Self-adaptive Electrodes for Energy Applications

Opportunity

Conventional battery electrodes with predetermined crystalline structures often undergo phase transitions upon intercalation of transporting ions. These phase transitions cause swelling of the electrode materials resulting in local atomic rearrangements, limited diffusion of ions, and ultimately capacity degradation.

Instead, meso scale open frame architectures enable bioinspired, evolutionary approach that may result in self-adapting and self-improving electrodes that preserve superior capacity/power over prolonged cycling.

Meso Challenge

How to preserve self-adaptive/self-improving property of nanoscale objects upon their incorporation into meso scale structures and furthermore create a device that self-organizes and self-improves with repeated operation (just like nature does it!).

How to preserve molecular level connectivity, ion/electron conductivity and elasticity on mesoscopic scale.

How to establish the foundations that enable the systematic development of future generations of bioinspired self-adaptive batteries.

Approach

Bioinspired, evolutionary approach involves: (i) specifying the activating force (voltage) (ii) samples that respond to this force (electroactive materials) (iii) methods to iteratively apply forces (repeated cycling). Contra intuitively, starting from amorphous, low-crystalline materials we created interconnected porous meso scale electrodes that undergo self-organization into optimized crystalline phase upon repeated cycling.

Self-organization of materials during electrochemical cycling has never been reported before and could be an easy general approach for synthesis of new, optimized crystalline forms of materials for energy applications.

Impact

Electrodes that with repeating cycling naturally choose and optimize their crystalline structure can achieve high power, energy density and stability needed for the next generation of hybrid systems. Electronically interconnected nanoporosity enables full participation of every electrode atom in achieving theoretical capacity while short diffusion length of transporting ions (Li, Na or Mg) enables exceptionally fast charging.

References: Self-Improving High Power/High Capacity Anode for Lithium Ion Batteries Based on Amorphous TiO_2 Nanotubes", J. Phys. Chem. C, 2011, 116, 3181-3187.

Nanostructured Bilayered Vanadium Oxide Electrodes For Rechargeable Sodium-Ion Batteries, ACS Nano, 2011, 6, 530-538.

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