FROM NANOTUBES TO HETEROGENEOUS NANOWIRES: FAST ELECTROCHEMISTRY FOR HIGH POWER AND HIGH ENERGY STORAGE DEVICES

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Abstract: This presentation describes a new electrochemical growth mechanisms and applications of the conductive polymer nanotubes and the heterogeneous composite nanowires composed of conductive polymer and metal oxide in cylindrical pores of a template. Fast electrochemistry of nanotube structured materials enables us to design extremely fast charge transport devices due to thin nature of nanotube wall and well-aligned array structure. This discovery makes mass production possible in the fabrication of well-defined nanotubes with various materials from metals to metal oxides to polymers and opens a numerous applications of nanotubes to electrochemical devices. For example, using poly(ethylenedioxythiophene) (PEDOT) nanotubes, we have demonstrated the world-first moving-image speed in the electrochromic device with high optical color contrast, which has never been achieved simultaneously before. Using the same principle of the fast electrochemistry, we are developing high-power high-energy storage devices such as supercapacitors that will enable fast charge for high energy electric devices. Many near-future electrical devices require both high energy and high power density energy source that has surge capacities to provide enough power in varying demands, e.g. electric cars, large scale energy grid of renewable energy, potable electrical devices, and sensor-actuator networks for military and medical applications. In addition, the high power energy storage device can also provide short recharging time that is one of important requirements for electric car batteries. This urgent requirement has led to much interest in high power high energy storage devices such as 'supercapacitors' and 'super batteries', but it is difficult to achieve devices which provide both high energy and high power.

The attributes of good electrode materials to satisfy both high power and high energy density are: (1) high reversible storage capacity for ions (e.g. $Li+$), (2) rapid ion transport into and out of ion storage materials, and (3) high conductivity for fast electron transport. Heterogeneous nanostructured materials offer a solution to this problem through (1) large surface areas per unit volume or weight and (2) fast ion transport rates due to very short ion-diffusion path, thus promising ultrafast charge-discharge (high power) simultaneously with high energy density. Therefore, massive uniform arrays of nanostructures should be synthesized from heterogeneous materials to achieve high charge storage capacity, rapid charge transport, mechanical stability during cycling, properties which are very difficult if not impossible to realize in single material systems. The fundamental study of capacitive properties will be discussed based on the PEDOT nanotube structures and MnO2/PEDOT composite nanowire structures. Electrostatic nanocapacors will also be discussed briefly based on heterogeneous nanotube structures enabled by atomic layer deposition (ALD).

Keywords: Heterogeneous nanostructure, PEDOT, nanotube, nanowire, composite nanowire, coaxial nanowire

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