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Architectures for Nanostructured Batteries[1]

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Heterogeneous nanostructures offer profound opportunities for advancement in electrochemical energy storage, particularly with regard to power. However, their design and integration must balance ion transport, electron transport, and stability under charge/discharge cycling, involving fundamental physical, chemical and electrochemical mechanisms at nano length scales and across disparate time scales. In our group and in our DOE Energy Frontier Research Center (www.efrc.umd.edu) we have investigated single nanostructures and regular nanostructure arrays as batteries, electrochemical capacitors, and electrostatic capacitors to understand limiting mechanisms, using a variety of synthesis and characterization strategies. Primary lithiation pathways in heterogeneous nanostructures have been observed to include surface, interface, and both isotropic and anisotropic diffusion, depending on materials. Integrating current collection layers at the nano scale with active ion storage layers enhances power and can improve stability during cycling. For densely packed nanostructures as required for storage applications, we investigate both "regular" and "random" architectures consistent with transport requirements for spatial connectivity. Such configurations raise further important questions at the meso scale, such as dynamic ion and electron transport in narrow and tortuous channels, and the role of defect structures and their evolution during charge cycling.

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