Electronic Supplementary Information for

# Highly selective lithium recovery system from brine water using rechargeable battery

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# $LiMn_2O_4$ characterization

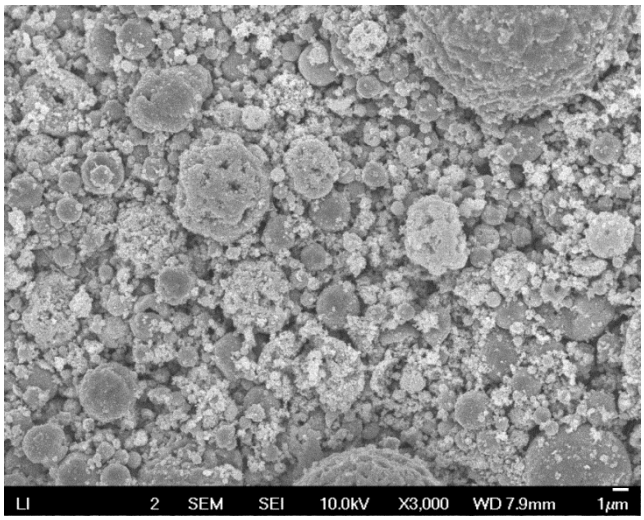


**Fig. S1** Scanning electron microscopy (SEM) image of spinel $LiMn_2O_4$.

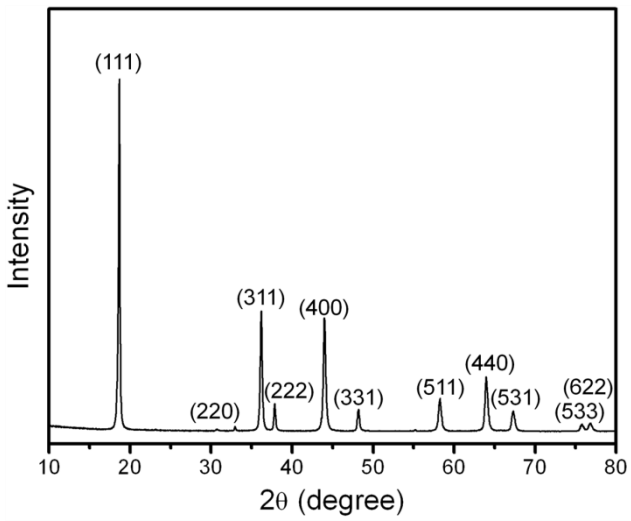


**Fig. S2** X-ray diffraction (XRD) pattern of spinel $LiMn_2O_4$.

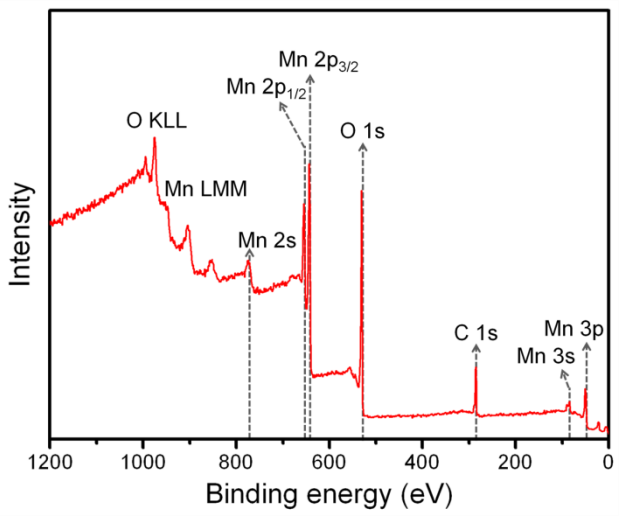


**Fig. S3** XPS survey spectrum of spinel $LiMn_2O_4$.

The $LiMn_2O_4$ powder was characterized by scanning electron microscopy (FESEM, JEOL JSM 6701 F), X-ray powder diffraction (XRD) measurements, and X-ray photoelectron spectroscopy (XPS). Powder XRD was performed using a Rigaku D/Max-3C diffractometer equipped with a Cu Kα radiation source (λ= 0.15418 nm). The XPS experiment was performed using an Al Kα source at base pressures (<10-10 mbar) (Sigma probe, ThermoFisher Scientific).

