METAL NANOPARTICLE IMPREGNABLE SEMICONDUCTOR NANOSTRUCTURES: PLASMON EFFECTS AND APPLICATIONS IN SOLAR CELLS

ABSTRACT

With the rate at which we are using the fossil fuels, it is easy to understand that energy become a big issue in future. Among the alternative energy sources for fossil fuels, the solar energy is more significant because of its low environment impact. Therefore researches all over the world are engaged in development of cheap devices for the conversion of solar energy to electricity. After nearly a decade of extensive work on dye sensitized photoelectrochemical solar cells (DSSC), based on nanostructured semiconductor films have begun to receive considerable attention as the most promising system for conversion of solar energy. A nanocrystalline films of wide band gap *n*-type oxide semiconductor coated with a dye constitutes for the light harvesting component of these devices. The transfer of charge carriers from photoexited dye molecules anchored on a semiconductor surface to its bulk is known as dye sensitization. The energy conversion efficiency achievable of this DSSC depends on many factors: (1) the bulk properties of the semiconductor and the structure of the film, (2) the photophysical properties of dye and the mode of anchoring of the dye molecules to the semiconductor surface, (3) the nature of the redox electrolyte and electrocatalytic properties of the counter electrode.

However the detailed kinetics of charge injection and recombination in DSSC are not fully understood. Although metal oxide in pure form is generally considered, the cells with surface modified films constitute for optimized efficiencies. Experiments with different surface modifications and dyes indicate that the surface states on metal oxide semiconductors can be enhanced for higher efficiencies by surface treatment with metal nanoparticles. The surface states of modified semiconductors mediate to suppress recombination of the injected electrons and encourage for chelation of the dye by suitable ligands.

Dye-sensitized photoelectrochemical solar cells made from nanocrystalline films of metal oxide semiconductors doped with copper and sensitized with Indoline 149 dye are found to have impressively higher efficiencies compared to equivalent cells made from undoped films. The surface concentration of copper atoms on the metal oxide semiconductor, TiO_2, SnO_2 or ZnO where this effect is optimized is nearly the same as the concentration of dye molecules on the semiconductor surface. Copper doping shifts the flat-band potential of the semiconductor in the negative direction, which is favorable for increasing the open-circuit voltage of the cell. It is suggested that in addition to the linkage of the carboxylate ligand of the dye to the semiconductor surface, moieties in the rhodamine rings of the dye coordinate to the copper atoms on the semiconductor surface. The coordination of the dye to copper seems to have a positive influence on the efficiency of the cell.

Significant enhancement in the overall efficiencies of DSSC based on TiO_2 can be achieved by incorporating gold nanoparticles into TiO_2 film. The incorporation of gold nanoparticles in TiO_2 thin films enhance the charge transport process, which should effectively improve the short circuit photocurrent density of DSSC. Polarization of gold nanoparticles and oscillations of electrons of the gold nanoparticle surface, positively influence this enhancement of photoresponse as a consequence of the Surface Plasmon Resonance (SPR) effect, due to the creation of a local electromagnetic field. Collective oscillations of surface electrons may occur in the Au-TiO_2 interfacial region, where bands of TiO_2 bend. In addition, polarized gold particles can influence the formation of electrochemical linkages between excited dye molecules to TiO_2 particles and between TiO_2-TiO_2 particles.

Efficiency and photovoltage of the DSSC based on nanocrystalline TiO_2 thin film can be further improved by TiO_2 doped with Ni. The low doping ratios of Ni in the TiO_2 films are affected to optimize the efficiency and high doping ratios are affected to optimize the photo voltage. Ni doping, decrease the carrier trapping rate, shift flat-band potential of TiO_2 in to the negative direction and decrease the band gap, which are favorable for increasing the efficiency and the open circuit voltage of the cell by suppression of recombination.