Flow-Through Electrochemical Membrane System for the Selective Removal of Cobalt Ions

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1. Introduction

Recently, decommissioning of nuclear power plant becomes a hot issue for nuclear power phase-out. The main radioactive isotopes in radioactive concrete wastewater is Co-60, because of its relatively long half-life and strong γ radiation. For the selective electro-adsorption of cobalt ions in concentrated calcium ions, we synthesized multi-wall carbon nanotube based, water permeable hollow fiber membrane (MWCNT-HM), and investigated as cathodic electrode.

2. Materials and methods

2.1 Materials

For the fabrication of MWCNT-HM, multi-walled carbon nanotube (MWCNT), PVB (Polyvinyl butyral, Butvar® B-74), and NMP (N-methyl-2-pyrrolidone) were purchased from Cheap Tubes, Sigma-Aldrich, and Junsei chemical Co. Ltd., respectively.

2.2 Fabrication of hollow-fiber electrodes

Wet-spinning technique was used for the fabrication of MWCNT-HM. Spinning solution prepared by mixing MWCNT, NMP and PVB homogeneously by magnetic stirring. The wet-spinning solution extruded through hollow-fiber spinning apparatus with deionized water as bore fluid. Obtained hollow-fiber electrodes dried at room temperature and then calcined at 350 ℃ for 1 hour under Ar environment to remove PVB.

2.3 Electro-adsorption of cobalt ions

The electrochemical removal of Co^{2+} by MWCNT-HM carried out by 3-electrode electrochemical cell with potentiostat (WonA-tech ZIVE SP1) at room temperature. MWCNT-HM, graphite rod, and saturated calomel electrode (SCE) were used as working, counter, and reference electrodes with -1.0 V vs. SCE of electric potential applied to MWCNT-HM. To simulate the acidic concrete leachate, 500 mM of $CaCl_2$ at pH 1.0 were used with 0 ~ 0.5 mM $CoCl_2$ concentration.

3. Result and discussion

3.1 Microstructure of MWCNT-HM

MWCNT-HM possessed a porous, hollow-fiber structure by interconnection of MWCNTs (Fig. 1). MWCNT-HM has 77.8 m^2/g of specific surface area, and 13.9 nm of BJH pore size, which is effective for water flow through the MWCNT-HM and electrochemical Co^{2+} removal.

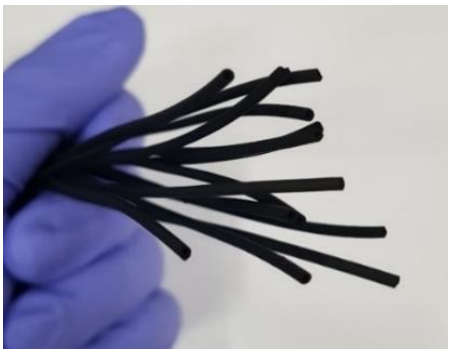

Fig. 1. Fabricated MWCNT-HM.

3.2 Selective electro-adsorption of Co^{2+}

After electrochemical reduction process, specific nanostructure appeared on the surface of MWCNT-HM. From EDS analysis, it was found that the nanostructure mainly composed with Co with minimal amount of Ca (22.7:1 mol/mol) on MWCNT-HM (Fig. 2).

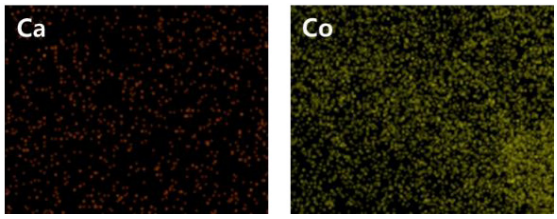

Fig. 2. EDS analysis result for appeared nanostructure on MWCNT-HM.

3.3 Co^{2+} sorption capacity of MWCNT-HM

Under electrochemical removal process of Co^{2+}, simulated acidic leachate was flown through MWCNT-HM with 80 L/m^2·h of flux. The average removal efficiency Co^{2+} was 74.5 % with 57.9 mg/g of removal capacity at pH 1. (Table 1)

Table 1. Co^{2+} removal properties of CHF

	Value
Leachate Co^{2+} concentration	12.0 mg/L
Co^{2+} concentration after reaction	3.1 mg/L
Leachate volume	55 mL
Mass of CHF	10.1 mg
Removal capacity	57.9 mg/g

4. Conclusion

In summary, MWCNT hollow-fiber membrane electrodes showed the selective removal of Co^{2+} via Ca^{2+} ion under strong acidic condition.

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