Supplementary Information

Pilot-scale demonstration of an electrochemical system for lithium recovery from the desalination concentrate

Hwajoo Joo,[a] Seoni Kim,[a] Seongsoo Kim,[a] Minjune Choi,[a] Seung-Hyun Kim,[b] and Jeyong Yoon*[ac]

[a] *School of Chemical and Biological Engineering and Institute of Chemical Processes (ICP), Seoul National University, 1 Gwanak-ro, Gwanak-gu, Seoul 08826, Republic of Korea.*

[b] *Department of Civil Engineering, Kyungnam University, 7 Gyeongnamdaehak-ro, Masanhappo-gu, Changwon 51767, Republic of Korea.*

[c] *Korea Environment Institute, 370 Sicheong-daero, Sejong 30147, Republic of Korea.*

* Corresponding author: Jeyong Yoon

(E-mail: jeyong@snu.ac.kr; Tel: +82-2-880-8927; Fax: +82-2-876-8911)

Experimental details

The electrochemical monopolar-type stack cell based on 14 pairs of λ-MnO_2 and Ag electrodes was used in the primary recovery process. Rectangular graphite plates with 200 mm length, 100 mm width, and 2 mm thickness were used as current collectors. λ-MnO_2 electrodes were prepared by the acid treatment of $LiMn_2O_4$ composite electrodes in 0.5 M of HCl solution for 1 hour. $LiMn_2O_4$ composite electrode was fabricated by the following steps. First, 80 wt % $LiMn_2O_4$ (TOB New Energy, China) as the active material, 10 wt % Super P (Timcal, Switzerland) as the conductive material, and 10 wt % polyvinylidene fluoride (PVDF, Sigma-Aldrich) as the binder were mixed with the 1-methyl-2-pyrrolidone (NMP, Sigma-Aldrich) solution and the slurry was made. Then, the slurry was casted on the current collector with a thickness of 300 mm, followed by the solvent evaporation at the temperature of 120 °C in the vacuum oven. Ag electrodes were prepared as the following steps. 80 wt % silver powder (Ag, Sigma-Aldrich) as the active material, 10 wt % Super P (Timcal, Switzerland) as the conductive material, and 10 wt % polytetrafluoroethylene (PTFE, Sigma-Aldrich) as the binder were mixed with the ethanol (99%, Sigma-Aldrich) and the slurry was made. The slurry was roll-pressed with a thickness of 300 mm and dried at the temperature of 120 °C in the vacuum oven. After the solvent evaporation, Ag electrodes were attached onto the current collector with the carbon paint (TED PELLA INC., USA). The electrochemical cell used in the secondary recovery process was comprised of single electrode pair of the λ-MnO_2 and Ag electrode. As a current collector, circular graphite sheets with 100 mm diameter and 0.2 mm thickness were used. The electrodes used in this process were fabricated in a similar way to the previous one.

Physicochemical characterization and operation of the electrochemical cell were conducted by the battery cycler (WBCS3000; WonATech, Korea) and the automated program (CIMON, Korea). The cation concentrations of the intermediate product and the final product were measured by the ion chromatography (IC-1100; Thermo-fisher, United states). A pH meter (Lab 860, SI Analytics GmbH) and a conductivity meter (F-74BW, Horiba) were used to characterize the desalination concentrate. TDS and element composition of the desalination concentrate were calculated from the chloride concentration measured by the Ion chromatography (DX-120, Thermo Fisher Scientific Inc.) and composition of standard seawater[1].

① Control panel (pump)
② Control panel (primary recovery)
③ Primary recovery system
④ Computer
⑤ Battery cycler
⑥ Secondary recovery system
⑦ Filter (100 μm)
⑧ Pumps and tank
⑨ Pipe lines of the system
⑩ Pipe lines for influents
⑪ Pipe lines for effluents

Fig. S1 Overview and specification of the pilot-scale electrochemical lithium recovery system.

