

Studies on the Characteristics of the Catalyst Layer of the PEMFC Electrode

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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 (PEMFC). This paper deals with the correlation of the platinum loading in the catalyst layer and the performance of the polymer electrolyte membrane fuel cell and also the correlation of the required hydrophilicity/hydrophobicity in the catalyst layer to get the optimum performance under given operating conditions.

Key words : PEMFC, Hydrophilic, Hydrophobic, Catalyst layer, Platinum loading

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 applications¹⁻⁴. A lot of work has been reported on the methods of reducing platinum loading in the catalyst layer and on improving the utilization of platinum⁵⁻¹¹. In order to improve the efficiency and the utilization of platinum, it is reported that a uniform catalyst loading is desirable.

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 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 reported¹² 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 repellent and allow gas flow, and those which are wettable to the electrolyte and fill with the electrolyte material. However, an electrode structure is disclosed¹³ 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. The amount of platinum on the surface for different platinum loading in the catalyst layer is analyzed by using Energy Dispersive X-ray Spectroscopy (Phoenix ver. 3.0).

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 a teflonized carbon paper (Sigracet GDL 10-H, SGL Carbon Group Technologies). Nafion 115TM was used as the polymer electrolyte membrane. 5 wt.% Nafion 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 catalyst ink was made from a slurry containing Nafion solution (5 wt.%), Pt/C (20%) and isopropyl alcohol after subjecting it to ultrasonication. The ink was applied on the support structure by brush method. The hydrophilic catalyst ink coated electrode was dried only at 80°C. Hydrophobic layer was sintered at 320°C 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 zone⁵. The electrodes with 5cm² area were hot-bonded on Nafion 115 membrane at 120°C. Membrane electrode assemblies (MEAs) were tested using HPCS 1 (Won-A-Tech, Korea) at 80°C and the reactants were kept at 1 atm. The hydrogen and oxygen humidification temperatures were maintained at 90 and 85°C, 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

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PEMFC is enhanced until a loading of 0.5 mg/cm^2 . When the loading is increased further to 0.75 mg/cm^2 , there is no further improvement in the performance. The additional platinum loading might not have surface availability of electrode. It is well understood that the electrode reaction takes place at the interface is reported to be order of 10 micron thick. For better performance of the electrode, the catalyst availability at the interface has to be the maximum. In the present study, it is found that on increasing the platinum loading from 0.25 mg/cm^2 and 0.50 mg/cm^2 , the performance has improved. EDS analysis (Fig. 2) also shows the greater availability platinum on the surface.

The results of the experiments in which the catalyst layer

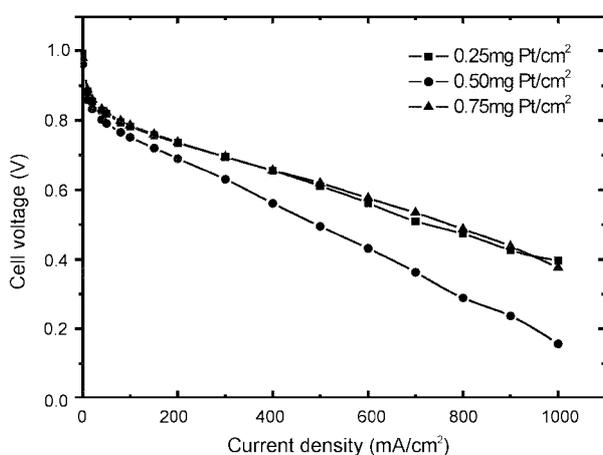


Fig. 1. Effect of platinum loading on the fuel cell performance.

