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EDITORIAL

Nanoscience and nanotechnology in next generation lithium batteries*

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Lithium ion batteries have enabled the portable electronics revolution that changed how we communicate and share information. They have also started to penetrate the vehicle electrification and grid storage markets, two applications that are at the core of a sustainable future. In the pursuit of higher energy densities, lower costs, and longer life, nanotechnology is regularly employed to create new materials and processes in order to achieve these goals. A wonderful example is the commercialization of the lithium iron phosphate cathode which functions as a high power material only in a nanophase form, clearly demonstrating the benefit of nanotechnology.

Materials engineered at the nanoscale are expected to offer a suite of advantages: high power densities are enabled by much reduced solid-state diffusion distance; high surface area reduces the effective current density; and new material structures and compositions are stabilized by nanostructuring, leading to new charge storage mechanisms. On the other hand, the use of nanomaterials in lithium ion batteries raises significant technological challenges. Thermodynamically unstable electrode/electrolyte interfaces combined with the high surface area of nanomaterials magnify the side reactions leading to performance losses. In addition electrically connecting large amounts of nanoparticles requires the use of large amounts of conducting diluents. Nanomaterials also tend to have low tap densities and are often more expensive to produce.

In order for lithium ion batteries to meet the performance and cost requirements for vehicle electrification and grid storage, they increasingly employ electrode materials with challenging reaction kinetics, such as limited ionic and electronic conductivities and complex multiphase processes. By understanding nanoscale processes and using this understanding to extend the spatial scale over which battery design can be implemented, nanotechnology is expected to play an increasingly important role in enabling these new chemistries. As illustrated by the papers in this issue, new synthesis, characterization, and computational tools will facilitate this design and enable us to identify new material systems as well as their economical production.

This special issue provides a snapshot of how various aspects of nanotechnology are being integrated in lithium ion batteries. Topics covered include synthesis of nanostructured intercalation and alloy anode materials, fundamental studies of the structure and mechanisms of nanostructured cathode materials based on intercalation and conversion, nanostructured solid-state electrolytes, and hierarchical electrode materials that contain nanometer scale building blocks.

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