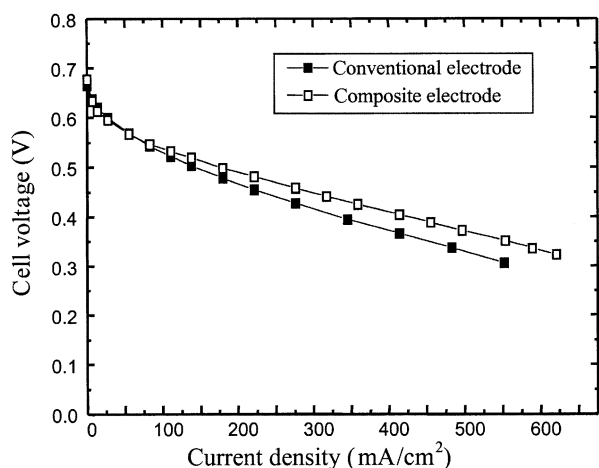


Fig. 5. I-V characteristics of DMFC single cell using by composite and conventional electrodes in anode at 90°C: anode, 60%Pt-Ru/C (3.0 mgPt/cm<sup>2</sup>), 2.5M methanol at 9 ml/min; cathode, 60%Pt/C (3 mgPt/cm<sup>2</sup>), 2 kg/cm<sup>2</sup> O<sub>2</sub> at 300 ml/min.

cm<sup>2</sup>. At high temperature, the high performance is attributed to the combined effects of decreasing of resistance and polarization.

I-V characteristics of DMFC single cell used composite and conventional electrode at 90°C are shown in Fig. 5. As is shown in the figure, current densities of composite and conventional electrode at cell voltage of 0.4 V were 427 mA/cm<sup>2</sup> and 336 mA/cm<sup>2</sup>, respectively. By replacing conventional electrode to composite electrode, increasing of current density about 90 mA/cm<sup>2</sup> was obtained. It is clearly attributed to the increasing methanol diffusion from fuel channel to electrode catalyst layer, and the improvement of contact area of catalyst layer with the fuel due to the hydrophilic porous active carbon as an uncatalysed diffusion layer in anode.

Fig. 6 shows the endurance test of DMFC single by using composite electrode as anode at constant current densities of

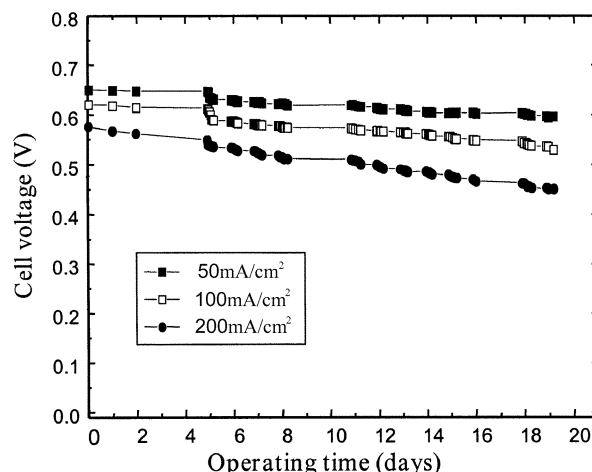


Fig. 6. Endurance test of DMFC single by using composite electrode as anode at constant current densities of 50, 100 and 200 mA/cm<sup>2</sup> for 20 days at 90°C. anode : 60%Pt-Ru/C (3.0 mgPt/cm<sup>2</sup>), 2.5 M methanol at 9 ml/min. cathode: 60%Pt/C (3 mgPt/cm<sup>2</sup>), 2 kg/cm<sup>2</sup> O<sub>2</sub> at 300 ml/min.

50, 100 and 200 mA/cm<sup>2</sup> for 20 days. To reduce variation of methanol concentration, mixed methanol with water was refilled to fuel tank at the days of 5, 7, 12, and 15th. As shown in the figure, at constant cell current density, the cell voltage is decreasing with the increasing operating time. The voltage at constant current density of 100 mA/cm<sup>2</sup> was slightly reduced from 0.62 V to 0.53 V with the voltage decay rate of 14.5%. Voltage drop of DMFC for long run operation is due to the poison of Pt by CO and structure change of Pt-Ru catalyst [7].

#### 4. Conclusions

Performance characteristics of DMFC in which a hydrophilic high porous carbon was used as an uncatalysed diffusion layer in anode (composite electrode) were investigated. The increased performance with composite electrode was attributed to the increase of hydrophilic groups, such as carboxyl and phenol groups, in high porous active carbon. The current densities of DMFC single cell at 0.4 V using composite electrode with the operating temperature of 80°C-120°C were obtained in the range of 210 mA/cm<sup>2</sup> to 510 mA/cm<sup>2</sup>. By replacing conventional electrode with composite electrode as anode electrode, increment of 90 mA/cm<sup>2</sup> in current density was obtained. Endurance test of the electrode for 20 days, the cell voltage at constant current density of 100 mA/cm<sup>2</sup> was reduced from 0.62 V to 0.53 V.

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