Abstract

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Title: Studies on Light Harvesting Mechanism at Near Infrared Region of Solar Radiation for Potential Application in Photovoltaics and Photocatalysis

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The demand for the development of efficient conversion technologies of clean and sustainable energy sources is increasing due to the climate change and decrease in the fossil-fuel sources. Among various renewable energy sources, solar energy is considered to be the most promising one because of its quasi-unlimited supply. Moreover, half of the solar radiation consists of the infrared light which is mostly unutilized. Therefore, development of efficient technology for better utilization of solar radiation is really important. The objective of this thesis is to study the ultrafast dynamical processes across the interface of various hybrid nanostructures to enhance the solar light harvesting efficiency in near infrared (NIR) region of solar radiation. We have mainly focused in the ultrafast charge dynamics at the interface and its correlation with the light harvesting applications.

Sensitization of wide band gap metal oxides (such as TiO_2 and ZnO) with NIR absorbing photosensitizers or dyes is a prevalent solution for harvesting the low energy photons. However, the interaction of different ions with the dyes plays a significant role in determining its light harvesting efficacy. Therefore, in one of our study, we have thoroughly investigated the optical properties of a NIR active aluminum phthalocyanine chloride molecule in the presence of different naturally abundant ions. Based on the photophysical studies, we have further developed a sensor for fast and selective detection of fluoride level in drinking water. Among various technologies, InAs quantum dot (QD) based heterostructure have attracted widespread attention as an active material for the electrical conversion of NIR solar radiation. In particular, such QDs are grown in molecular beam epitaxy (MBE) by using two well established techniques, such as Stranski-Krastanov (SK) and submonolayer (SML). However, ultrafast dynamics of the optically injected carriers

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play a crucial role in determining the efficiency of such QD based optoelectronic devices. Thus, in one of our study, a detailed characterization has been carried out to unravel the impact of various strain reducing layers in ultrafast carrier dynamic of InAs/GaAs QD based heterostructures. In another work, we have studied the carrier recombination dynamics in a coupled SK and SML QDs based heterostructure. Our main motive has been to optimize the coupled heterostructure for potential application in photovoltaic devices. Moreover, in case of environmental cleaning application, the NIR harvesting is an important factor due to its deeper penetration and longer working hours in comparison to the visible light. Among different bismuth based semiconductors, Bismuth oxyiodide (BiOI) possesses a narrow band gap (~ 1.7 eV) and a wide absorbance band that covers the entire visible as well as a significant portion of the NIR region of the solar spectrum. However, BiOI suffers from a higher recombination rate of photo-generated charge carriers due to strong hybridization between valence band Bi 6s and O 2p orbitals which limits its photocatalytic efficiency. Thus, in one of our study, we have synthesized flower like BiOI microspheres and further decorated with noble gold (Au) nanoparticles to increase the charge separation efficiency of the semiconductor. The synthesized nanohybrid has been further used for the photocatalytic degradation of methyl orange as well as reduction of hexavalent chromium.

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