From Synchrotron Radiation to Advanced X-ray Microscopy: Exploring Secondary Batteries with STXM and Cross Modal Imaging

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Synchrotron radiation has become one of the most powerful tools for probing the structure and properties of matter at the nanoscale. By providing highly intense, tunable, and coherent X-rays, synchrotron facilities enable researchers to investigate materials with exceptional spatial and chemical sensitivity. Among various synchrotron-based techniques, Scanning Transmission X-ray Microscopy (STXM) plays a central role in visualizing chemical states and microstructures with nanometer scale resolution. In this colloquium, I will first introduce the fundamental principles of synchrotron radiation and explain how its unique characteristics such as high brightness, energy tunability, and coherence make advanced X ray imaging possible. I will then discuss the working principles of STXM, including X ray absorption spectroscopy based on chemical mapping and its ability to provide element specific and oxidation state sensitive information. To further enhance spatial resolution and structural sensitivity, I will also introduce ptychography, a coherent imaging technique that extends beyond conventional focusing limits.

As an application example, we will explore lithium-ion secondary batteries, which are essential for modern energy technologies. The electrochemical performance of these batteries strongly depends on microstructural and chemical changes occurring in cathode materials during charge and discharge cycles. By integrating large field-of-view STXM and ptychography, an approach referred to as cross modal imaging, we can bridge multiple length scales and simultaneously probe chemical heterogeneity and nanoscale structural features. This integrated methodology provides deeper insight into how particle size distribution, grain structure, and phase inhomogeneity influence electron and ion transport.

Keywords: Synchrotron radiation, Scanning Transmission X-ray Microscopy (STXM), Ptychography, Cross modal imaging, Lithium ion batteries