Nanostructures: Rational Design for Energy-related Applications

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I present our recent work on three types of nanomaterials, based on near-infrared (NIR) quantum dots (QDs), plasmonic nanostructures and transition metal (or metal oxide) nanohybrids, developed for energy-related (including solar cells and catalysis) applications.

Harvesting NIR photons represents an attractive approach to improve the energy conversion efficiency of organic photovoltaics. Herein I present some of our most recent development in the NIR QDs, PbS QDs and PbS@CdS core@shell QDs, and their application in photovoltaics. One example is about the controlled hybridization of NIR PbS QDs with carbon nanotubes (CNTs) and their further integration into poly(3-hexylthiophene), which is a hole-transporting polymer. The nanohybrid cells show considerably enhanced power conversion efficiency, which is attributed to the significantly extended absorption in NIR by PbS QDs and the effectively enhanced charge transportation due to CNTs. We have also realized controlled hybridization of PbS QDs with TiO$_2$ nanobelts, which show markedly extended “effective” sensitization up to 1400 nm. The development of PbS@CdS core@shell QDs for solar cell applications will also be briefly introduced.

On the other hand, plasmonic nanostructures have been recently explored for enhancing the efficiency of solar cells. Our recent work on some interesting plasmonic nanostructures (such as Ag nanorice and nanocarrots) that have strong resonances in the NIR regime, and their application in solar cells will also be briefly highlighted.

Transition metal and transition metal oxide nanohybrids have also drawn a lot of attention during the past decade. They are extremely attractive for realizing high-efficiency, low-cost catalytic reactions. As an example, I present novel Ni-core@Ru-shell NPs synthesized via a new organometallic approach. These core-shell NPs show remarkable performance in the hydrolysis of ammonia borane, in addition to showing interesting superparamagnetic properties. Other recently developed hybrid nanostructures such as binary oxide nanotubes will also be presented.

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