자외선 그라프트 양이온교환섬유를 충진한 전기탈이온 시스템에서의 코발트 이온의 이동특성

송정훈, 연경호, 문승현*

광주과학기술원 환경공학과

Removal Characteristics of Co^{2+} in a Continuous Electrodeionization (CEDI) with UV (Ultra-violet) Treated Cation Exchange Textile (CIET)

Jung-Hoon Song, Kyeong-Ho Yeon, Seung-Hyeon Moon*

Department of Environmental Science and Engineering, Gwangju Institute of Science and Technology (GIST)

1. Introduction

Ion exchange textile is a new type of ion exchange media used in a CEDI system. Ion exchange textile (IET) can overcome disadvantages of ion exchange (IX) resins, showing high permeability and reaction rate constant. Also, it was reported that the removal rate and power consumption was comparable to commercial IX resins. In spite of the reasonable properties of CIET, the removal characteristics through a CIET have not been elucidated due to their electrochemical complexity [1].
The aim of this study is to investigate the removal characteristics of cobalt ions through IET in a CEDI system.

2. Experimental

2.1. Electrochemical properties of CIET

A flow cell was used to measure the electric conductivities of cobalt-saturated CIET. Cobalt solutions with various conductivities were used as feed solutions and circulated through the flow cell apparatus until a steady state was reached with the IX resins. Conductivities of each solution and textile were measured using an LCZ meter (model 2321, NF electronics, Japan) [1].

1 cell pair 3 compartments CEDI system with an effective membrane area of 50 cm^2 was used for the investigation of I-V relationships. Feed solution composed of 0.34 mN $Co(NO_3)_2 \cdot 6H_2O$ was flushed through the both concentrate and diluate compartments at a flow rate of 10 $ml \cdot min^{-1}$. Na_2SO_4 500 $\mu s \cdot cm^{-1}$ was circulated through the electrode chamber at a flow rate of 20 $ml \cdot min^{-1}$ [2].

2.2. CEDI operation with different operating parameters

1 cell pair 3 compartment CEDI system with an effective membrane area of 20 cm^2 was used for CEDI experiment. The feed solution composed of 0.34 mN $Co(NO_3)_2 \cdot 6H_2O$ was flowing through the diluate compartment. Na_2SO_4 500 $\mu s \cdot cm^{-1}$ was circulated as initial concentrate and electrode rinsing solution at a flow rate of 10 $ml \cdot min^{-1}$. The operation in a constant current mode was carried out with various operating parameters. Cobalt concentrations during a CEDI operation were analyzed using an inductively coupled plasma spectrophotometer (Model – Thermo Jarrel ash IRIS/AP).

3. Results and Discussion

3.1. Electric conductivity of CIET

Fig. 1 shows the changes in the electric conductivities of the CIET with various interstitial solution conductivities. From Fig. 1, the applicable conductive region of feed solutions for CEDI operation was determined as 3300 $\mu s \cdot cm^{-1}$ and this also indicated that CEDI operation is more efficient than ED operation for the treatment of feed solution less than 3300 $\mu s \cdot cm^{-1}$ based on the electrical conductance.

Fig. 1. Electric conductivities of cation exchange textile

3.2. Current-Voltage (I-V) relations

Fig. 2 shows the stack I-V relations in the CEDI system. Two distinct regions in the I-V curve appeared. In the first region, the current density increased linearly with the stack voltage, while, in region II, it increased sharply. The linear relation in the region I was based on the ionic transport through the ion exchange media and ion exchange membrane. Under these circumstances, the cation exchange membrane (CEM) and CIX resins can be considered as one medium and leads to the linear relationships according to Ohm's law. At a high current density, the water splitting reaction occurred at the bipolar junction layer between the CIET and AEM. In this region, charged materials cause catalytic water splitting, or decomposition reaction that forms hydrogen and hydroxide ions,

Fig. 2. Current-voltage (I-V) relations in a CEDI stack

inducing the high current density. As a result, the point where water splitting occurs exists around the inflection point in Fig. 2, between water splitting (region II) and ionic removal (region I), which is also the point where the current efficiency is the highest with the high removal rate for the CEDI operation. Thus, the optimal current density was determined to be 6.5 $A \cdot m^{-2}$.

3.3. Effect of flow rate

CEDI experiments were carried out with various flow rates. Fig. 3 shows effect of flow rate on CEDI performances. The CEDI removal rate decreased exponentially with an increasing flow rate. When the flow rate increases through the textile, the exchange zone where both cobalt and hydrogen ion exist becomes dispersed due to its decreased preference [3]. The dispersed exchange zone resulted in decreased removal rate. If the zone expands to the outlet of the system, removal in the CEDI stack is not completed. Thus, CEDI operation at a low flow rate shows a high performance for the production of high quality water at a sacrificed current efficiency.

Fig. 3. Schematic illustration of effect of flow rate on CEDI performances

3.4. Removal mechanism of Co^{2+} through an ion exchange textile

Fig. 4 shows the ion exchange textile after CEDI operation for 4,500 min. As shown in Fig. 4, color change in CIET indicates the two regimes existed. Over the diagonal line, electroregeneration regime is dominant, and under the diagonal line, ionic transport regime is dominant. This experimental result indicates that the CEDI system is usually under the mixed effect of convective flow and electromigration. Due to the electromigration effect, the cobalt ions are to move to the cathode, but also move along with the stream due to the convective flow. The mixed effects generate the boundary of electroregeneration and ionic transport regime. Thus, it is possible to control the regeneration region using flow rate (convection) and applied electric potential (electromigration) for the effective use of a CEDI system.

4. Conclusion

This study suggested the removal and transport mechanism of a CEDI system. Electric conductivity and I-V relations showed the ionic transport and water dissociation phenomena in the different operating regions. Removal of ions in a CEDI system was mainly governed by the electromigration and convective force. Further study to minimize the electroregeneration region to increase current efficiency and for effective use of CEDI system is now being investigated.

Fig. 4. Suggested transport mechanism of cobalt ion through CEDI system [two pictures indicates the surface of CIET contacted with AEM (left) and with CEM (right)

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References

[1] Jung-Hoon Song, Kyeong-Ho Yeon, and Seung-Hyeon Moon, Separation Science and Technology, 15(39), 3601-3619, 2004

[2] Jung-Hoon Song, Min-Chul Song, Jung-Bae Kim, Kyeong-Ho Yeon, Kun-Jai Lee, and Seung-Hyeon Moon, Journal of radioanalytical and nuclear chemistry, 3(262), 725-732, 2004

[3] F. Helferrich, Ion Exchange, Mc-Graw Hill, 1962, USA