Studies on the characteristics of the catalyst layer of the PEMFC Electrode
고분자전해질막 연료전지의 촉매층 특성에 대한 연구

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Abstract
The present paper highlights on the need to understand the correlation of the characteristics of the catalyst layer with the performance of the polymer electrolyte membrane fuel cell. The paper deals with the correlation of the platinum loading in the catalyst layer and the performance of the Polymer Electrolyte Membrane Fuel Cell(PEMFC) and also the correlation of the required hydrophiliticity/hydrophobicity in the catalyst layer to get the optimum performance under given operating conditions.

1. Introduction

Polymer Electrolyte Membrane Fuel Cell has been gaining a lot of attention on account of its simplicity of operation and high power density for both stationary and mobile applications[1-4]. A lot of work has been reported on the methods of reducing platinum loading in the catalyst layer and on improving the utilization of Platinum[5-11]. In order to improve the efficiency and improve the utilization of platinum, it is reported that a non-uniform catalyst loading is desirable. The stated advantage of the non-uniformity is that a progressive increase in electrocatalyst loading corresponding with the direction along the gas flow channel from the inlet to the outlet so that a uniform current distribution is achieved across the surface of the electrode.

Various methods of fabrication of the electrodes have also been reported. Ideally a three-phase contact has to be established between the electrolyte, electrode and the reactant gases. The electrode has to be hydrophobic in character to prevent the flooding of the electrodes, which can happen, with the filling of the pores of the electrodes by the electrolyte or water. When flooding occurs, it becomes more difficult for the reactant gases to diffuse through to the catalyst sites and also for water, the product of the fuel cell reaction to diffuse out of the electrode structure and the cell performance drops. The problem of flooding was reported[12] to have been overcome by depositing layers onto a substrate in which each layer contains different proportions of catalyst and hydrophobic and hydrophilic agglomerates. This layered structure is reported to assist in maintaining a correct balance between electrode pores which are electrolyte repellant and allow gas flow, and those which are wettable to the electrolyte and fill with the electrolyte material. However, an electrode structure is disclosed[13] in which deposition of almost all of the catalyst onto a single hydrophilic region while minimal deposition in a single hydrophobic material.

In the present paper an attempt has been made to understand the need for the requirement of hydrophobicity or hydrophilicity in the catalyst layer under given operating conditions. The correlation of performance of PEMFC with the catalyst loading is also presented. Energy Dispersive X-ray Spectroscopy(Phoenix ver. 3.0) is done to analyse the amount of platinum present on the surface for different platinum loading in the catalyst layer.

2. Experimental

The electrocatalyst used for the preparation of the MEAs was 20% Pt on Vulcan XC-72 (E-TEK Division of De Nora North America Inc., USA). The backing layer of the electrode was teflonised carbon paper (GDL 10-H, SGL Carbon Group Technologies Sigracet). Nafion 115™ was used as the polymer electrolyte membrane. Nafion 5 wt.% solution supplied by Du Pont Inc., U.S.A. was used as the polymer electrolyte. Hydrophobic type catalyst ink was prepared by mixing teflon emulsion, 20% Pt on Vulcan XC-72, water and IPA in proper proportions. Hydrophilic type catalyst ink was prepared by mixing Nafion(5 wt.%) solution with 20% Pt/C. The ink was applied on the support structure by brush method. Hydrophobic layer was sintered at 320℃ for 15 minutes. Before the MEA was made Nafion(5% by wt.) solution was brushed on the sintered surface to extend the two-dimensional reaction zone into a three-dimensional zone[5]. The electrodes with $5cm^2$ area were hot-bonded on Nafion 115 membrane at 120 ℃. MEA assemblies were tested using Won-A-Tech(HPCS 1) at 80℃ and the reactants were kept at a pressure of 1 atm. The hydrogen and oxygen humidification temperatures were maintained at 90℃ and 85℃, respectively.

3. Results and Discussion

The effect of increase in platinum loading on the fuel cell performance is given in Fig.1. It can be clearly seen that with increase in Platinum loading the performance of the PEMFC is higher. This is also shown by Energy Dispersive Spectroscopy(Fig.2) for Pt loading of $0.25\ mg/cm^2$ and $0.50\ mg/cm^2$.

