This research is focused on the developments of novel nanomaterials and subnanometer-scale materials for applications in superior lithium-ion rechargeable batteries, advanced solar cells, and efficient photocatalysis. The major work is divided into two categories. First, ultrathin and highly-conformal oxide coatings are deposited via atomic layer deposition (ALD) method for surface modification and enhanced electrochemical performance of high-capacity lithium-excess layered cathode material Li[Li,Ni,Mn,Co]O2. The high-quality surface coating can effectively isolate electrode from electrolyte, reduce HF attack and alleviate metal dissolution, to improve cycleability of electrode. In addition, thickness of ALD coating can be accurately tuned at atomic scale by varying ALD growth cycles for optimization of battery performance. Six oxide ALD layers (as thin as ~1 nm) are demonstrated to have optimal thickness for maximized performance of new-generation lithium ion batteries. The second part of the work concentrates on fast electrochemical synthesis of bamboo-type TiO2 nanotube arrays with enhanced surface area due to bamboo ridges, for applications in advanced dye-sensitized solar cells (DSSCs) and efficient photocatalysis. Ridge spacing and length of bamboo-type nanotubes can be facilely tuned by adjusting time of high-voltage step and electrolyte composition, for maximized performances of DSSCs. The titania nanotubes are also modified with silver nanoparticles for plasmon effect and reduced graphene oxide sheets for increased electronic conductivity, to achieve further improved performance in photovoltaics and photocatalysis.

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