Energy storage with dissolution/re-deposition of metal ions

Huimin Wang, Denis Y. W. Yu*
Battery and Energy Storage Technologies Laboratory, School of Energy and Environment, City University of Hong Kong, Hong Kong

E-mail: hmwang8-c@my.cityu.edu.hk

Existing materials in lithium-ion batteries have reached their maturity, and new electrochemical systems are needed to meet the rising demand in energy storage. Here we proposed to increase capacity by storing energy with the dissolution and re-deposition of metal ions. For example, a $Fe \leftrightarrow Fe^{2+} + 2e^-$ reaction is expected to give a voltage of 2.6 V vs. Li/Li^+ with a theoretical capacity of 959 mAh g^{-1} and an energy density of 2493 Wh kg^{-1}, which is about 5 times more than the practical energy density of $LiCoO_2$. In addition, the system is free from complex material synthesis processes, and can turn cheap and abundant metals into potential high-energy batteries.

To enable high voltage and prevent gas evolution during cycling, aprotic electrolyte with large stability window is needed. We demonstrate the feasibility of the system with stainless steel (410L) as the working electrode and Li metal as the counter electrode. 1M $LiPF_6$ in EC/DEC = 1:1 by volume with 0.05M LiCl is used as the electrolyte. Cl^- is added to the electrolyte to facilitate the dissolution of the metal into the electrolyte. An anion exchange membrane (Fumasep FAPQ310-PP) is used to reduce cross-over of Fe^{2+} to the counter electrode. Figure 1a shows the charge-discharge curves of our battery with a capacity limitation of 100 mAh g^{-1}. A flat discharge voltage of 2.5V vs. Li/Li^+ and a stable discharge capacity are observed. Currently, the coulombic efficiency of the battery is about 85% (see Figure 1b). There are some degrees of self-discharge in the system, possibly because of diffusion of Fe^{2+} through the not-optimized anion exchange membrane. Further works to increase capacity, enhance coulombic efficiency and understand the charge-discharge mechanisms with different metal electrodes such as Fe, Cu, Ni are underway, and will be presented at the meeting.

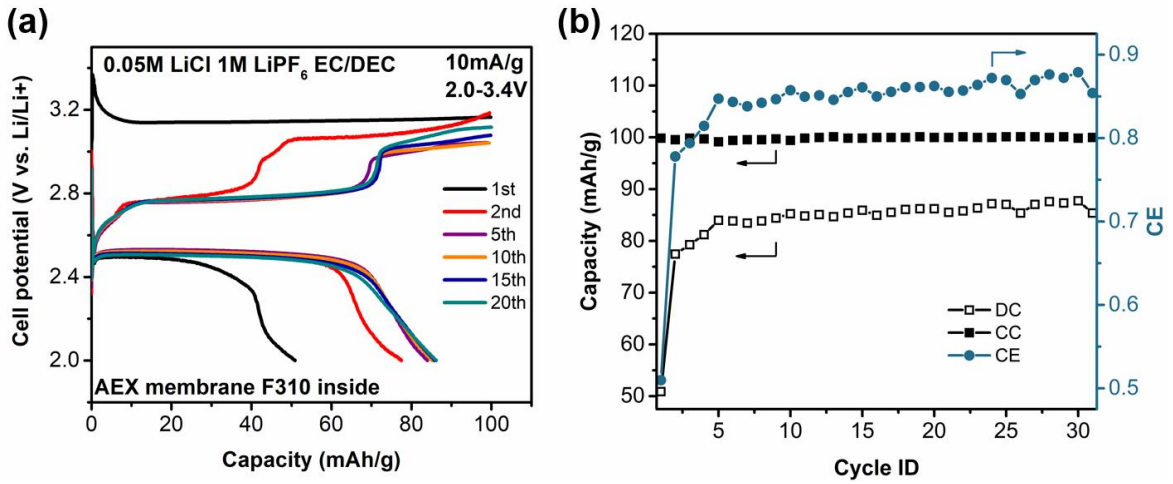

Figure 1. (a) Constant charge/discharge behavior and (b) cycle performance of stainless steel 410L in 0.05M LiCl 1M $LiPF_6$ EC/DEC with anion exchange membrane at 10mA g^{-1}.