Preface

Motivation

The In\textsubscript{x}Ga\textsubscript{1-x}As/GaAs and Al\textsubscript{x}Ga\textsubscript{1-x}As/In\textsubscript{y}Ga\textsubscript{1-y}As/GaAs systems are important heterostructures for high speed and optoelectronic device applications. They also provide a convenient system for investigating the physics of strained quantum well and superlattice structures. Nearly ideal conditions for the study of many-body effects, namely, the Fermi-edge singularity, band-gap renormalization, or shake-up processes are provided by pseudomorphic modulation-doped Al\textsubscript{x}Ga\textsubscript{1-x}As/In\textsubscript{y}Ga\textsubscript{1-y}As/GaAs heterostructures.

The localization of excitons and the formation of localized biexcitons in the naturally formed quantum dots due to quantum well (QW) interface roughness and the many body effects such as Fermi-edge singularity, bandgap renormalization are the interesting topics for investigation. Therefore, there is an obvious interest in investigating these heterostructures.

This thesis devoted to the study on undoped In\textsubscript{x}Ga\textsubscript{1-x}As/GaAs and modulation-doped Al\textsubscript{x}Ga\textsubscript{1-x}As/In\textsubscript{y}Ga\textsubscript{1-y}As/GaAs heterostructures. The samples used in this study were grown by molecular beam epitaxy. In the undoped In\textsubscript{x}Ga\textsubscript{1-x}As/GaAs QW samples, a photoluminescence (PL) study of the excitons and biexcitons localized in the naturally occurring quantum dots has been carried out. In modulation doped pseudomorphic Al\textsubscript{x}Ga\textsubscript{1-x}As/In\textsubscript{y}Ga\textsubscript{1-y}As/GaAs QW samples, PL study of the Fermi edge singularity, electroluminescence (EL), hydrogenation, and magnetotransport studies have been carried out.

The first chapter is an introduction to this thesis. It gives an overview of pseudomorphic In\textsubscript{x}Ga\textsubscript{1-x}As/GaAs and modulation doped Al\textsubscript{x}Ga\textsubscript{1-x}As/In\textsubscript{y}Ga\textsubscript{1-y}As/GaAs QW heterostructures.

The second chapter is about the biexcitonic luminescence from naturally occurring quantum dots formed due to monolayer well width fluctuations in undoped
In$_x$Ga$_{1-x}$As/GaAs QWs of width of around 75Å. In this study we have carried out conventional PL measurements on two In$_x$Ga$_{1-x}$As/GaAs QW samples. The first sample consists of six QWs of width 75 Å grown at different growth temperature (480-600°C). This growth is carried out to optimize the growth temperature of InGaAs layers. The second sample is a 20 period 75 Å multiple QWs. At certain positions on these QW samples additional PL line was observed below the primary excitonic line. The observed intensity variations of the primary excitonic and the additional lower energy line and the energy separation of about 3 meV between them indicate their origin must be due to the localized excitons and biexcitons in the naturally occurring quantum dots in the quantum wells.

The third chapter is concerned with hydrogenation studies on modulation doped pseudomorphic and partially relaxed Al$_x$Ga$_{1-x}$As/In$_y$Ga$_{1-y}$As/GaAs quantum wells. The PL spectra of the modulation-doped pseudomorphic Al$_x$Ga$_{1-x}$As/In$_y$Ga$_{1-y}$As/GaAs structure taken after hydrogenation of the sample in the temperature range of 150 – 200°C for 1 hour indicates a reduction in the two-dimensional (2D) electron density in the quantum well. We attribute the reduction in the two-dimensional (2D) electron density in the quantum well to the passivation of the donors in the Al$_x$Ga$_{1-x}$As supply layer. Annealing the hydrogenated sample at about 250°C in hydrogen ambient leads to the reactivation of the donors. In the partially relaxed modulation-doped Al$_x$Ga$_{1-x}$As/In$_y$Ga$_{1-y}$As/GaAs heterostructure, a large improvement in the subband PL is observed after hydrogenation of the samples above 250°C. The as grown sample shows only a weak PL peak related to the optical transition from the first electronic subband to the first heavy hole subband in the InGaAs quantum well. After hydrogenation of the sample, two PL peaks, arising from the optical transition from the first and second electronic subbands to the first heavy hole are observed. The improvement in the PL spectra of the sample is attributed to the passivation of the dislocation related defects in the InGaAs quantum well and an increase in the 2D electron density in the InGaAs quantum well by atomic hydrogen.

The fourth chapter deals with magnetotransport studies on a modulation doped Al$_x$Ga$_{1-x}$As/In$_y$Ga$_{1-y}$As/GaAs quantum well sample. The Shubnikov de Haas measurement is carried on the sample at 1.5 K and with magnetic field up to 7 Tesla.
The quantum lifetime and quantum mobility of the two-dimensional electron gas were determined from the Shubnikov de Haas data.

The chapter fifth is on the photoluminescence studies of Fermi edge singularity (FES) in the modulation doped pseudomorphic Al$_x$Ga$_{1-x}$As/In$_y$Ga$_{1-y}$As/GaAs quantum wells. In these samples the FES from the Fermi wave vector of the first electron subband in InGaAs QW is observed under the conditions of the second electron subband population with 2DEG. FES is visible even at 4.2 K and with initial increase in temperature, an enhancement of the FES intensity is observed and it grows into a separate peak at around 20 K. With further increasing temperature it is found to be quenching and disappears at around 40 K.

The chapter sixth is on the low-temperature electroluminescence (EL) studies on modulation-doped pseudomorphic Al$_x$Ga$_{1-x}$As/In$_y$Ga$_{1-y}$As/GaAs quantum wells. The EL measurement is carried out by applying a bias between a semi-transparent gold gate and alloyed gold-germanium Ohmic contacts made on the top surfaces of the samples. The EL observed under positive bias to the gate appears identical in shape to that of the PL spectra from the samples. With increasing gate voltage an increase in the EL intensity and a red shift in the EL spectra has been observed. The shift in the luminescence peak due to the transition from the second electron subband to the first heavy-hole subband is found to be more significant compared to the peak due to the transition from the first electron subband to the first heavy-hole subband with increasing bias.

Finally, in chapter seven the overall work presented in the thesis is summarized and conclusions and limitations in the presented work is given. It also discusses the future scope for the work in this area.