Breaking Performance Barriers of Lithium-Ion Batteries by Exploring New Materials and Storage Processes

Lithium-ion batteries have emerged as the barrier separating the corded technologies of past decades from the portable systems of the future. As advances in commercialized lithium-ion batteries over the past several years has resulted in only minor improvements, the growing intersection between technology innovation and mobile power systems is bottlenecked by the stagnant performance metrics of lithium-ion battery technology. In this talk, I will discuss broad efforts from my group to investigate energy storage platforms with promise of power capability, energy density, and/or cost that can enable advancement beyond current commercial energy storage systems. First, I will discuss our recent efforts studying co-intercalation-based storage of earth-abundant alkali metals, such as Na⁺ and K⁺, in carbon materials. Unlike conventional metal-ion storage where desolvation occurs at the electrode-electrolyte interface, co-intercalation bypasses desolvation and leads to a mechanism enabling both bulk storage characteristics of batteries, but with diffusion kinetics and durability characteristic of electrochemical supercapacitors. Next, I will discuss our efforts to develop materials toward the pursuit of a stable room-temperature sodium sulfur battery – a holy grail for rechargeable batteries, which intersects low-cost components with extraordinary energy density capability. This involves developing an understanding of the cycling of pure metallic Na anodes in the absence of dendrite formation with atomic-scale engineering techniques for cathodes that enable anchoring and confinement of electrolyte-soluble polysulfide storage products. Finally, I will discuss our recent efforts combining strain engineering, a concept native to semiconductor electronics, with electrochemistry to engineer the electrochemical potential and kinetics of storage processes based on controlled mechanical strain as an input. To conclude, I will briefly discuss some of our efforts aimed to bring advances in energy storage materials to practical integrated platforms, such as multifunctional energy storage and seamless solar-storage systems.