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Materials Challenges and Opportunities of Lithium-ion Batteries for Electrical Energy Storage

ARUMUGAM MANTHIRAM, University of Texas at Austin

Electrical energy storage has emerged as a topic of national and global importance with respect to establishing a cleaner environment and reducing the dependence on foreign oil. Batteries are the prime candidates for electrical energy storage. They are the most viable near-term option for vehicle applications and the efficient utilization of intermittent energy sources like solar and wind. Lithium-ion batteries are attractive for these applications as they offer much higher energy density than other rechargeable battery systems. However, the adoption of lithium-ion battery technology for vehicle and stationary storage applications is hampered by high cost, safety concerns, and limitations in energy, power, and cycle life, which are in turn linked to severe materials challenges. This presentation, after providing an overview of the current status, will focus on the physics and chemistry of new materials that can address these challenges. Specifically, it will focus on the design and development of (i) high-capacity, high-voltage layered oxide cathodes, (ii) high-voltage, high-power spinel oxide cathodes, (iii) high-capacity silicate cathodes, and (iv) nano-engineered, high-capacity alloy anodes. With high-voltage cathodes, a critical issue is the instability of the electrolyte in contact with the highly oxidized cathode surface and the formation of solid-electrolyte interfacial (SEI) layers that degrade the performance. Accordingly, surface modification of cathodes with nanostructured materials and self-surface segregation during the synthesis process to suppress SEI layer formation and enhance the energy, power, and cycle life will be emphasized. With the high-capacity alloy anodes, a critical issue is the huge volume change occurring during the charge-discharge process and the consequent poor cycle life. Dispersion of the active alloy nanoparticles in an inactive metal oxide-carbon matrix to mitigate this problem and realize long cycle life will be presented.