Electrical Properties of PVA/PSSA Ion-Exchange Membranes

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PVA/PSSA 이온교환막의 전기적 특성

강문성, 최용진, 최재환, 문승현
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1. Introduction

Ion-exchange membrane (IEM) processes including diffusion dialysis (DD), electrodialysis (ED), water-splitting electrodialysis (WSED), and electrodeionization (EDI) exhibit great potential as efficient and economic tools for environmental pollution control in end-of-pipe treatment (1). The development of high performance IEM having special properties is a prerequisite for the efficiency of these processes (2). Water-swollen IEM can be applied to CO_2 separation and metal recovery, etc.

Ion-exchange membranes are characterized as their electrical properties. The electrical properties having an effect on ion transport can be investigated using chronopotentiometry, membrane conductivity, membrane potential and current-voltage curves.

In this study, the electrochemical characterization for water-swollen cation-exchange membranes (CEM) was performed using various electrochemical methods.

2. Backgrounds

Concentration polarization is a well-known phenomenon occurring at the interface between an ion-exchange membrane and an electrolyte solution when the current passes through it. The current-voltage curve usually reflects the electric property of the membrane and gives information on the transport mechanism of ions, including concentration polarization. The classical theory of concentration polarization, based upon the concepts of an unstirred layer and local electroneutrality, predicts a plateau of the current-voltage curve (3, 4).

Chronopotentiometry is an electrochemical method, which allows the monitoring of changes in the electrode potential produced by a controlled current as a function of time. The total potential drop measured consists of the overvoltage of the membrane potential and the ohmic potential drop because of concentration polarization in the ion-exchange membrane. The resulting changes in potential give more important information regarding polarization phenomena, electrical conductivity, heterogeneity, and the values of permselectivity and transference number of the ion-exchange membrane. The characteristic expression is given as,

$$i\tau^{1/2} = \frac{C_o z_k F}{\overline{t_k} - t_k} \frac{(\pi D)^{1/2}}{2} \quad (1)$$

where i, C_o, z_k, and F are current density, concentration of electrolyte, valence of k ion, and Faraday constant, respectively. D is diffusion coefficient and $\overline{t_k}$, t_k are transport numbers of k ion in the membrane and solution phase, respectively. This expression is known as the Sand equation, frequently used for many analytical applications including the evaluation of kinetic parameters that are directly or indirectly associated with charge transfer processes (3).

3. Experimental

Water-swollen cation-exchange membranes were prepared using Poly(vinyl alcohol) (PVA) and Poly(styrene sulfonic acid) (PSSA) as the base materials. PSSA was purchased from Polyscience (30% soln. in water) and PVA was obtained from Aldrich (99+% hydrolyzed, Avg.

Mw. 89,000-98,000). PVA/PSSA composite membranes were prepared with various blending ratios. The membranes were dried for 5 days at room temperature and then thermally treated in an air oven at 100 ℃. These membranes were successively cross-linked with glutaraldehyde (GA) solution. The prepared membranes were washed with deionized water and stored in 0.5 mol dm^{-3} NaCl solution. Various electrochemical cell experiments for determining V-I relation, membrane potential for determining transport number for sodium ion, and chronopotentiometry were performed as well as basic characterizations including the measurements of water-swelling ratio, ion-exchange capacity, and electrical resistance. All experiments were carried out at 25 ℃.

4. Results and Discussion

PVA/PSSA water-swollen membranes were characterized in terms of their electrical properties including the limiting current density (LCD), the plateau length, R_{3rd}/R_{1st} values, electrical resistance, membrane potential, and transition time (τ) of chronopotentiometry, etc.. Moreover, classical characterizations, such as ion-exchange capacity, water-swelling ratio, potentiometric titration, SEM, and FT-IR analysis, are carried out.

Fig. 1 shows the current-voltage curve for water-swollen PVA/PSSA membrane cross-linked with GA in 0.025 M NaCl solution. The limiting current density was determined by the intersection of the two slopes of the ohmic and the plateau region. The plateau length and LCD values were decreased as the GA concentration increased. This result indicates that the membrane morphology was changed into finer structure.

Fig. 2 presents the $i\tau^{1/2}$ values according to PVA/PSSA weight fraction. In this figure, the $i\tau^{1/2}$ values increase with an increase of PVA content. This observation indicates that the transference number of sodium ion is controlled by the content of sulfonic acid groups.

As a result, the electrical properties of the water-swollen membranes prepared in various conditions were characterized precisely. It seems that the water-swollen cation-exchange membranes having excellent electrical properties controlled by the characterization can be applied to many industrial purposes, such as acidic gas separation, Donnan dialysis for metal separation, and electrodialysis for desalination and concentration.

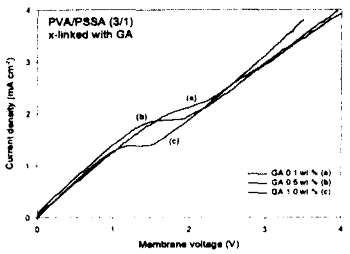

Fig. 1. Current-voltage curve for PVA/PSSA membrane cross-linked with GA. (electrolyte: 0.025M NaCl)

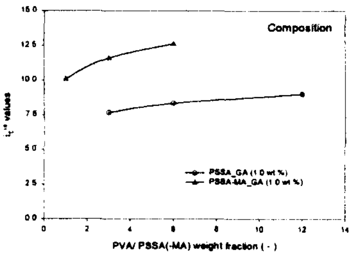

Fig. 2. $i\tau^{1/2}$ values according to PVA/PSSA weight ratio.

5. Acknowledgment

This work was supported by the National Research Laboratory (NRL) Program of Korea Institute of Science and Technology Evaluation and Planning (Project No. 2000-N-NL-01-C-185).

6. References

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