Understanding Heterogeneities in Battery Materials through Multi-Modal X-ray Microscopy

William E. Gent[1], Yiyang Li[1], Jongwoo Lim[1], William C. Chueh[1]
[1]Department of Materials Science & Engineering, Stanford University, Stanford CA

Heterogeneities in batteries come in many forms and are crucial in determining their electrochemical properties. In particular, failure mechanisms are often heterogeneous, and so engineering long-lasting batteries necessarily requires an understanding of the spatial distributions in their electrochemical behaviors. X-ray microscopy is a powerful tool we can use in this effort as the spatially resolved spectroscopy it provides allows one to map evolving chemistry at the nano-scale. Here, I present the recent progress we have made in the Chueh group in developing and applying *in situ* and *ex situ* X-ray microscopy methods to understand lithiation and degradation phenomena in lithium ion batteries. I will cover three main areas in which we have employed these methods: (a) Using hard X-ray microscopy to image micron-scale non-uniform strain in layered oxide secondary particles, (b) Understanding the heterogeneous oxygen redox chemistry in Li-rich layered oxide electrodes through soft X-ray microscopy and using this to shed light on their unusual electrochemistry, (c) Mapping the lithiation dynamics of $LiFePO_4$ *in operando* with soft X-ray microscopy and developing a holistic understanding of the meso-scale intercalation behavior in this phase-separating battery material.