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TRANSPORT CHARACTERISTICS OF CO^{2+} THROUGH AN ION EXCHANGE TEXTILES IN A CONTINUOUS ELECTRODEIONIZATION (CEDI) SYSTEM UNDER ELECTRO-REGENERATION

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1. Introduction

It has been known that transport characteristics of ions are very complicated in CEDI system due to the inter-relations between ion exchange media and solution. Thus, this study sought to determine the ionic mobility of cobalt ion through cation exchange textile under electroregeneration and consequently verify the transport mechanisms of cobalt ion in a CEDI system. The porous plug model was applied to determine the current distribution and initial concentration of the ion exchange textile. The extended Nernst-Plank equation was used to determine the mobility of cobalt ion through the ion exchange textile. Accordingly, the transport mechanism of cobalt ion in the CEDI was discussed.

2. Theory

The CEDI process is a novel hybrid separation process consisting of electrodialysis (ED) and ion exchange (IX). The principle is illustrated in Figure 1. During the operation of a CEDI system, a water spliting reaction at the bipolar interface continuously regenerates the ion exchange resins. Current flowing through the diluted compartment in CEDI system is complex since it is composed of two phases of different properties. In CEDI system the current distribution is usually explained with the porous plug model. Moreover, the extened Nernst Plank equation with geometrical parameters can be applied to describe ionic transport through the media. Finally, the transport of ions through a medium under an electrical field is expressed by the following relationship (1).

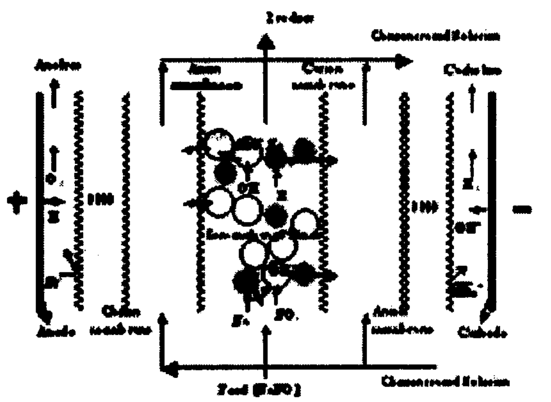

Figure 1. Principle of continuous electrodeionization

$$J_{i,tot} = z_i\bar{c}_i\left(\bar{u}_i + \frac{\bar{u}_o}{z_i}\right)grad\varphi = z_i\bar{c}_i\bar{u}_i^{*}\,grad\varphi, \qquad \left(\bar{u}_i^{*} \equiv \bar{u}_i + \frac{\bar{u}_o}{z_i}\right) \qquad (1)$$

where, $\overline{u}_{i}^{*}$ is the apparent mobility that includes the convection conductivity. From these relationships, apparent mobility through ion exchange textile $\overline{u}_{i}^{*}$ can be determined from the plot between the potential drop ($grad\varphi$) and the effluent flux ($J_{i,tot}$). Apparent mobility through the ion exchange textile dependson the thermodynamic characteristics of ion exchangers including its capacity, degree of cross-linking, swelling ratio, osmotic pressure, valence of the counter ion, type of co-ion and solvent, *etc.*

3. Experimental

Cation exchange textile was prepared with UV graft polymerization. Ion exchange capacity, swelling ratio, electrical conductivity was measured. CEDI operation packed with prepared ion exchange textile was carried with 1 cell pair 2 compartment. In the CEDI operation, ultrapure water was used as feed solution and 1M H_2SO_4 was concentrate solution. 1000 μs/cm of Na_2SO_4 was used as electrode rinse solution. Stack voltage was chaged from 10 volt to 60 volt and cell potential was calculated using the electrical conductivity model.

