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Applications of PVA/PAA proton exchange membrane in fuel cell

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Abstract

Different ratios of PVA (polyvinyl alcohol) and PAA (polyacrylic acid) blending films were prepared by solution casting method. Sample thicknesses of the films were about 70~80 μ m. The polymeric blending films were used as the proton exchange membranes in fuel cell in this study. The structure of proton exchange membranes were investigated by X-ray and SEM. The crystallinity of the membranes was decreased as the PAA component increases. In addition, the ionic conductivity was examined with AC Impedance, the value was increased to 10⁻⁶ order and the open current voltage of the membranes can be approached to 0.6 V in fuel cell.

I. Introduction

In recent years, fuel cell applications capable of transforming fuel into energy directly and efficiently have attracted more attention due to the consideration of environment protection [1]. Among the fuel cells the PEMFC shows great advantages such as low operation temperature, high power density with respect to weight and volume of the cell, and easy start-up. In this study, new proton exchange membranes are prepared and applied in fuel cell. A large number of usage on the fossil energy results in a serious air pollution, greenhouse effect, and makes global climate changed, natural ecology destroyed. It is imperative to look for new and clear ways to produce and use energy. The fuel cell provides a way to produce high-efficiency electricity without any pollution. In this study, we choose the polyvinyl alcohol (PVA) and polyacrylic acid (PAA) resins to prepare the proton exchange membranes, since their excellent hydrophilic properties and the blending films can be easily formed by solution casting method. The co-solvent used for the PVA/PAA system is pure water; this is another advantage for the sample preparation. The purpose of this article, we are not only prepared the proton exchange membranes from the PVA and PAA materials, but also characterized the properties of the blending films by FTIR, X-ray, SEM, and AC impedance spectroscopy. The open-circuit voltage of the blending films used as the proton exchange membranes also tested by fuel cell testing system in this study.

II. Experiment

Polyvinyl alcohol (PVA) and polyacrylic acid (PAA) were dissolved in deionized water to form a 5% solution. Weight ratios of PAA to PVA were fixed at 0/100, 10/90, 20/80, 30/70, 40/60, 50/50, 100/0. Each solution was stirred and heated overnight to ensure complete dissolution.

Blending films were prepared by casting the solutions onto glass plates at room temperature. All films were dried in the ambient condition first, and then dried at 75°C 8 hours under vacuum.

X-ray diffraction data were obtained using MacScience M03XHF²² type XRD system. Each sample was scanned with Cu K α radiation (40KV, 30mA) of wavelength $\lambda=0.154$ nm at a continuous scan rate of 5deg/min. X-ray scanning range covered from 10 to 35°. The cross-section morphology of the membranes was observed by a JEOL-6360 scanning electron microscopy operating at a 15 kV accelerating voltage and under secondary electron image mode. All of the blending membranes were fractured in liquid nitrogen. A layer of gold was coated on the fracture surfaces by vapor deposition using a vacuum sputter (Sputter JEOL JFC-1100E) prior to SEM characterization. The resistances of the blending membranes were measured by AC impedance spectroscopy (Autolab PGSTAT30). All the membranes were not soaked with any solutions before conductivity measurement. The ionic conductivity, σ , can be calculated by Eq. (1)

$$\sigma = l / R \times A \quad (1)$$

where l is the thickness of the membrane, A is the area of the blocking electrode, and R is the resistance obtained from the AC impedance spectroscopy [2]. The open-circuit voltage of different ratios blending films was measured by fuel cell testing system at room temperature.

III. Experimental Results and Discussion

X-ray diffraction (XRD) spectroscopy could be used to investigate the change in the crystalline structure. The X-ray patterns of pure PVA, PVA/PAA, and pure PAA were shown in Fig. 1, respectively. The peak at $\sim 21^\circ$ represented the (101) crystal plane of pure PVA [3]. The (101) crystal peak was gradually broadened as more PAA adding, this can be observed evidently in Fig. 1. This means that the degree of crystallinity of the blending films was decreased as PAA increased. The broad peak of the pure PAA was corresponding to amorphous arrangement of the polymer chains. The amorphous characteristic could have enhanced the ionic conductivity due to the more flexible local chain segmental motion in the polymeric matrix [4, 5].

The SEM pictures (Figs. 2a-d) of PVA/PAA blending films provided the information on the change of cross-section morphology. In Figs. 8(a), (b), It has been found that there is no phase separation for the PVA/PAA blending films and no obvious cavity could be found in this structure. In Figs. 2(c), (d), wrinkles were exhibited on the surface when PAA content over 40%. In Figs. 8(c), (d), we

also can found that the fracture surfaces at the cross-section of the blending films were strongly influenced by the PAA adding amount.

