

# A Novel Aqueous Lithium-Tin Chloride Rechargeable Battery

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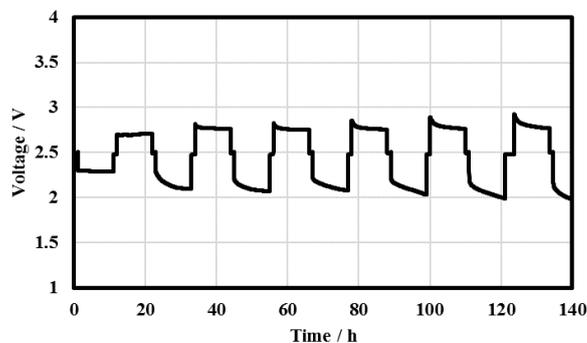
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In the previous paper [1], we reported a demonstration of the feasibility of an aqueous lithium rechargeable battery with a water soluble cathode of  $MCl_2$  ( $M = Fe, Co, Ni, Cu, \text{ and } Zn$ ) using a high lithium-ion conductivity solid electrolyte of  $Li_{1.4}Al_{0.4}Ge_{0.2}Ti_{1.4}(PO_4)_3$  (LAGTP) film [2] as the separator between lithium and the aqueous catholyte. Here we focus on the  $Li/SnCl_2$  aqueous solution cell.

NASICON-type LAGTP-epoxy resin film used as the separator was prepared by the previously reported procedure [2]. LAGTP powder prepared by a sol-gel method was mixed with ethanol, toluene and a binder to prepare a slurry. The slurry was tape-casted and dried, and then fired at 900 °C for 7 h. In order to fill the hole of the obtained tape-casted film, a solution obtained by dissolving 1 M 1,3-phenylenediamine and 2 M 2,2-bis (d-glycidylphenyl) propane in THF was added dropwise to soak the epoxy resin solution, and then heated at 170 °C for 24 h. The LAGTP-epoxy resin film with around 3 wt% epoxy resin was water permission free. The test  $Li/SnCl_2$  cell consisted of a lithium anode,  $[Li(F_3SO_2)_2N$  (LiFSI)-2 tetraglyme (G4)]-50 vol.% 1,3-dioxolane (DOL) interlayer, LAGTP-epoxy resin film, saturated  $SnCl_2$  and  $LiCl$  aqueous solution, and Sn current collector.

The theoretical energy density of 763 Wh/kg for the  $Li/SnCl_2$  cell is around two times higher than that of the conventional lithium-ion batteries and a high power density is expected because the aqueous solution is used as the cathode active materials. The open-circuit voltage (OCV) of the  $Li/saturated SnCl_2$  cell was 2.84 V at 25 °C, which is comparable to that of the theoretical value, but that of the  $Li/saturated SnCl_2$  and  $LiCl$  cell was as low as 2.55 V. The low OCV may be due to the formation of a complex of  $SnCl_2$  with  $LiCl$ . However, the CV study suggested a reversible Sn deposition and dissolution reaction. The Sn metal deposition potential was around 0.5 V higher than the hydrogen evolution potential. A around 94 %  $Sn^{2+}$  in the cathode solution was reduced to Sn before the hydrogen evolution reaction at 1.0 mA/cm<sup>2</sup> and 25 °C, Fig. 1 shows the charge and discharge cyclic characteristics of  $Li/LiFSI-2G4-50vol\% DOL/LAGTP/saturated SnCl_2$  and  $LiCl$  aqueous solution/Sn at 1.0 mA/cm<sup>2</sup> and 25 °C. The cell showed a good cyclic performance at a high surface area capacity of 10 mAh/cm<sup>2</sup>.



**Fig. 1** Charge-discharge cyclic performance of  $Li/(LiFSI-2G4)-50vol\% DOL/LAGTP/saturated SnCl_2$  and  $LiCl/Sn$  at 1.0 mA/cm<sup>2</sup> and 25 °C

## References:

- [1] Y. Morita et al. J. Electrochem. Soc., 164, A1958 (2017)
- [2] P. Zhang et al., J. Electrochem. Soc., 162, A1265 (2015)