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Electrochemomechanical degradation of high-capacity battery electrode materials

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ABSTRACT

Enormous efforts have been undertaken to develop rechargeable batteries with new electrode materials that not only have superior energy and power densities, but also are resistant to electrochemomechanical degradation despite huge volume changes. This review surveys recent progress in the experimental and modeling studies on the electrochemomechanical phenomena in high-capacity electrode materials for lithium-ion batteries. We highlight the integration of electrochemical and mechanical characterizations, *in-situ* transmission electron microscopy, multiscale modeling, and other techniques in understanding the strong mechanics-electrochemistry coupling during charge-discharge cycling. While anode materials for lithium ion batteries (LIBs) are the primary focus of this review, high-capacity electrode materials for sodium ion batteries (NIBs) are also briefly reviewed for comparison. Following the mechanistic studies, design strategies including nanostructuring, nanoporosity, surface coating, and compositing for mitigation of the electrochemomechanical degradation and promotion of self-healing of high-capacity electrodes are discussed.

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1. Introduction

Rechargeable lithium-ion batteries (LIBs) have served as the primary power source for a variety of portable electronics in today's mobile society, including smart phones, laptop computers, and wearable electronics, as well as in power tools, electric vehicles and grid-scale storage [1–11]. However, the current LIB technology still cannot meet the rapidly growing demand for high energy density and long cycle life. In particular, the volumetric energy density of the current LIB cells severely limits miniaturization of electronics as well as the driving distance of electric vehicles. These have motivated relentless search for new electrode materials with higher gravimetric and volumetric specific capacities [12–17]. However, capacity and cyclability appear to be two conflicting properties since improving one often compromises the other. In particular, high-capacity electrodes are prone to chemomechanical failure upon electrochemical charge-discharge cycling, leading to

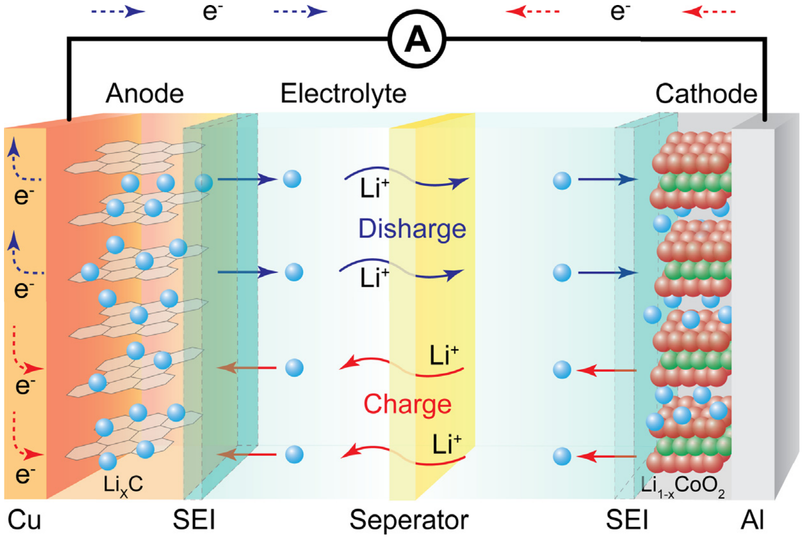

Fig. 1. Schematic of a LIB cell comprised of a negative electrode (graphite) and a positive electrode ($LiCoO_2$), separated by a liquid electrolyte. Li ions migrate from the positive (negative) electrode to the negative (positive) electrode through the electrolyte during charging (discharging); meanwhile electrons migrate through an external circuit to maintain charge neutrality. Current collectors (here are Al and Cu) are used to transport electrons to and from the electrodes.