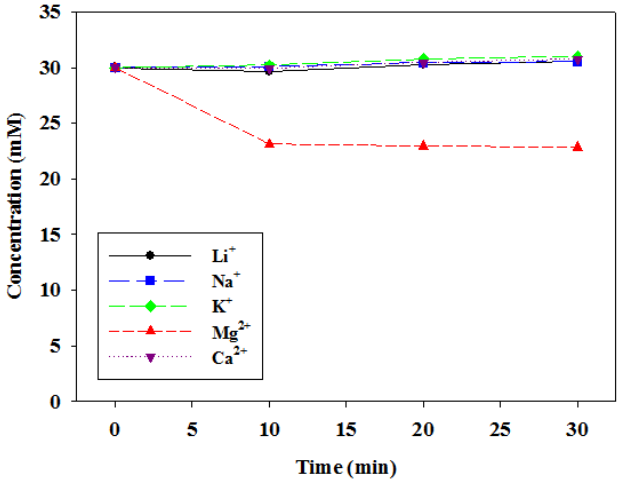


**Fig. S4** The concentration changes of various cations. The λ-$MnO_2$ electrode was submerged in the salt water without applying potential ($Li^+$: ●, $Na^+$: ■, $K^+$: ♦, $Mg^{2+}$: ▲, $Ca^{2+}$: ▼).

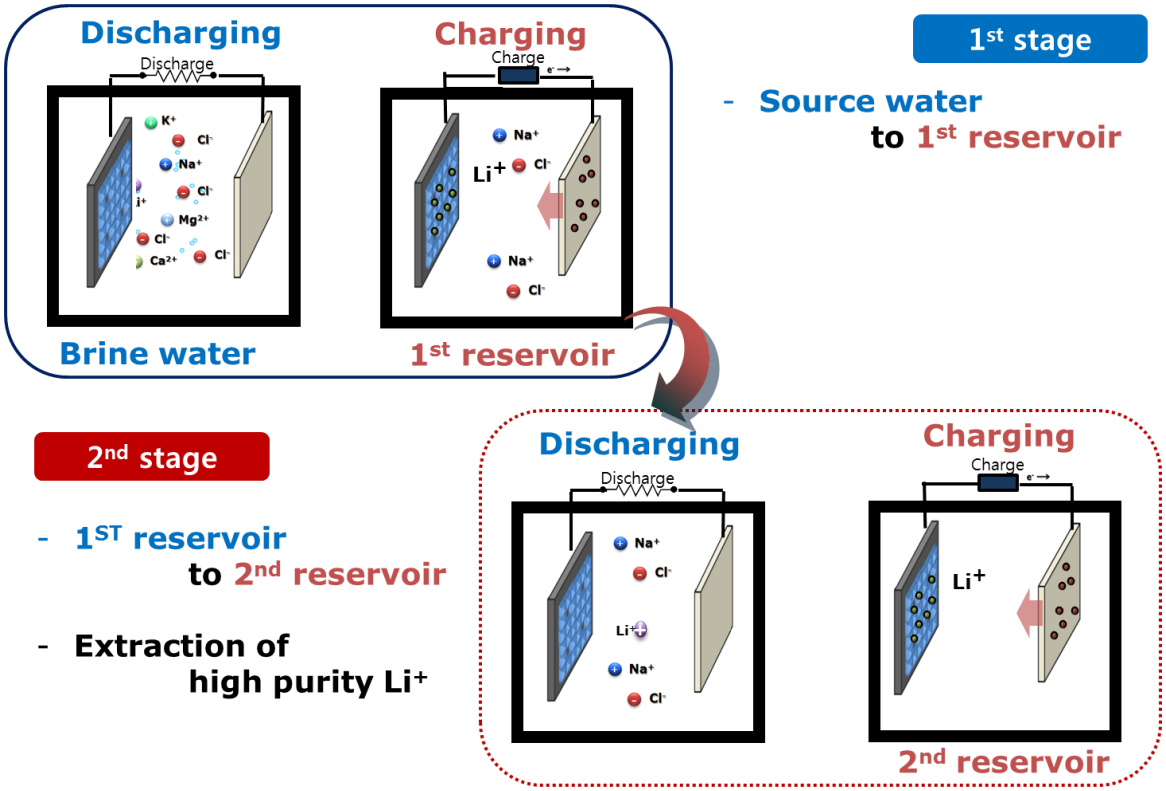


**Fig. S5** Schematic of lithium ion capturing processes in simulated brine water ("Salar de Atacama",Chile).

Fig. S5 shows the process of lithium extraction from the simulated brine water with a 2 stage process. In the first stage, the prepared λ-$MnO_2$/Ag cell was immersed in the simulated brine, and then discharged at a constant current to capture lithium ions. Next, the brine water was exchanged with the 1st reservoir solution (30 mM LiCl), and then the cell was charged to release ions. This cycle was repeated four times. In the second stage, the λ-$MnO_2$/Ag cell was immersed in the 1st reservoir solution and the discharging step was carried out. Then, the 1st reservoir solution was replaced with the new recovery solution (2nd reservoir solution, 30 mM LiCl) and the cell was charged. The 2nd stage was also repeated four times.