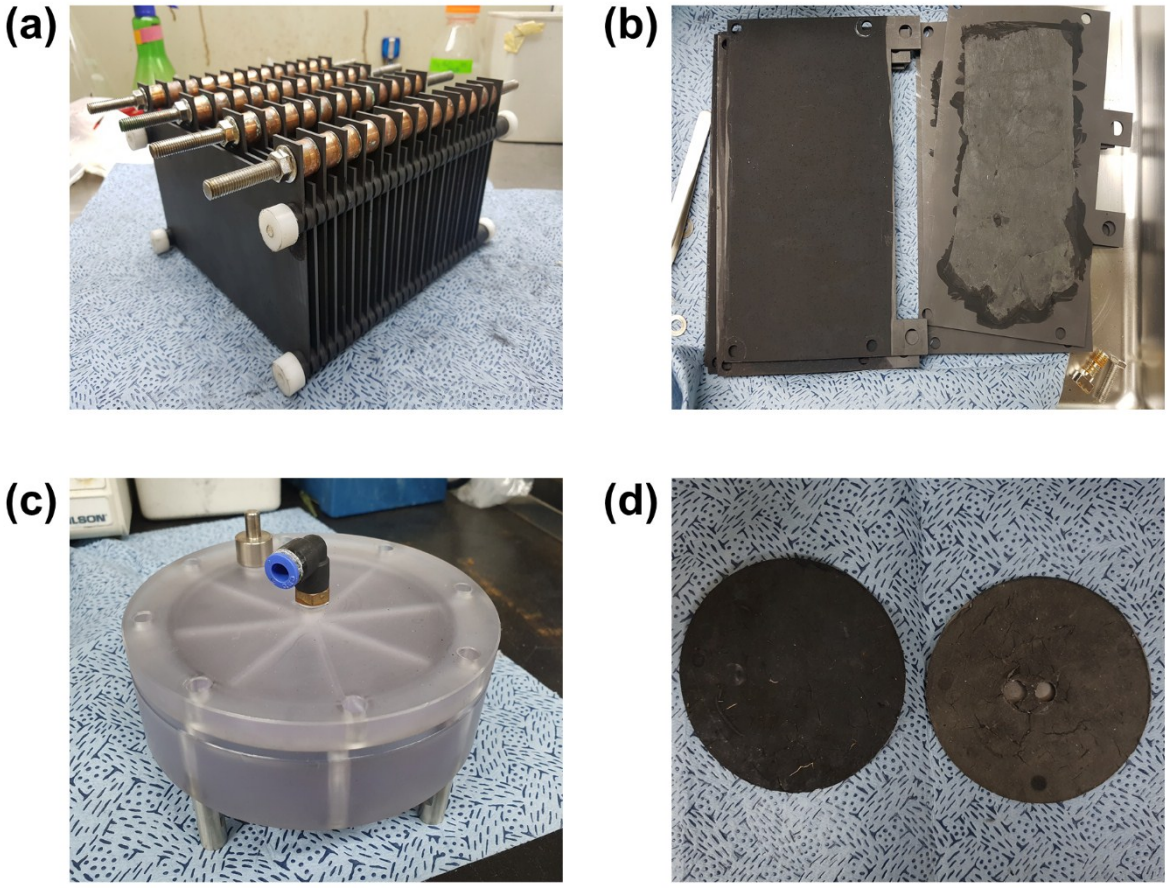

Fig. S2 (a) The electrode stack used in the primary recovery process and (b) the electrodes comprising the stack. (c) The electrochemical cell used in the secondary recovery process and (d) the electrode comprising the cell

Table S1 Characterization of the desalination concentrate

Measured properties		
pH	8.0	
Conductivity (S/m)	6.53	
TDS (mg/L)	43895	
Composition		
Compound	**Concentration**	
	mg/L	**mM**
Chlorine	25246	712
Sodium	14463	629
Magnesium	1732	71
Sulfur	1215	38
Calcium	553	14
Potassium	536	14
Bromine	90	1
Carbon	38	3
Strontium	11	0.121
Boron	6	0.559
Silicium	3	0.096
Fluorine	2	0.092
Lithium	0.24	0.035
Nitrogen	0.20	0.014
Rubidium	0.16	0.002
Phosphorous	0.08	0.003
Iodine	0.08	0.001

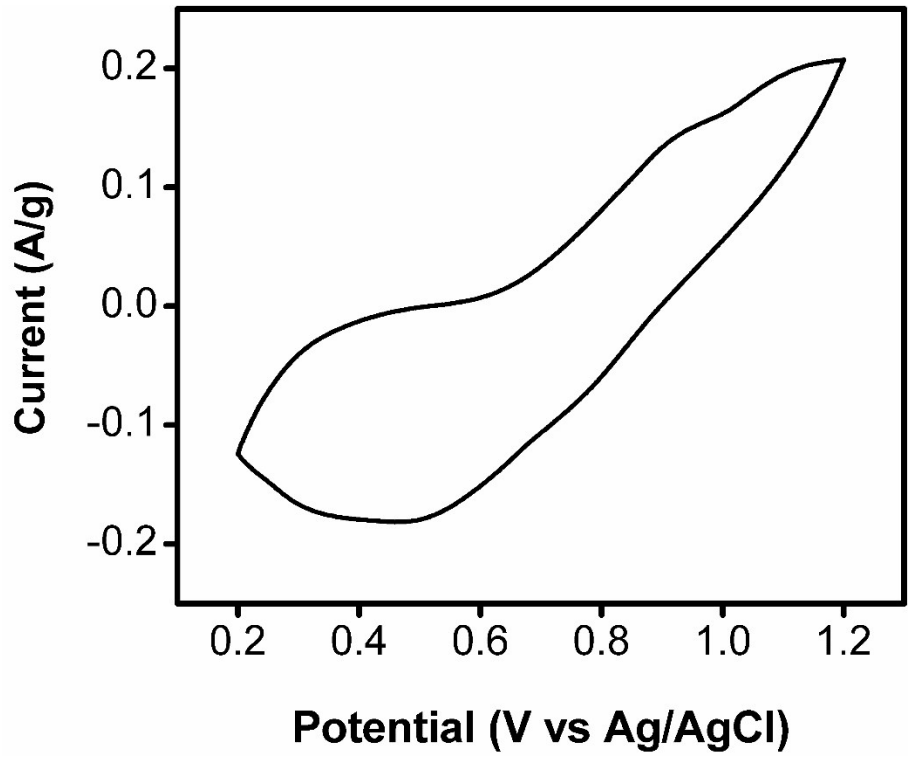

Fig. S3 Cyclic voltammogram of λ-MnO_2 electrode (solution: 1 M LiCl, scan rate: 1 mV/s)

Reference

1 S. A. Gerlach, *Marine Pollution*, Springer Berlin Heidelberg, Berlin, Heidelberg, 1st edn., 1981, ch. 1, pp. 1-5.