ABSTRACT

The present research work focuses on the growth and characterization of group III-Nitride (InGaN) epitaxial layers as well as nanostructures on Si(111) substrates. The growth system used in this study was a plasma-assisted molecular beam epitaxy (PAMBE) system equipped with a radio frequency (RF) plasma source. Device quality GaN epilayers were obtained and InGaN/Si(111) heterojunctions were studied. In- GaN based multi-quantum well LED structure has been realized for green emission. Further catalyst free ultra fine GaN nanorods were grown using a two step method and further InGaN nanostructures were embedded in the as-grown nanorods. InGaN quantum dots were grown using droplet epitaxy and were characterized by Scanning Tunnelling Microscopy and Spectroscopy.

It gives a brief introduction about III-nitride materials, growth, substrate selection, significance of III-Nitrides and Si integration and role of dimensionality.

It deals with experimental techniques including the details of PAMBE system used in this work, substrate preparation, and detailed characterization of III-nitride epitaxial layers as well as nanostructures.

It deals with the optimization of GaN epilayers on AlN/Si (111) templates. AlN underlayer was chosen to minimize the concentration of defects and also acts as an insulating layer which is crucial when it comes to integration of many other devices. The growth temperature was optimized under nitrogen rich growth regime and with the use of a thinner and better quality AlN underlayer and Si doping we could achieve device quality epilayers (1500 arc sec) for a thickness of 150 nm. The electron concentration and mobility were found to be -1.374 _1019cm⍰3 (indicating n-type) and 72 cm2/V.s. Current-voltage measurements were carried out in temperature range of 77K-400K and the current conduction mechanisms at room temperature were identified. An in-depth analysis of temperature dependent current-voltage measurements reveal that the barrier height at the interface is not uniform and is found to have a double Gaussian distribution of barrier heights.

It deals with the growth of InGaN epilayers on Si (111) with various substrate treatments. Actual indium composition was determined considering the bi-axial strain present in the epilayers. The effect of substrate treatment on epilayers evolution and quality are discussed. We could observe room temperature photoluminescence from the as-grown epilayers indicating that the epilayers are of good optical quality. InGaN/Si heterojunctions were studied for UV-detection applications. It was found that the heterojunction behaved as a self-powered device, i.e., the device showed a sharp rise in the photocurrent under UV illumination at zero bias. The rise and decay times were found to be 20ms and 33 ms respectively. The bandgap of grown InGaN epilayers were tuned for emission in Green wavelength range. (500nm-550nm)

It discusses the sequential process involved in the unition of individual layers to successfully achieve a multi- quantum well structure. In the previous chapter, InGaN epilayers with emission in the green (500nm) region were obtained and having identified the growth conditions for green emission, InGaN epilayers were further grown on GaN/Si (111) and we could tune the bandgap to obtain the emission in blue region. The effect of InGaN growth on

thickness was studied which finally led us to develop a growth sequence for successfully obtaining a multi quantum well structure.

It deals the growth, structural and optical characterization of InGaN nanostructures embedded in GaN nanorods. The first part deals with the spontaneous growth of very fine (20nm diameter) GaN nanorods on Si (111). Low temperature photoluminescence spectroscopy (LTPL) was used to determine the optical properties of the GaN nanorods. The second part discusses the growth conditions for embedding InGaN in the earlier formed GaN nanorods. The effect of substrate temperature on the evolution of InGaN structures is assessed. Scanning Transmission Electron Microscopy along with Energy Dispersive Spectroscopy (STEM/EDS) is used to determine the elemental distributions in the as-grown nanostructures. LTPL was carried out to determine the emission characteristics of the InGaN/GaN nanostructures. We could successfully obtain room temperature emission in blue region from the core-shell nanorods which happens to be rare achievement.

It deals with the growth of high indium content InGaN QDs by droplet epitaxy has been attempted for the first time. The experimental conditions behind InGa droplet formation have been discussed. The influence of droplet formation temperature on the transition from nanoscale structures to quantum dots has been discussed. Room temperature scanning tunnelling microscopy and spectroscopy measurements were carried out. It was found that the QDs exhibited compositional variations even at nanoscale from STM/STS studies.

It gives the summary and conclusions of the present study and also discusses about future research directions in this area.