III-V COMPOUND SEMICONDUCTOR NANOSTRUCTURES BASED NANOHETEROSTRUCTURES

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ABSTRACT

The nanostructures of III-V compound semiconductors have been widely studied for the development of next generation of photonic and electronic devices. Immense research efforts are ongoing to develop economical methods to obtain device quality uniform semiconductor nanostructures in high yield and having good structural, optical, & electrical characteristics. The present thesis is mainly focused on working out convenient and easily scalable methods for preparation of good optical quality uniform epitaxial nanostructures of GaAs, and GaN, in high yield to fabricate nanoheterostructures (NHSs) for energy/charge transfer applications. Both, bottom-up and top-down approaches have been adopted to prepare high quality, uniform nanostructures. The bottom-up approach involved the epitaxial growth of GaAs nanostructures using self-assembled Ga droplets as catalyst by Metalorganic Vapor Phase Epitaxy (MOVPE). In top-down approach, epitaxial GaN nanostructures have been prepared by plasma etching of GaN epilayers and AlGaN/GaN heterostructures grown by MOVPE.

First two chapters (Chapter 1 and 2) present an account of extensive literature survey of recent research work in the field of growth and fabrication of III-V compound semiconductor nanostructures for device application along with brief description of various methods and techniques employed for the growth, fabrication, and characterization in this work. In Chapter 3, an understanding of evolution of self-assembled structure of Ga under different growth conditions of MOVPE has been developed, as the droplets have to be used as catalyst for the growth of GaAs nanostructures. In addition, fabrication and characterization of the novel Ga-Ga_2O_3 core-shell NHSs obtained by *ex situ* oxidation of the droplets have been presented as

major spin-off of the study. In Chapter 4, growth of good optical quality and highly uniform, vertical, epitaxial, hexagonal GaAs nanostructures with six symmetric sidewall facets by MOVPE has been presented. In addition, efficient resonance energy transfer from CdSe quantum dots (QDs) to GaAs nanostructures has been demonstrated that has led to enhanced quenching of the fluorescence of QDs due to non-radiative relaxation on the surface of six {110} side facets of the nanostructures through shallow traps.

Convenient top-down fabrication schemes of GaN nanostructures and nanowires based on mask and maskless etchings have been presented in Chapters 5 and 6, respectively. The first scheme involved three easy process steps, namely, thin film coating, rapid thermal annealing (RTA), and plasma etching. The first two steps resulted in fabrication of mask comprising the self-assembled nanoparticles by RTA of thin film of Ni deposited on GaN epilayer. A good mask composed of sub-50 nm agglomerated nanoparticles in high density has been fabricated that led to the formation of reasonably uniform conical GaN nanostructures in the third step by inductively coupled plasma reactive ion etching (ICP-RIE). The second scheme has been based on a highly convenient single step novel fabrication of GaN nanowires by maskless plasma etching without using the ICP and a mask to cut down the overall process cost and the complexity. Vertically aligned GaN nanowires and nanowires comprising AlGaN/GaN axial NHSs with sub-50 nm diameter have been fabricated in high density for charge transfer application using the maskless scheme by etching GaN epilayers with high density of threading dislocations (TDs). Effective passivation of the NHSs by suitable polymer has led to significant enhancement in the emission characteristics with negligible effect on the charge transfer.