전기투석공정에서 임피던스를 이용한 실시간 막오염 모니터링

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Real-time fouling monitoring using an electrical impedance spectroscopy in electrodialysis

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1. Introduction

Electrodialysis (ED) is increasingly of importance in various applications such as demineralization of whey, recovery of metals from metal plating rinse waters, recovery of inorganic and organic acids, and separation of amino acids from a fermentation broth [1-3]. Despite their usefulness, fouling of ion-exchange membranes is one of the essential problems in the design and operation of the ED. In the ED handling solutions containing foulants, they cause deterioration in the membrane performances such as a decline in the flux and an increase in the electric resistance. Hence, fouling control in ED is very significant for its efficient operation. For this, accurate identification of the occurrence of the fouling should be done in advance.

An electrical impedance spectroscopy (EIS) has been widely used to characterize a variety of electrochemical phenomena concerning solid state, porous materials, synthetic and biological membranes, and liquid electrolytes [4]. Moreover, it provides valuable information on the functional and structural characteristics of membrane systems. Hence, it can give rise to get a better insight into the changes in the interfacial phenomena such as the fouling phenomena.

The purpose of this study was to develop a real-time monitoring means of identifying the membrane fouling phenomena in the ED. Using a two-terminal measurement system, impedance were measured due to the geometric difficulty of the ED in using a four-terminal one.

2. Experimental

Measurement of the impedance spectra and ED experiments of KCl solutions in the presence of BSA are obtained using a two- compartment cell as shown in Fig. 1. The effective area of the membrane was 0.785 ㎠. Two platinum wire electrodes were used to measure basic impedance spectra of the ion-exchange membrane system and to inject alternating current with 0.2 mA of amplitude in the frequency scan ranging from 10^6 to 10^3 Hz. For the real-time fouling identification in the ED, the impedance was measured at 50 Hz with operation time. The membranes used in the experiments were the Neosepta AMX anion-exchange membrane (Tokuyama Corp., Japan).

3. Results and Discussion

Fig. 1 shows the basic appearance of the impedance spectra of the ion-exchange membrane system when measured using two platinum wires inserted in both sides of the ion-exchange membrane. They show the two distinct dispersions with frequency. At high frequencies, the constant conductance is shown for all the concentrations. It is independent on stirring, but concentration of the KCl solution. It implies that the conductance at high frequencies corresponds to that of the bulk solution. Similarly, another constant conductance appears at low frequencies, which is caused by effects of electric double layers and/or chemical reactions at the interface between the solution and the pt wire. It is also independent on stirring, but weakly concentration. At middle frequencies, stirring-dependent conductance is observed in the entire impedance spectra. In the ion-exchange membrane system, only an element dependent on hydrodynamic conditions is the diffusion boundary layer (DBL). It is believed that impedance at the middle frequencies is dominantly affected by the DBL.

As a result, the basic impedance spectra can be divided into three distinct regions, i.e., a solution/membrane (including dielectric properties), a diffusion boundary layer/membrane (including heterogeneous transport), and an electrical double layer/chemical reaction.

The dispersions arising from the interfacial phenomena such as the DBL and electrical double layer occurred in the frequency range from 1 to 104 Hz. So did dispersions from the BSA and fouling layers. The results in Fig. 2 imply that the BSA addition caused to decrease the solution/membrane conductance at high frequencies, and the dispersions with different relaxation time appeared in the frequency range from 1 to 104 Hz. In the impedance spectrum for the ion-exchange membrane system with the fouling layer formed at 5 V d.c. for 13 hrs, the dispersions in the frequency range from 1 to 104 Hz was vanished so that it looked as if one dispersion existed.

One of the frequencies in the frequency range from 1 to 104Hz, 50 Hz, was chosen to identify the fouling occurrence and the growth of the fouling layer in the ED. During a constant current ED, impedance at 50 Hz was measured with time while making the AMX membrane to be fouled using the KCl solution in the presence of BSA. Fig. 3 shows a clear indication of the fouling occurrence and the growth of the fouling layer by thickening of the layer (note that capacitance is inversely proportional to thickness).

4. Conclusions

The impedance measurement using a two-terminal system was investigated to identify membrane fouling in ED. The impedance spectra showed the distinct dispersions arising from the solution, the membrane, the DBL, and the electrical double layer at the electrodes. The suggested measurement at 50 Hz at which the dispersion arising from the interfacial phenomena occurred can be a real-time monitoring means of monitoring the occurrence and growth of the membrane fouling in the ED.

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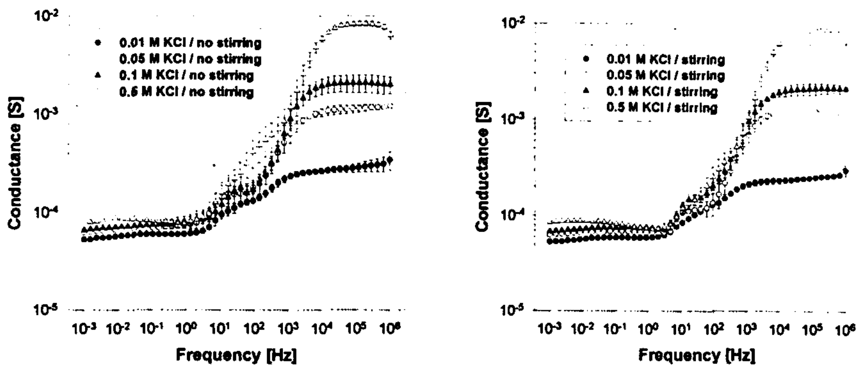
References

1. J.-H. Choi, S.-H. Kim, and S.-H. Moon, Sep. Purif. Tech., 28 (2001).

2. Y.-H. Kim, and S.-H. Moon, J. Chem. Tech. Biotech., 76 (2001).

3. J.-S. Park, H.-J. Lee, S.-J. Choi, K.E. Geckeler, J. Cho, and S.-H. Moon, J. Colloid Interf. Sci., 259 (2003).

4. H.G.L. Coster, T.C. Chilcott, and A.C.F. Coster, Bioelectrochem. Bioenerg., 40 (1996).



(a) (b)

Fig. 1. Dispersions of the conductance in the AMX membrane system with concentration under (a) stirring and (b) no stirring (frequency scan range, 10-3-106 Hz; amplitude, 0.2 mA)

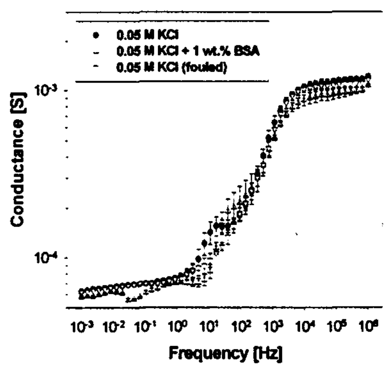


Fig. 2. Dispersions of the conductance in the un- and fouled membrane system.

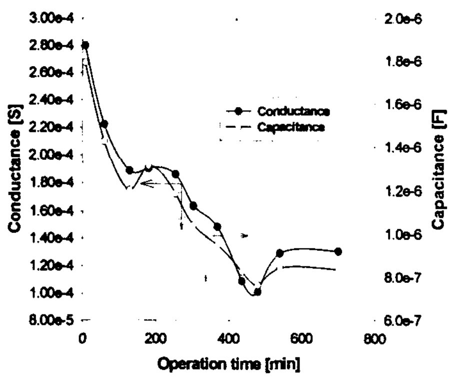


Fig. 3. Impedance of the AMX membrane system at 50 Hz with time during an ED operation.