Techniques for Next-Generation Batteries: Unlocking Mechanisms Beyond Lithium

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Operando synchrotron techniques are becoming essential tools to unravel the complex mechanisms governing next-generation batteries. [1] By enabling structural and spectroscopic measurements during electrochemical operation, they provide a unique window into dynamic processes that are otherwise hidden. [1] In this presentation, I will introduce the concept of operando approaches and their advantages for battery research, highlighting the role of synchrotron light as an unparalleled source for multiscale and multimodal characterization. Two case studies will be presented: (i) the simultaneous use of operando energy-dispersive XRD and time-resolved tomography to investigate aluminum/graphite batteries, revealing staging behavior, inhomogeneous strain, and electrode volume changes; [2] and (ii) a combined operando SAXS/WAXS approach to directly observe the anion intercalation process in graphite, capturing intermediate phase transitions, staging evolution, and full structural reversibility, along with microporosity reorganization. [3] [4] These examples demonstrate how synchrotron-based operando studies can unlock fundamental insights into ion intercalation and interfacial phenomena, paving the way for the rational design of high-performance energy storage systems beyond lithium.