

Designing reversible electro-chemo-mechanical reactions in alkali-ion batteries

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Abstract:

Innovation in transportation is key to stopping climate change. True enablers of zero-emission electric vehicles (EVs) and renewable power generation for sustainable energy future are rechargeable batteries. Among many types of the batteries, Li-ion batteries dominate the modern battery technology. As the market for large-scale batteries rapidly evolves, the need for next-generation batteries continues to grow.

In light of this clear motivation, various promising next-generation batteries will be highlighted in this talk. First, a new battery construction that physically does not require anode materials will be introduced. The concept of this "anode-free" battery was proposed to achieve high energy density. However, practical use of anode-free batteries faces challenges due to fundamental problems associated with their poor Coulombic efficiency and substantial volume change of the anode-side. Factors to unlock the potential of anode-free batteries will be demonstrated. We will discuss how to shift energetics of Li plating and stripping in anode-free batteries by employing three-dimensional frameworks as a current collector. Mechanically robust structures enable reversible Li cycling by suppressing volume change over the extended number of cycles. In the context, the practical applications of anode-free batteries will also be discussed.

Second, challenges and opportunities in making solid-state batteries work will be discussed. Solid electrolytes that ensure ultimate safety in operating batteries require high lithium conductivity and excellent stability against redox reactions. $\text{Li}_7\text{La}_3\text{Zr}_2\text{O}_{12}$ and its sister compositions, also known as garnet oxides, have been successfully optimized to have balanced ionic conductivity and electrochemical stability, growing into important materials for the next-generation solid-state batteries. However, obstacles are apparent in the cell assembly due to high processing temperature that brings about side reactions between solid electrolyte and cathode layers. To integrate oxide-based all-solid-state batteries at low temperature and stabilize their interfaces, we show how materials engineering can be employed. We found that ceramic additives that have low melting temperature play a significant role in integrating solid-state batteries using $\text{Li}_7\text{La}_3\text{Zr}_2\text{O}_{12}$.