Abstract

The thesis investigates the optical, photo-physical, and electrical properties of CdTe and HgCdTe nano- and micro-structures synthesized by hydrothermal/solvothermal technique. Application oriented studies like fluorescence resonance energy transfer (FRET), bio-sensing, two photon absorption are carried out on colloidal CdTe QDs. Defect related and temperature dependent luminescence studies are carried out in detail on HgCdTe nano and micro-crystals. The electronic device application-oriented studies of nano- Schottky diode and electrical bistability are carried out on colloidal CdTe QDs. This work is presented in seven chapters including summary and directions for future work.

Chapter 1 provides a brief introduction to optical, electrical, and photo-physical properties of semiconductor QDs and hydrothermal/solvothermal technique in preparation of quantum nanostructures. A review of CdTe and HgCdTe nanostructures and its technological applications are discussed.

Chapter 2 provides the experimental techniques used in this work. First, the hydrothermal/solvothermal synthesis of CdTe, HgCdTe nano- and micro-structures, and secondly, the characterization tools used in this work are briefly presented. Also, we presented hydrothermal/solvothermal synthesis of few other nanostructures such as CdSe, PbTe and Au for future work.

Chapter 3 describes, the interaction of CdTe QDs with biomolecules and the energy transfer phenomena between two different size CdTe QDs in aqueous media with the use of steady-state PL spectroscopy. The structural and optical properties of the QDs were characterized by transmission electron microscopy, photoluminescence and UV-visible spectroscopy and their formation mechanism is discussed. The hydrothermally grown highly luminescent 3-MPA capped CdTe QDs shows good stability in aqueous media even after 45 days under natural ambient and room conditions. The presence of thioalkyl acid groups in 3-MPA helps the QDs to become bio-compatible. The quenching of photoluminescence intensity of CdTe QDs in the presence of l-cysteine and DNA confirms its bio-compatibility nature for bio-sensing. The overlapping in absorption and emission spectra of two different size CdTe QDs is described here as one of the reasons for energy transfer in aqueous media.

Chapter 4 describes the growth and PL properties of NIR emitting Hg1–xCdTe (MCT) nanostructures with different compositions (x = 0.1 - 0.8) synthesized by solvothermal method, which is a facile, cost effective and solution growth approach to the large-scale preparation of MCT at relatively low temperature (180 °C) using an air stable and water soluble Te source. The room temperature FTIR transmission and low temperature PL studies for a composition of x = 0.8 gives a band gap of 1.1 eV and a broad emission in NIR region (0.5 - 0.9 eV) respectively. The temperature dependent PL study is understood by the configuration-coordinate model that give insight on the competition between radiative recombination through localized states and non-radiative recombination.
process which involves phonon emission. Hence, it is suggested that the observed luminescence bands are related to defect states originating from the compositional disorder in MCT nanostructures.

Chapter 5 describes non-linear absorption studies in 3-mercaptopropioninc acid capped water-soluble CdTe QDs using open z-scan technique in near resonant regime. The origin of optical limiting is predominantly effective two photon absorption mechanism which varies with QD size. The effective two photon absorption coefficient ($\beta$) was observed to be 0.55 cm/GW for 2 nm size QDs which is about 10 times higher than the value reported in off-resonant region. Because of their excellent nonlinear optical properties, they are considered to be promising materials for all-optical switching and optical limiting devices.

Chapter 6 describes the current-voltage characteristics of MPA capped CdTe QDs in different device geometries such as planar and sandwiched using Pt, Ag, and ITO as metal electrodes. In particular, nano-Schottky diodes of CdTe QDs with platinum metal electrodes in metal-semiconductor-metal planar configuration fabricated by drop-casting shows an asymmetry and non-linear I-V characteristics between forward and reverse directions, which has been explained in detail in terms of size distributions of QDs. It also describes the observation of electrical bistability in CdTe QD/polymer heterostructures in sandwich device geometry.

Chapter 7 presents the summary and directions for the future work.