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Nanoscale Architectures for Energy Applications[1]

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In my group, we have developed a number of different potential architecture systems for gaining insights into energy storage and photovoltaics. In one manifestation of our efforts, generating a heterojunction comprising nanotubes and nanocrystals, externally bound and connected, has been significant. The unique, innovative, and important aspect of this particular nanoscale architecture is that it takes advantage of the tunability, in terms of size, shape, and chemistry, of nanotubes and nanocrystals, to create a sharp junction interface, whose properties are inherently manipulable, tailorable, and hence, predictable. For example, the electrical resistance of nanotube-nanoparticle networks is dependent on the nanoscale junctions that exist between these constituent nanomaterials as well as on microscale and macroscale connectivity. Thus, rational design of these nanomaterials is critical to a fundamental understanding of charge transport in single molecules and the determination of their conductance. Results on these systems can therefore be used to increase understanding of intrinsic factors affecting carrier mobility, such as electronic structure, carrier trapping, and delocalization. In a second manifestation, three-dimensional, dendritic micron- scale spheres of alkali metal hydrogen titanate 1D nanostructures (i.e.: nanowires and nanotubes) have been generated using a modified hydrothermal technique in the presence of hydrogen peroxide and an alkali metal hydroxide solution. Sea-urchin-like assemblies of these 1D nanostructures have been transformed into their hydrogen titanate analogues by neutralization as well as into their corresponding semiconducting, anatase titania nanostructured counterparts through a moderate high-temperature annealing dehydration process without destroying the 3D hierarchical structural motif. The as-prepared hollow spheres of titanate and titania 1D nanostructures have overall diameters, ranging from 0.8 μm to 1.2 μm, while the interior of these aggregates are vacuous with a diameter range of 100 to 200 nm. We have demonstrated that these assemblies are useful for example as active photocatalysts for the degradation of synthetic Procion Red dye under UV light illumination. In a third set of experiments, a size- and shape-dependent morphological transformation was demonstrated during the hydrothermal soft chemical transformation, in neutral solution, of titanate nanostructures into their anatase titania counterparts. Our results indicate that as-synthesized titania nanostructures possessed higher photocatalytic activity than the commercial titania precursors from whence they were derived.

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