Reaction Mechanisms and Degradation Processes in Energy Conversion and Storage Systems Characterized by In-Situ Electron Microscopy

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Developing new paradigms for energy generation, storage, distribution, and utilization is amongst the most challenging problems facing this generation. Several major visions exist for sustainable energy generation and utilization, including; renewably generated and stored electricity and the conversion of green or renewable energy sources into fuels. System cost and efficiency impose major barriers on alternatives to fossil fuels for electricity generation and transportation. Key to developing energy storage and conversion systems with low cost, long cycle life, high efficiency, and high energy density is the need for fundamental insights into atomic and nanoscale processes associated with chemical and electrochemical reactions. For example, local strain gradients due to lithium insertion govern mechanical degradation of electrode materials, and interfacial reactions between electrodes and liquid electrolyte can drive capacity fade. Appropriately characterizing such phenomena requires in-situ and in-operando probes with appropriate spatial and temporal resolution. Electron microscopy provides high spatial resolution and reasonable temporal resolution, and the introduction of environmental cells enables access to a rich variety of chemical and electrochemical systems. This talk will describe our contributions to the development of environmental electron microscopy and its application to understanding reaction and degradation processes in electrochemical energy conversion and storage systems. Specifically, the presentation focuses on characterizing local strain effects in high capacity Li-ion anode materials during cycling, the nucleation and growth of electrolytic H_2 gas, and several short vignettes demonstrating the general utility of in-situ environmental TEM as a tool for characterizing electrochemical processes. The presentation will also include a description of future scientific opportunities provided by access to novel environments and probes.

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