The use of synchrotron radiation for operando studies of performance and failure of advanced batteries

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Electrochemical device is a term used to describe a group of technologies including fuel cells, batteries, electrolysers and super-capacitors. Whilst many of these technologies are already in common daily usage, for example Li-ion batteries that power our mobile phones, in the future electrochemical devices will play an increasing role in our lives – from fuel cells that can power our homes to high performance batteries for our cars.

At a microscopic length scale, these devices can be considered as one of a general class of porous materials, whereby the physical microstructure will influence a range of phenomena, including diffusion, catalysis and conductivity – our ability to engineer these microscopic features to maximize performance can be translated to substantial improvements in macroscopic device design. At macroscopic length scales the robustness of device design will influence the system energy and power density and its ability to safely store/convert energy over extended periods of time.

As these materials are likely to evolve over time, in response to range of processing and environmental conditions (sintering, corrosion, failure etc); understanding how these changes in microstructure can be linked to understanding of degradation and failure is pivotal to improving device lifetime and safety.

Over the past 10 years the increasingly widespread use of X-ray imaging and tomography has revolutionized our understanding of these materials; with increasing sophistication researchers have been able to characterize samples over multiple time and length scales from nm to mm and from ms to days. Here we consider examples of our work to explore these materials in three and “four” dimensions, to examine materials evolution with time. We will explore case studies that utilize both laboratory and synchrotron X-ray sources across a range of spatial and temporal domains, and examine how improvements in these imaging techniques, alongside correlative spectroscopy, is providing unprecedented insight into these materials and devices.