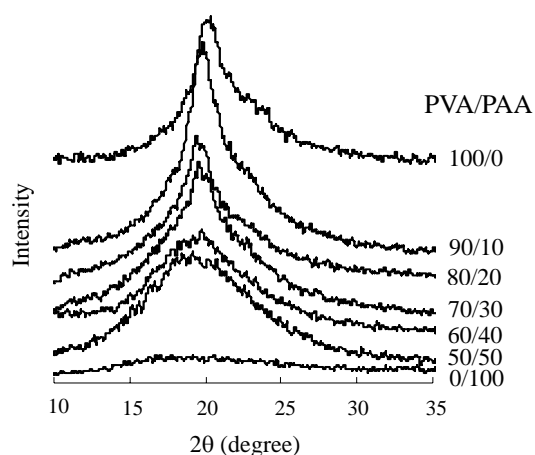


Fig. 1. X-ray diffraction spectra different ratios of PVA/PAA blending films.

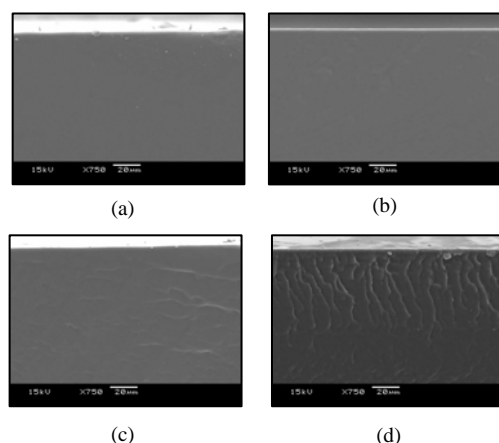


Fig. 2. SEM micrographs of PVA/PAA (a) 90/10; (b) 80/20; (c) 60/40; (d) 50/50.

Fig.3. shows the ionic conductivity of PVA/PAA polymer membrane electrolytes of the various compositions. It has been evidenced that the ionic conductivity of PVA/PAA polymer membrane electrolyte increases as PAA content is increased. The reason is that the amorphous characteristic of PAA could have enhanced the ionic conductivity [4].

The open-circuit voltages of different PVA/PAA blending films were shown in Fig. 4. Here we found that the open-circuit voltage of the fuel cell is very low, when a small amount (10% PAA) of PAA adding into PVA, but it would be increased to 0.6 V as PAA increased approached to 50%. The reason is that the amorphous characteristic could have enhanced the ionic conductivity. In addition, Open-circuit voltage would be decreased rapidly when PAA

added over 50%.

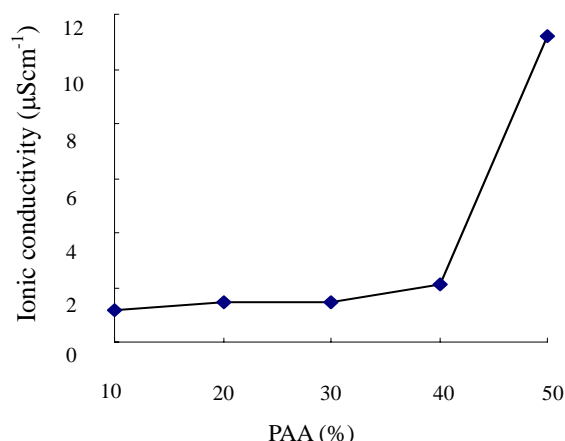


Fig. 3. Ionic conductivity of different ratios of PVA/PAA blending films.

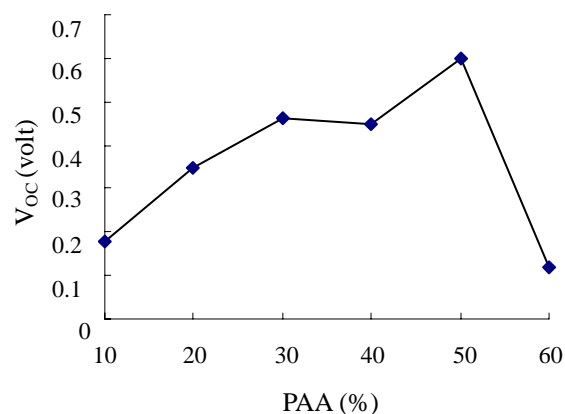


Fig. 11. Open-circuit voltages of different PVA/PAA blending films.

Conclusions

In summary, when the PAA% was increased, the blending films were changed from crystalline to amorphous gradually. Higher PAA blending membranes showed lower degree of crystallinity. The amorphous component, PAA, can enhance the ionic conductivity and increase the open-circuit voltage of the proton exchanged membrane. The best values for both ionic conductivity and open-circuit voltages in the hydrogen fuel cell can be approached as the optimum ratio of PVA/PAA blending film was at the ratio of 50/50.

Reference

- [1] J. O'M. Bockris and S. Srinivasan, *Fuel Cells: Their Electrochemistry*, McGraw Hill New York (1969).
- [2] G. M. Wu, S. J. Lin, *Advancement of Material and Process Engineering with permission*. Long Beach, California, USA (2006).
- [3] G. Hirankumar, S. Selvasekarapandian, N. Kawamura, T. Hattori, *J. Power Sources*, 144, 262(2005).
- [4] G. M. Wu, S. J. Lin, C. C. Yang, *J. Membrane Sci.*, **275**, 127(2006).
- [5] P. V. Wright, *Brit. Polym. J.*, **7**, 319(1975).