일반강연 A-13

음이온교환막의 오염특성 연구

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A study on fouling characteristics of anion-exchange membranes

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1. Introduction

Membrane fouling is an important aspects that needs consideration in the design and operation of membrane systems, including electrodialysis. The extent and the nature of such fouling tendencies are influenced by electrochemical properties such as electric resistance of the membrane, hydrophilicity, and exchange capacity, as well as the electrokinetic properties. The zeta potential is commonly used as the electrokinetic value that describes the surface charge properties related to the streaming potential (SP) and is given by the Helmholtz -Smoluchowski equation. [1-2]

Through this study, the fouling tendencies have been examined according to the electrochemical properties and their effects on the performance of anion exchange membranes. As well, the fouling potential was analyzed according to a newly defined fouling index for electrodialysis.

2. Theory

A measure of the fouling tendencies, the fouling index, can be obtained to describe fouling phenomena for the pressure-driven processes, but has had difficulties in being applicated to electrodialysis systems.[3] The fouling index for electrodialysis (EDMFI) presented in this study was derived and is based on the gel layer formation on the surface of an ion exchange membrane during electrodialysis. The total resistance of the cell is the sum of the intrinsic membrane resistance, R_m, and the additional resistance due to the fouling gel layer, R_f, *i.e.*,

$$\frac{E(t)}{I(t)} = R_m + K\frac{C_b r_c}{C_g A}Q(t) \quad \text{.............................. (1)}$$

For operation under a constant current, the above equation can be rewritten:

$$\frac{E}{I^2} = \frac{R_m}{I} + \frac{KC_b r_c}{C_g A}t \quad \text{.............................. (2)}$$

Under these conditions, the EDMFI can be obtained from the slope of the plot of $E(t)/I^2$ vs. time.[4]

3. Experimental

For membrane characterization, the hydrophilicity, electric resistance, and exchange capacity were determined. Streaming potentials (SP) were measured with a streaming channel in a tangential flow cell, BI-EKA, by increasing pressures and zeta potentials were calculated with SP coefficients from a linear regression at pH 6.0±0.1. To observe the fouling phenomena, 2 cell pairs of CMX & AMX, CMX & AM-1, CMX & ACM, and CMX & AMV were assembled in TS-1 electrodialysis stack. The initial concentrate solution was 5.0 L of 0.1 M NaCl containing 100 mg/L of sodium humate. Electrodialysis experiments for each cell configuration were carried with the following procedures: desalting without sodium humate, desalting with sodium humate, and then desalting without sodium humate.

4. Results and Discussion

Changes in the membrane characteristics due to fouling are listed in Table 1. Little change in electric resistance was observed for AMX and AM-1 while ACM and AMV showed a greater resistance after being fouled. The hydrophilicity of the membranes, indicated by the contact angle, did not change significantly after fouling experiments for all membranes except ACM, which became less hydrophilic. It is thought that the hydrophobic portions of the humate are the dominant contributers to the fouling of the ACM membrane. A significant decreases in the ion exchange capacity was observed for all the membranes tested except AM-1. Particularly, ACM lost about 50 % of its ion exchange capacity due to humate fouling. This result implies that the humate may bind strongly to the membrane structure, causing irreversible fouling. The zeta potential shows a specific adsorption of the ions on the surface and related to the electrical surface charge density, interacting with its surface.[5] It is obvious that a higher zeta potential represents the higher electrical charge density showing a higher adsorption capability. An anion-exchange membrane with a high zeta potential can adsorb foulants more easily than other membranes and be highly fouled by negative charged foulants, causing a reduction in its zeta potential. The zeta potentials of AM-1 and AMX changed little after the fouling experiments while those of ACM and AMV notably decreased. AM-1 showed lower selectivity in the fouling experiment as 0. 324 rather than AMX. Through characteristics results, ACM has the highest fouling potential and AMX the lowest. It is thought that the fouling tendency can be determined by the exchange capacity and zeta potential change due to fouling.

Through the fouling experiments, the phenomena of anion exchange membrane fouling were observed and the fouling potentials for different membranes were compared quantitatively. The resistance of AMX, AM-1 and AMV membranes were changed little until the concentration of NaCl was depleted. However, it was noted that resistance of ACM was increased with time due to formation of an irreversible fouling layer, which was confirmed through calculation of irreversible and reversible foulant. For quantitative prediction of the fouling potential, the EDMFIs of fouling experiments containing humate were obtained graphically from experimental data in the constant current region and their indices were compared with the EDMFIs increased after fouling as compared with those before fouling, ACM membrane showing the highest fouling potential and AMX membrane the lowest potential. These fouling tendencies are in accordance with the changes in the characteristics of virgin and fouled anion exchange membranes.

5. Conclusion

Fouling potentials of anion exchange membranes were investigated through their electrical resistance, hydrophilicity, exchange capacity, and electrokinetic property and were confirmed by fouling phenomena examination. Of the characteristics, the exchange capacity and zeta potential were found to indicate the presence of fouling. The membrane fouling index for electrodialysis, EDMFI, was defined and agreed reasonably with the fouling systems investigated in this study. Of the anion-exchange membranes tested, ACM membrane showed the highest fouling potential through the characterization and fouling experiments with humate.

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Table 1. Characteristics of anion exchange membranes

Mem.	Properties	Fouling status	Electric resistance (Ohmcm^2)	Contact angle (Degree)	Exchange capacity (meq/g-dried mem)	Zeta potential (mV)
AMX	High mechanical strength	Virgin	3.47	33.7	2.5	5.3
		Fouled	3.47	36.5	1.8	6.7
AM-1	Low electric resistance	Virgin	2.45	36.4	2.3	3.9
		Fouled	2.49	37.6	2.2	4.0
ACM	Low H+ transport	Virgin	6.35	38.5	4.0	16.6
		Fouled	7.64	45.1	2.1	2.1
AMV	Low electric resistance	Virgin	3.16	38.3	3.2	5.0
		Fouled	4.28	36.2	2.7	3.7