4. Results and Discussions

4.1 Characterization of cation exchange textile

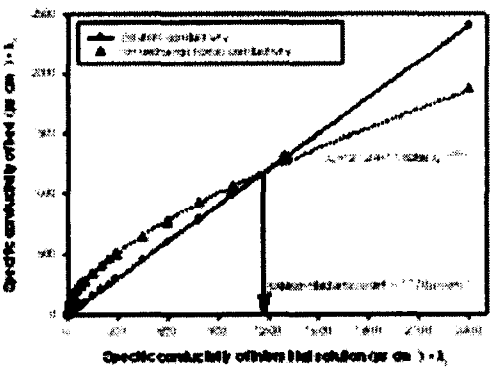
Figure 2. Electrical conductivity of cation exchange textile

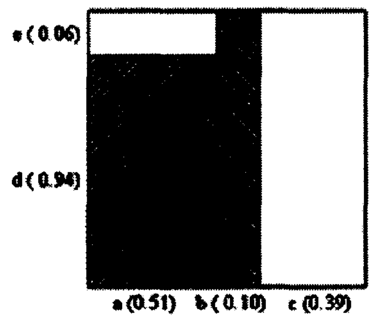

Figure 3. Application of porous plug model into cation exchange textile

Ion exchange capcity of the synthesized ion exchange textile was found to be 2.267 meq/g, and its density 1.3 g/cm^3. The total cobalt concentration of ion exchange textile was calculated and it was 1.472 mmol/cm^3. Figure 3 shows the results of application of porous plug model into prepared ion exchange textile. From Figure 2 and 3, the conductivity of ion exchange textile in the diluted compartment (thickness 1cm) was found to be 121.24 μs/cm. Moreover, the initial mole concentration of cobalt ion in the pathway b in Figure 3 was determined as 0.25 mmol cm^{-3}.

4.2 Effect of potential drop in the diluted compartment on the cobalt flux

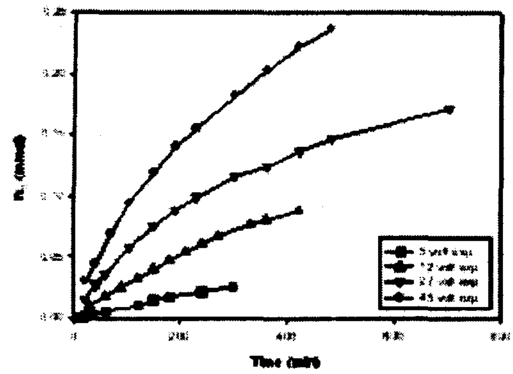

Figure 4. Comparison of the cobalt concentration with the potential drop in diluted compartment

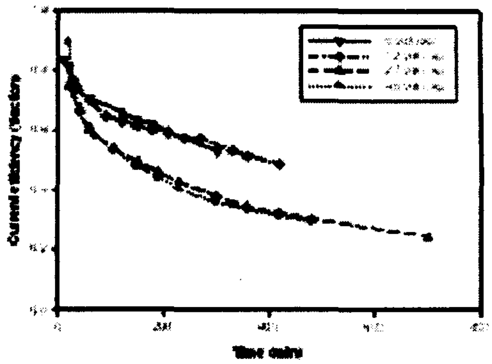

Figure 5. The time profiles of current efficiency in terms of transport number for cobalt ion

Figure 4 shows the relationship between the operating time and the number of moles of cobalt transported into the concentrated compartment under various potential drops. The curves show linear relations at the initial operating time. This result implies that homogeneity was not developed within the time period; such nonhomogeneity may be induced by the concentration change in the textile. To confirm the quantitative changes in the ion exchange textile, current efficiency was calculated.

Figure 5 show the time profiles of current efficiency in terms of transport number for cobalt ion. The transport number of cobalt decreased with time, although it was close to 1.0 under the initial operating condition. This result indicates that the initially applied current was used for the transport of cobalt ion but later for the transport of hydrogen ions. Figure 4 and 5 imply that the Nernst-Plank equation can be applied during the initial CEDI stage only.