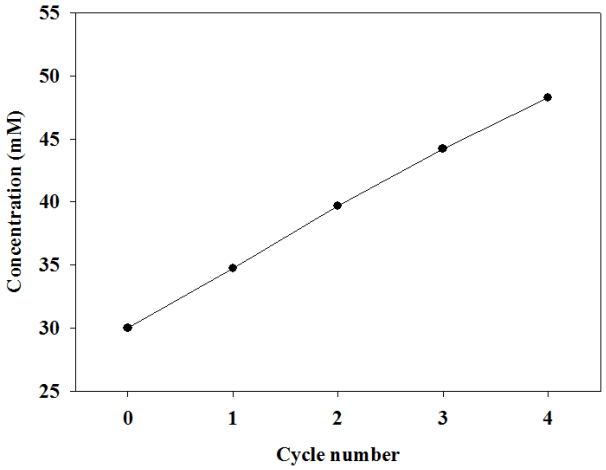


**Fig. S6** Lithium ion concentration changes in 1st reservoir solution at 1st stage (charging process).

As shown in Fig. S6, linear increase of lithium concentration was observed. This results shows that the captured lithium ions from simulated brine water are successfully released into 1st reservoir solution.

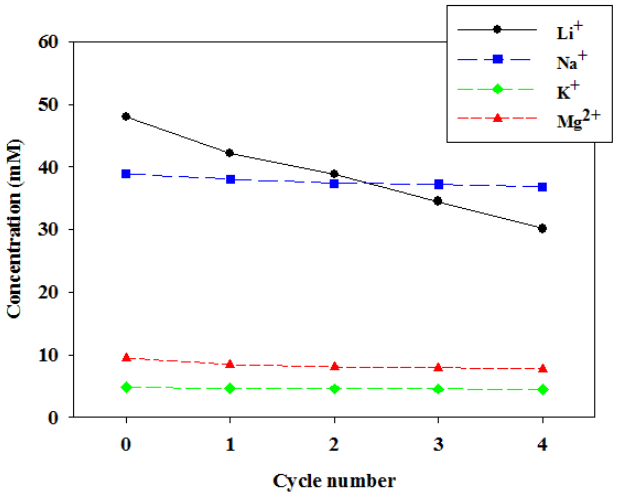


**Fig. S7** Selective lithium ion capturing in 1st reservoir solution at 2nd stage (discharging process) ($Li^+$: ●, $Na^+$: ■, $K^+$: ♦, $Mg^{2+}$: ▲).

As shown in Fig. S7, the concentration of lithium ions in 1st reservoir solution decreased with the cycle number. On the other hand, the concentrations of other ions were stable.

**Table S1.** The discharging and charging energy of lithium recovery process at each cycle.

| Cycle number | Discharging energy (J) | Charging energy (J) | Energy consumption (J) |
|---|---|---|---|
| 1 | 5.16 | 6.47 | 1.31 |
| 2 | 5.02 | 6.35 | 1.33 |
| 3 | 4.81 | 6.24 | 1.43 |
| 4 | 4.65 | 6.18 | 1.53 |

**Table S2.** The discharging and charging energy of lithium recovery process from simulated brine at each stage and cycle.

| **1st Stage** | | | |
|---|---|---|---|
| Cycle number | Discharging energy (J) | Charging energy (J) | Energy generation (J) |
| 1 | 7.18 | 6.42 | 0.76 |
| 2 | 7.02 | 6.31 | 0.71 |
| 3 | 6.97 | 6.29 | 0.68 |
| 4 | 6.91 | 6.27 | 0.64 |
| **2nd stage** | | | |
| Cycle number | Discharging energy (J) | Charging energy (J) | Energy consumption (J) |
| 1 | 5.33 | 6.10 | 0.77 |
| 2 | 5.04 | 5.99 | 0.95 |
| 3 | 4.89 | 5.93 | 1.04 |
| 4 | 4.69 | 5.89 | 1.2 |