Project Title :

Investigation of optical properties and electronic transport mechanisms in n ve p- type Modulation Doped $Ga_{1-x}In_xN_yAs_{1-y}$ /GaAs Quantum Well Structures

Abstract

III-V Semiconductors are indispensable for the realization of today's optoelectronic devices and this class of materials is also dominant in key high frequency electronics components for wireless communication such as mobile telephone systems. Thank to progresses in epitaxial growth techniques, the miscibility of binary III-Vs and the possibility to stack such layers of various compositions and doping levels (thus creating "heterostructures") is crucial for all these applications. The tailoring of heterostructure properties is limited by the different lattice constants of the range of available band gaps in order to prevent imperfections. Thus, for example, GaAs-based materials are limited to emission for a maximum of about 1200nm. This limitation can be greatly reduced by incorporating a few percent of nitrogen as a group V element into GaAs or GaInAs, i.e. by creating the so-called dilute nitrides. Nitrogen into the lattice of host material increases the lattice and causes a reduction in bandgap energy. Dilute nitride semiconductors are considered as an alternative to current systems for using applications such as laser, photodiode, solar cell, optical amplifier etc. due to their superior performance and low cost production. During the past decade, dilute nitrides, particularly the quaternary material system of GaInNAs/GaAs have attracted a great deal of attention, both because of unusual physical proper- ties and potential applications in a variety of optoelectronic devices. Although the optical properties of GaInNAs/GaAs heterostructures have been extensively studied, there have been comparatively little experimental studies in transport properties in GaInNAs. The introduction of small nitrogen strongly disturbs the conduction band of Ga(In)As leading to significant effect on the electron mobility. A large drop in the electron mobility at room temperature has been observed in GaInNAs alloys, which can be attributed to both the enhanced electron effective mass due to the flattening of the conduction band edge, and the nitrogen complex-related strong alloy scattering. However, the addition of N has negligible effect on valance band, thus the hole mobility is expected to be much higher than that of electron at low temperatures due to the lack of N-related alloy scattering. In the proposed project, it is aimed to investigate optical properties and electronic transport mechanisms in n- and p-type modulation doped GaInNAs/GaAs quantum well structures depending on different nitrogen compositions and post-growth thermal annealing effects.

The structures of n- and p-type modulation doped GaInNAs/GaAs quantum wells have been designed by the project leader and growth by Tampere Technical University, Finland where the project leader has collaboration via COST Action MP0805 by using Molecular Beam Epitaxy (MBE). Optical properties will be studied using Photoluminescence, Photocounductivity, Photomodulated Reflectance techniques, whereas Hall Effect and Magnetransport measurements will be carried out for determining electronic transport mechanisms. The temperature dependent mobility of 2D electron gas will be explained using an analytical model that accounts for the most important scattering mechanisms. Under the light of the obtained results, at the last stage of the proposed project, it is aimed to fabricate a laser structure for 1300 nm optical window that will be composed of the most ideal modulation doped structure with high optical quality and highest carrier mobility.

In the theoretical stage of the proposed project, the electronic band structure of the samples will be determined by using the k.p method and then the characteristic physical properties of the system will be obtained. Also we will obtain the intersubband and interband optical transition energies, excitonic recombination, impurity binding energies, radiative and nonradiative transition time for the considered structure. The obtained theoretical results will be compared with experimental results.

The outcomes of the project prepares a strong background for designing edge and surface emitting laser structures having an active region composed of modulation doped structures.

It is aimed to complete the proposed project in 36 months. Project team have experience on electrical and optical characterization techniques, theoretical calculations of optical transition energy and absorption spectrum and the physics of dilute nitrides. The outputs of the project has potential to be published in SCI journals because the results of the project will fill in important gap in the literature.