Abstract

This thesis is an attempt to investigate few unsolved problems related to the properties of III-V semiconductor nanostructures to get an in-depth view of some of the unexplained phenomena. After introducing the subject, we have interpreted theoretically the interdiffusion induced significant changes in the peak energy, linewidth, and intensity of the photoluminescence (PL) spectra of annealed In$_x$Ga$_{1-x}$As/GaAs quantum dots (QDs) through suitable quantum mechanical models and concepts. We have also investigated the dependence of the PL of annealed realistic In$_x$Ga$_{1-x}$As/GaAs and In$_x$Ga$_{1-x}$N/GaN QDs on their shape and dimension, through quantum mechanical computations. We have considered various dot geometries which are of theoretical and practical interest such as pyramidal, truncated pyramidal and lens shaped.

A model has been formulated in this thesis to investigate the interband optical absorption of realistic QD systems having finite potentials at the boundaries. Considering the Gaussian distribution of the dot size, the absorption spectra of In$_{0.7}$Ga$_{0.3}$N/GaN and In$_{0.66}$Ga$_{0.33}$As/GaAs QD systems have been calculated, where it is observed that for realistic dots there is red shift of the absorption peak and the linewidth decreases as compared to that of the ideal QD system for the same size deviation.

In this thesis we have estimated the ratios of conduction band offset to valence band offset ($\Delta E_C : \Delta E_V$) of In$_x$Ga$_{1-x}$N/GaN quantum wells (QWs). Reported values of $\Delta E_C : \Delta E_V$ vary widely from 38:62 to 83:17. While trying to explain some experimental PL results, obtained from In$_x$Ga$_{1-x}$N/GaN QWs, it has been found that a new band offset ratio, $\Delta E_C : \Delta E_V = 55:45$, supports most experimentally reported data precisely. In this work detailed theories,
procedures, results and discussions to establish the newly estimated band offsets are presented.

Subsequently, we have suggested the prominence of higher order transitions \( e_2 - h_4 \) in the PL spectra of the \( \text{In}_x\text{Ga}_{1-x}\text{N/GaN} \) QWs, which is not usual. When a strong piezoelectric field exists across a QW, as encountered in \( \text{In}_x\text{Ga}_{1-x}\text{N/GaN} \) QWs, the probability of optical transitions from higher sub-bands of the QW is enhanced. In our work this theory has been established from reported experimental results.

Finally we conclude with some suggestions for future work related to III-V semiconductor nanostructures.