Free standing semiconductor nanocrystals (NCs) are promising candidates for optoelectronic applications and biological mapping studies due to unprecedented optical properties that evolve as a consequence of quantum size effects, in particular discretization of electron energy levels. High surface to volume ratio adversely affect the photoluminescence emission yield and decay dynamics. Managing electron-hole localization in the central region of quantum dot requires formation of core-shell NCs instead of usual organically capped semiconductor NCs. Growth of shell on the semiconductor NCs can generate strain and hence needs to be addressed.

In the present work, undocumented properties of semiconductor nano-heterostructures, observed in the optical spectra are explored. Effect of the lattice mismatch of about 7% between CdS and ZnS on the electron energy levels of core-shell CdS-ZnS quantum dots with shell thickness up to four monolayers is studied. As a manifestation of strain, the low temperature radiative lifetime measurements indicate a reduction in Stokes shift from 36 meV for CdS to 5 meV for CdS/ZnS with four monolayers of overcoating. Concomitant cross-over of S- and P-symmetric hole levels is observed which can be understood in the framework of theoretical calculations predicting flipping the hierarchy of ground hole state by the strain in CdS NCs. Furthermore, a non-monotonic variation of higher energy levels in strained CdS NCs is discussed.

In order to avoid erroneous effects of strain, graded core-shell NCs are prepared, wherein composition changes along the NC radius. Temperature dependent photoluminescence studies were carried out on CdZnS-ZnS alloy core graded shell NCs with varying composition. The effect of grading on the emission line width and hence exciton-phonon coupling is studied. Contrary to the consensus that narrow emission line width is observable with reduction in size (due to increased exciton-acoustic phonon coupling coefficient $\sigma$), an increased value is noted with size. Based on a theoretical report on graded core-shell NCs, the relationship between electron-hole wave function overlap and exciton lifetime was invoked to understand this anomaly. Smaller sized alloy core-shell NCs (CdZnS/ZnS-I) have larger lifetime than that of larger NCs (CdZnS/ZnS-
II) as determined from time-resolved spectroscopy. Thus, CdZnS/ZnS-I NCs should have smaller electron-hole wave function overlap giving larger effective size of NCs even though the actual size, estimated from TEM, was smaller. Graded core-shell NCs reveal an additional functionality to control the emission line width in NCs.

Metal-semiconductor interfaces are being investigated not only to understand the charge transfer mechanism but also due to the ability of metal NCs to capture the electromagnetic radiation by Plasmon excitation and transfer energy to the semiconductor. Interaction between ZnSe and Ag in hybrid NCs is probed by photoluminescence and Raman spectroscopy with varying amount of Ag. A non-trivial phenomenon of charge transfer from Ag to ZnSe is predicted to be responsible for the enhancement in PL and Raman intensity in case of ZnSe-Ag core-shell NCs. Metal induced increase in the radiative decay rate of semiconductor NCs is reflected in an enhancement in the PL emission intensity at lower amount of Ag. Even though both Raman and PL intensity increased in ZnSe-Ag hybrid compared to that of ZnSe NCs, an enhancement in Raman scattering intensity and PL emission intensity follow the opposite trends.

Interestingly, ZnSe nanorods (length about 15 nm) tipped with Au NCs of size 4.5 nm were also prepared by the wet chemical route. Raman scattering intensity is enhanced 1.8 times and is attributed to the local electric field enhancement.