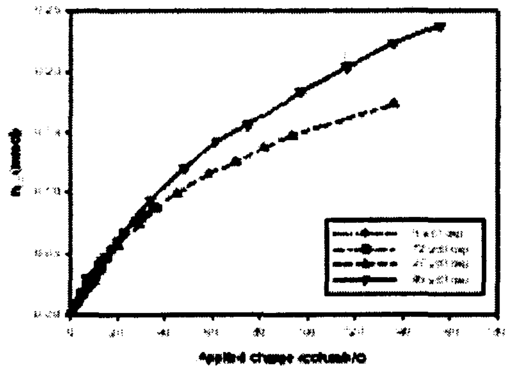

Figure 6. The amount of transported Co^{2+} into concentrated compartment according to applied charge

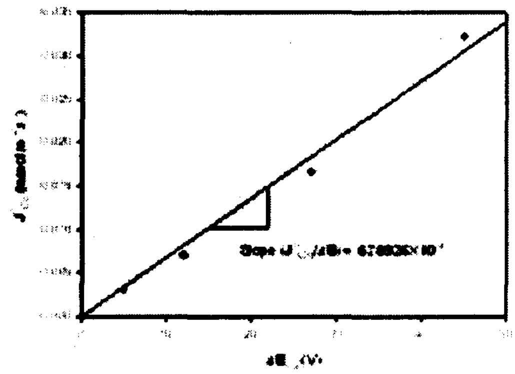

Figure 7. Initial cobalt flux with respect to potential drop in the diluted compartment

Figure 6 presents the amount of the cobalt ion transported into the concentrated compartment according to the applied charge. Results show that the relationship between the transported cobalt ion and the applied charge did not depend on the potential drop in the diluted compartment; thus indicating that the transported cobalt is a function of the applied charge. Deviations may also occur due to the electrochemical reactions in the cobalt ion, indicating metallic cobalt generation.

4.3. Removal mechanism of cobalt ion through the ion exchange textile

Figure 7 shows the flux change of cobalt ion in the CEDI system according to the potential drop in the diluted compartment. A large potential drop in the diluted compartment resulted in a high flux of cobalt. Nonetheless, the flux decreased over time by the transport of hydrogen ions into the concentrated compartment using equation (1).

From Figure 8, the slope was found to be 6.78926× 10^{-4} (mmol m^{-2} s^{-1} V^{-1}) and the apparent mobility of the cobalt ion through the ion exchange textile was calculated as 1.36× 10^{-11} (m^2 s^{-1} V^{-1}) when the ion exchange textile was fully saturated with cobalt ion.

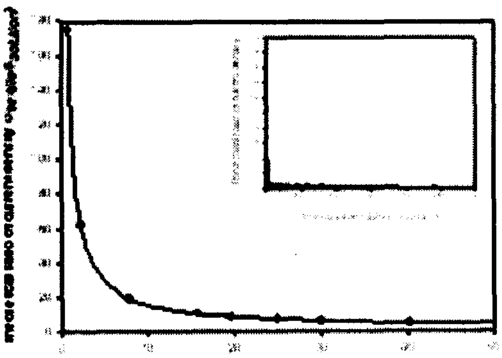

Figure 8. Theoretical ratio of current density for the textile packing to that of solution in the CEDI system

This value was lower than the mboility in the limiting diluted solution. These results showed that the removal mechanism of ions in the CEDI system was not mainly dependent on the ionic mobility but on other electrical properties. Figure 8 shows the predicted ratio of current density with textile to that without textile in the CEDI system for cobalt nitrate solution. This ratio was much greater under textile packing at a low solution conductivity, because the CEDI system with textile packing induced a higher current than that without packing due to the self-conductivity of polyelectrolyte.

5. Conclusions

The apparent mobility of cobaltions in the CEDI system under regeneration was determined using the porous plug model and the extended Nernst-Plank equation.The apparent mobility of the ion exchange textile proved that the removal mechanism of the CEDI system is not due to the accelerated ionic mobility but to the induced current in the ion exchange textile. Moreover, the ratio of flux for the textile packing to that of solution shows high values at a low interstitial solution conductivity thus indicating that the CEDI enhanced the transport of ions more effectively at a low feed concentration.

6. Acknowledgement

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7. References

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