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Free Standing Quantum Wells

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Abstract

Recent advances in microfabrication techniques in conjunction with the precise growth of layers of single crystalline materials by epitaxial growth techniques allow the creation of new electro-optic microstructures. We have selectively etched compositionally modulated III-V heterostructures to produce quantum wells (QW's) which are confined on both sides by air or vacuum. The material is patterned so as to have the QW's suspended horizontally between vertical support posts. This structure is ideal for probing the local properties of solids, e. g., the interaction of quantum confined states with surface or interface states.

Objectives

The research goal is to achieve a fundamental understanding of the physical processes occurring at the surfaces and interfaces of epitaxially grown semiconductors. This will facilitate the development of quantum well devices for optoelectronic and photonic integrated circuit applications and provide quantitative descriptions of key phenomena which impact their performance. Quantum well devices such as laser diodes, optical amplifiers and optical modulators are key components for data transmission and remote sensing. Such optical systems are of interest for applications in high speed plasma physics experiments, advanced computational systems, metrology, and communications networks. The work proposed here is intended to develop a strong research program at Clark Atlanta University in the fundamental aspects of the material systems utilized in these areas. The training of graduate and undergraduate students is an integral part of this program.

We are developing the infrastructure to study the interaction kinetics of the quantum confined exciton states in the free standing GaAs QW's by low temperature photoluminescence (PL). The immediate goals of this project were to construct a solid source molecular beam epitaxy (MBE) system for III-V arsenide growth and to identify suitable regions for PL analysis at Lawrence Livermore on the currently available free standing AlGaAs/GaAs quantum well samples with scanning electron microscopy.

The presently existing QW structures have been prepared from both GaAs/AlGaAs and InGaAs/InP superlattices. The GaAs/AlGaAs superlattices were grown by both solid source molecular beam epitaxy (MBE) and metal-organic vapor phase epitaxy (MOVPE) on GaAs (100) substrates. The InGaAs/InP superlattices were grown by MOVPE on InP (100) substrates. We have been able to achieve reproducible well widths from 80-200 Å with variable spacings from 100 to 2000 Å without difficulty.

Spectroscopy of the free standing GaAs (100) QW's has been done with near-field optical microscopy (with J. Trautman of AT&T Bell Labs). Preliminary results show little luminescence at room temperature from the 200 Å thick wells with 2000 angstrom gaps. The luminescence signals from the supporting AlGaAs/GaAs posts and the surrounding GaAs substrate, however, are strong. This suggests either excess recombination due to surface states in the quantum well region or insufficient absorption length for photoluminescence. Room temperature cathodoluminescence (with C. A. Warwick of AT&T Bell Labs) showed that the luminescence efficiency of the mesa etched structure exceeded that of the GaAs substrate but was not able to differentiate the signal from the support posts and the suspended wells.

State-of-the art facilities exist within LLNL to conduct a broad based investigation of quantum well materials. On site at LLNL in the Condensed Matter Science Division we have the capabilities to perform a variety of optical probes, such as Raman spectroscopy, photoluminescence and femtosecond optical spectroscopy. In addition we have the capability to do these optical experiments at high pressure and low temperature. The initial analysis of the existing sample set by the scanning electron microscope at Clark Atlanta reveals that the samples are in various stages of the fabrication process ranging from raw substrate to fully exposed free standing QW's. Suitable regions on the appropriate samples were mapped out for probing by photoluminescence at LLNL.

An undergraduate student, Mr. Jason Collins, has participated in the room temperature photoluminescence measurements with H. W. H. Lee at LLNL. The results were inconclusive. Low temperature measurements are currently being planned with collaborators at the New Jersey Institute of Technology. Mr. Collins presented a poster entitled "Free Standing Quantum Wells" on this project at the Annual Student Scientific Research Symposium held at Clark Atlanta University, Atlanta, Ga. on April 30, 1998. Mr. Collins completed his degree requirements for the B. S. degree in Physics here at Clark Atlanta in December 1998.

The solid source III-V MBE reactor and its associated cryogenic system have been installed at Clark Atlanta. The system is now operational. A faculty member in the department of Physics, Mr. Terry Harrington, was sent to TLC Precision Wafer Manufacturing in Minneapolis, Minn. for training in the operation of the MBE apparatus.

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