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Editorial

Aqueous indium metal batteries

Energy storage devices have been extensively owing to their critical role in addressing the energy and environment challenges. Aqueous trivalent metal batteries are promising due to their unique three-electron redox reactions for high reversible capacity and high safety [1]. Especially, aqueous aluminum-based batteries have attracted significant attention [2]. However, severe water decomposition occurs due to their low redox potential (Al^{3+}/Al, −1.66 V *vs.* SHE) [3]. In contrast, the metallic indium (In)/or In^{3+} has a more suitable redox potential (−0.34 V *vs.* SHE), which is within the water stability window, minimizingwater decomposition [4]. Recently, a study on trivalent indium metal batteries was firstly reported by Wu's group in *Journal of the American Chemical Society* [5].

The developed aqueous In metal batteries demonstarted superior electrochemical performance. They also investigated the reaction chemistry of In||MnO_2 battery [5]. The In||In symmetrical cell operated 1600 h without a short circuit when the voltage polarization reached at 0.5 mA/cm^2 (Fig. 1a). This cell exhibited high rate performance with a ultrasmall overpotential of 11 mV at 10 mA/cm^2 (Fig. 1b). Moreover, the In||Ti cell showed a ultrahigh average Coulombic efficiency CE value (>99.3%) at 1 mA/cm^2 after 500 cycles (Figs. 1c and d). The constructed In||MnO_2 battery delivered an outstanding rate performance and high energy and power density 120 Wh/kg, 1200 Wh/kg, achieving long-term cycling stability with a high retention of ~70% after 680 cycles at 500 mA/g (Fig. 1e). Such excellent performance has demonstrated the feasibility of aqueous In metal batteries.

They also studied the reaction mechanism of In||MnO_2 battery uisng *ex-situ* X-ray diffraction (XRD) pattern (Figs. 2a and b). The H^+ proton insertion into MnO_2 to generate MnOOH was demonstrated. This process could lead to indium precipitation on MnO_2 cathode, affecting the operation of the battery, which was also confirmed by *ex-situ* SEM analysis (Figs. 2c–e). The battery reaction mechanism was attributed to proton insertion into MnO_2 to form MnOOH, while local pH changes lead to the precipitation of In_2O_3, InOOH or InOCl on MnO_2 vicinity (Fig. 2f).

In conclusion, Wu's group has demonstrated an aqueous In metal anode with high capacity, high efficiency of In plating/stripping, low polarization and dendrite-free In deposition. Moreover, the assembled In||MnO_2 battery achieved impressive performance with ~1.2 V voltage, ~330 mAh/g capacity and 680 cycles long life. This work exemplifies the efficacy of exploiting trivalent metals as an excellent metal anode, providing a new direction for developing aqueous multivalent metal batteries.

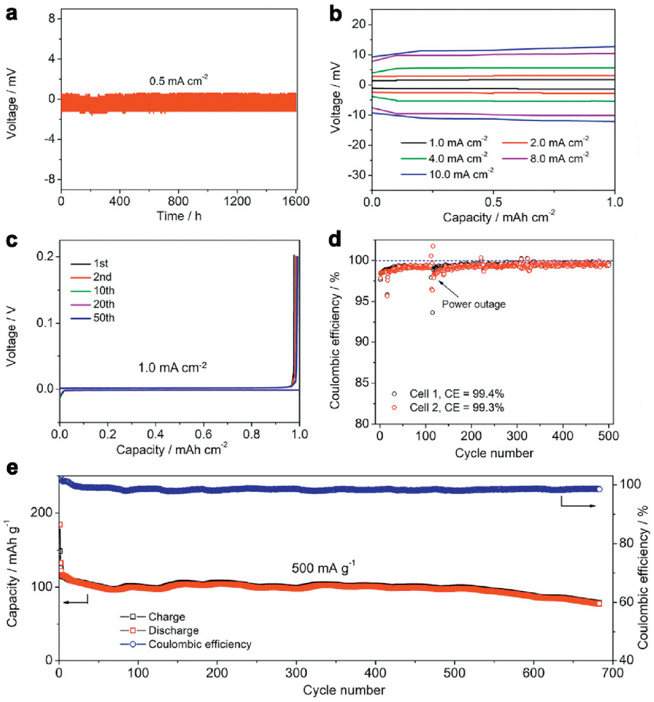

Fig. 1. (a) Cycling performance of In||In cells. (b) Charge/discharge curves of In||In cells. (c, d) Charge/discharge curves and cycling performance of In||Ti cells. (e) The cycling performance of In||MnO_2 batteries. Reprinted with permission [5]. Copyright 2023, American Chemical Society.

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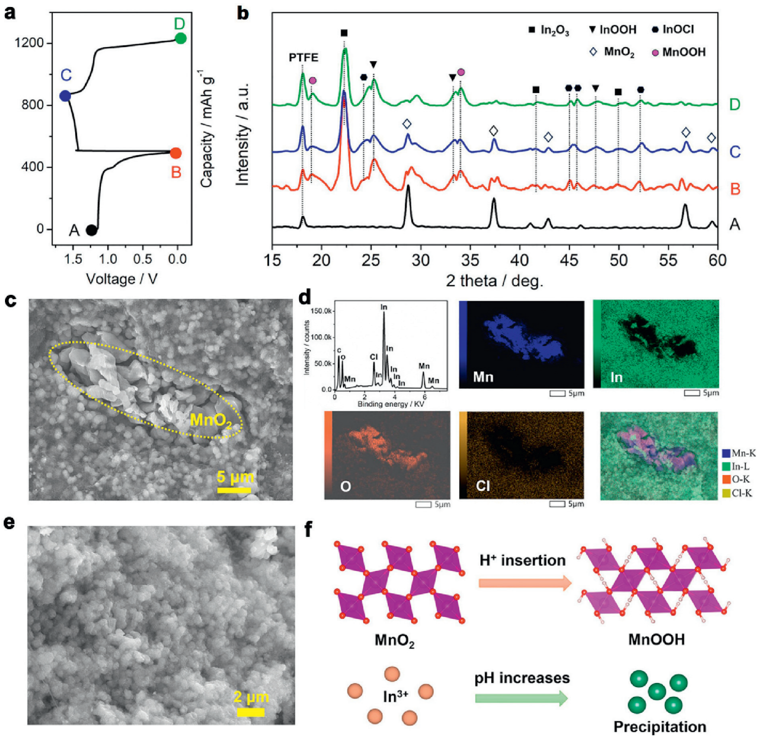

Fig. 2. (a) The galvanostatic charge/discharge curve and (b) *ex situ* XRD patterns of MnO_2 cathodes. The SEM image of point (c) B and (e) C. (d) The EDS spectrum and element mapping images of Point B. (f) The schematic reaction mechanism. Reprinted with permission [5]. Copyright 2023, American Chemical Society.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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