The results of the experiments in which the catalyst layer was either made more hydrophobic or hydrophilic or a combination of both are given in Fig.3. It can be clearly seen that the performance of the MEA assembly in which the catalyst layer is made as a two layered structure with hydrophobic and hydrophilic was better than those in which the catalyst layer is made either more hydrophilic or hydrophobic. The reason could be for proper electrochemical reaction to take place, three phase contact of the reactant, electrolyte and catalyst is required. This is facilitated by the hydrophilic layer in which the Nafion solution and supported catalyst are properly mixed[6-7, 14-15]. The flooding of the pore structure is prevented by having an adjoining layer which is more hydrophobic in nature.

4. Conclusions

Optimal loading of the platinum is required to achieve better performance. In order to achieve better utilization of platinum with lower loading, different method of fabrication of catalyst layer may be advisable. A combination of hydrophobic and hydrophilic layered catalyst structure is preferred rather than having exclusively more hydrophobic or more hydrophilic catalyst structure.

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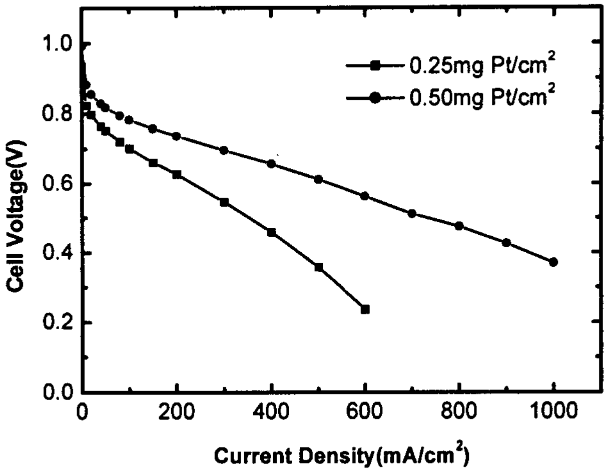

Fig. 1. Effect of platinum loading on the fuel cell performance.

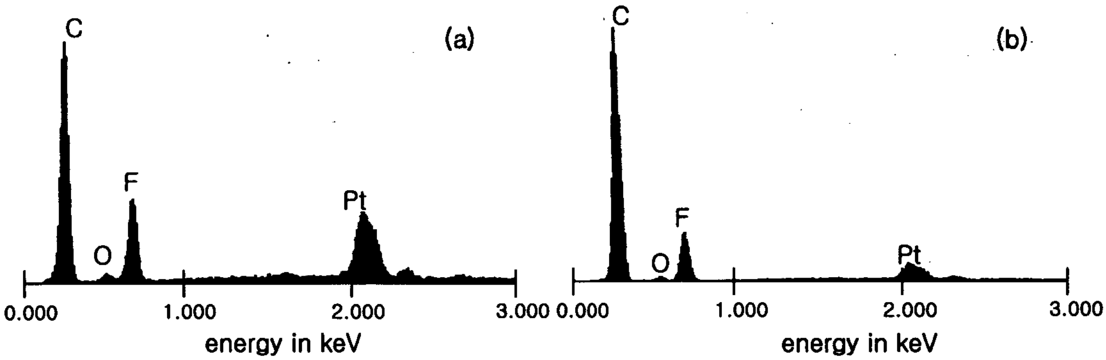

Fig. 2. Comparative availability as shown by EDS of platinum on the surface for different platinum loadings in the catalyst layer : (a) 0.50 mg Pt/cm^2, (b) 0.25 mg Pt/cm^2.

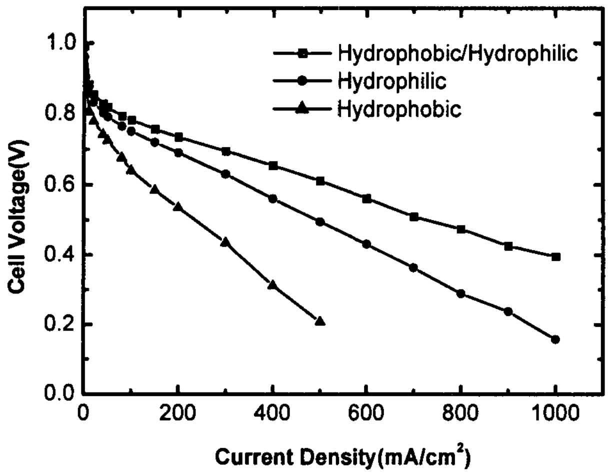

Fig. 3. Effect of hydrophilicity/hydrophobicity on the performance of fuel cell.