High-Power and High-Capacity Na-ion Full Cells

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Introduction Alternative rechargeable battery systems with transporting ions other than Li ion have attracted growing interests in recent years. While lithium-ion battery technology is quite mature, there remain questions regarding safety, lifetime, and cost. Sodium-based batteries are particularly attractive due to the promise of low cost associated with the abundance of sodium and enhanced stability of nonaqueous battery electrolytes due to the lower operating voltages[1]. Creation of nanostructured electrode materials represents one of the most attractive strategies to dramatically enhance the transport of electrons, ions, and molecules associated with cycling, enabling the use of variety of nonconventional substrates as active electrode materials. To achieve fast mass transport and high power density, unique hierarchical nanoarchitectures such as nanotubes and nanoribbons have been investigated. Excellent electronic and/or ionic conductivity is required for unhindered charge flow through out the whole device. Nanomaterials can offer a possible solution to these requirements with their ability to connect materials and build up structures from the molecular level. Electronically interconnected nanoporosity enables full participation of every electrode atom in achieving theoretical capacity while short diffusion length of Na^+ transporting ions leads to exceptionally fast charging.

Results and Discussion We will present feasibility of development of high-power and high-capacity Na-ion full cell rechargeable batteries that operate at ambient temperature. Full battery was assembled by employment of electrodes (anodes and cathodes) with tailored nanoarchitectures. Electrochemically synthesized 1D titanium dioxide nanotube (TNT) electrodes are the only metal oxide 1.2 V (vs. Na) anode that demonstrated reversible self-improving specific capacity. In contrast to crystalline TiO_2 polymorphs such as anatase and rutile that do not support Na^+ intercalation TNT shows ~150 mAh/g capacity while cycled in the presence of Na ions[2]. Nanostructured bilayered V_2O_5 is highly efficient 3 V cathode material for ambient temperature sodium ion batteries. It shows superb performance: theoretical reversible capacity for $Na_2V_2O_5$ stoichiometry of 250 mAh/g, excellent rate capability and cycle life, as well as high energy and power densities[3]. The most striking advantage of full cells exclusively made by these nanostructured electrodes is that they can deliver similar capacity in a much shorter time compared to their conventional counterparts (Figure 1). Furthermore, we developed new high-capacity Na-ion full cells that combine nanostructured bilayered V_2O_5 cathode with tin antimony alloy anode to form an energy storage devices that can achieve high power, energy density and stability needed for the next generation of hybrid systems.

Conclusions We have developed safe, high-power and high-capacity Na-ion battery systems by emphasizing the importance of tailoring nanoarchitecture of electrode materials and opening up new opportunities for rechargeable Na-ion batteries.

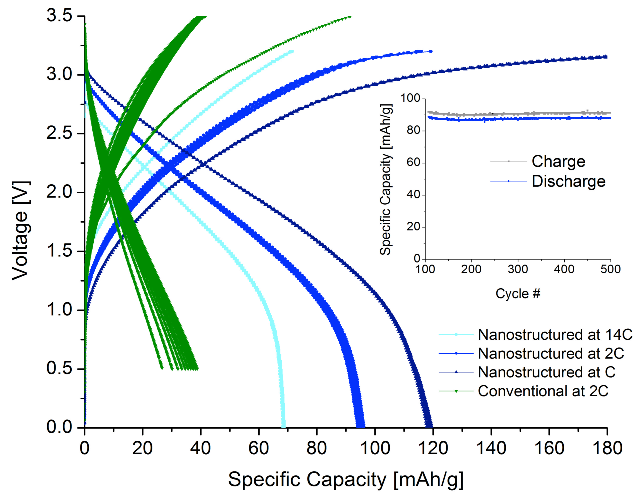

Figure 1. Performance comparison of “conventional” and “nanostructured” Na-ion full cells at different cycling rates (2-14C) in terms of delivered capacity. Even at the fast cycling rate of 2C nanostructured” Na-ion full cell preserves reversible capacity of ~90 mAh/g and operates with 100% Coulombic efficiency for 350 cycles (inset).

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