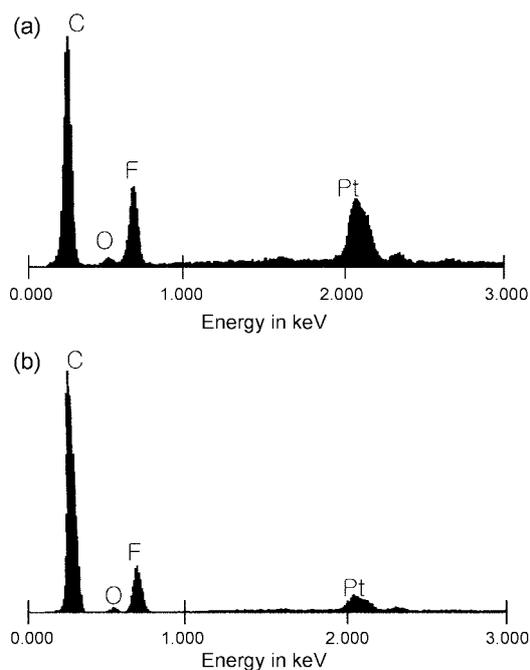


Fig. 2. Comparative availability as shown by EDS of platinum on the surface for different platinum loadings in the catalyst layer : (a) 0.50 mg Pt/cm^2 , (b) 0.25 mg Pt/cm^2 .

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 in which the catalyst layer is made as a single hydrophilic layer or a two hydrophobic and hydrophilic layers is better than that in which the catalyst layer is made more hydrophobic. The reason could be that three phase contact of the reactant, electrolyte and catalyst is required for proper electrochemical reaction to take place. 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. The amount of Nafion that needs to be present in the hydrophilic layer was studied by variation of Nafion amount with respect to Pt/C. The results are presented in Fig. 4. The optimum ratio of Nafion to Pt/C was found to be 1 : 4. Decrease in the ratio (0.4 : 4) results in poor contact of the electrolyte with the electrode particles. Similarly, too high a concentration of Nafion ionomer (2 : 4) results only in increasing the mass transfer polarization since the pores of the electrodes are

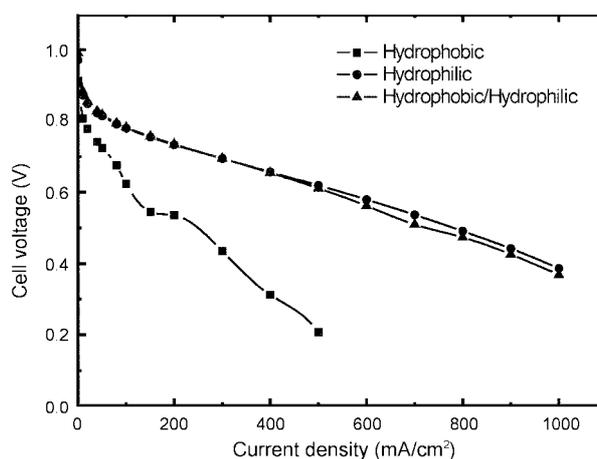


Fig. 3. Effect of hydrophilicity/hydrophobicity on the performance of fuel cell

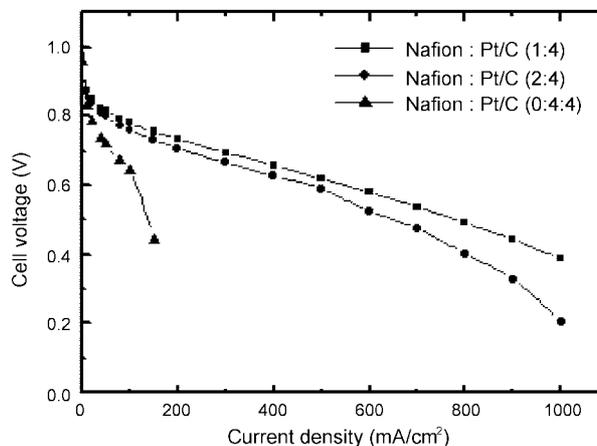


Fig. 4. Effect of Nafion content in the catalyst layer on the performance of fuel cell.

likely to be blocked by the increased amount of the Nafion ionomer.

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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