ABSTRACT

Group III nitrides such as Indium Nitride (InN), Gallium Nitride (GaN) and Aluminium Nitride (AlN) are currently the most challenging and technologically important materials, which have the potential for optical devices for the entire visible spectrum and extending far into the ultraviolet wavelengths. The best understood III-nitride semiconductor is GaN with a bandgap of 3.40 eV at room temperature. In addition, GaN is the most favorable material system for high power electronic devices that can operate at high temperatures. GaN substrate material is not widely available for homoepitaxial growth due to the difficulties in GaN bulk crystal growth. Hence, GaN layers are grown heteroepitaxially on foreign substrates such as sapphire and silicon carbide (SiC) which introduce high dislocation density in the grown layer due to large lattice mismatch and thermal issues.

GaN epitaxial layers are grown by metal organic chemical vapour deposition (MOCVD), molecular beam epitaxy (MBE) and hydride vapour phase epitaxy (HVPE) methods for further processing as functional devices. The process of epitaxy is also unique in its ability to control the composition and doping. Using epitaxy, the electronic and optical properties of a material can be engineered to create device structures with unique characteristics. Chloride Vapour Phase Epitaxy (Cl-VPE) technique is a near equilibrium process. The other epitaxial techniques (MOVPE and MBE) operate far from equilibrium conditions.
GaN epilayers are grown on (0001) sapphire substrate through the reaction between GaCl$_3$ and ammonia (NH$_3$) in a resistively heated quartz reactor. As the growth occurs at a relatively high temperature, the reaction chamber is designed with a quartz tube of length 90 cm, wall thickness 2 mm and diameter 70 mm. The crystalline GaCl$_3$ in the quartz cell assembly is melted by a liquid paraffin bath, in which it is immersed. The bath is maintained at the desired temperature. The purifier system consists of molecular sieves, which is a palladium and silica based compound, to remove moisture, carbon monoxide and carbon dioxide from the ammonia gas. The purified ammonia is of analytical grade. After this online purification of ammonia gas, the flow is monitored using an ammonia gas flow meter.

Growth conditions for GaN using GaCl$_3$ precursor and ammonia have been investigated. Experiments have been performed for various flow rates of ammonia and the experimental conditions have been optimized for obtaining GaN. The grown GaN epilayers are subjected to various characterization techniques. The crystalline and optical qualities of GaN layers grown by Cl-VPE have been evaluated at various flow rates of ammonia. X-ray diffraction (XRD) study is used to determine the structural properties of the film. The optical properties are evaluated using UV transmittance spectrometer and photoluminescence (PL) studies at room temperature. The surface features of GaN at different flow rates have been analyzed through atomic force microscopy (AFM). The qualities of the films grown at different flow rates have been compared. The optimum conditions to
realize good crystal structure and smoother surface morphology have been obtained and reported.

Raman and ellipsometry studies are used to determine vibration modes and refractive index, extinction coefficient of GaN on sapphire (0001) substrate. Etching of GaN samples are performed using ortho phosphoric acid (H₃PO₄) (85%) at four different temperatures. After the acid reached specified temperature, GaN samples are immersed in the acid for a time period of 5 minutes. GaN samples is also etched with molten potassium hydroxide (KOH) contained in a ceramic crucible. For this etching, the experiments are performed at different temperature and lasting for 3 minutes. The surface morphology of the GaN etched samples have been examined using Scanning Electron Microscope (SEM). Hexagonally shaped etch pits are formed on the etched sample surface.

The study of ion beam irradiation in semiconductor is important for the understanding and modification of surface, optical and electrical properties. High energy light ions (HELI) 40 MeV lithium, High energy heavy ion (HEHI) 100 MeV gold and intermediate ion of 100 MeV nickel irradiation are carried out on Cl-VPE grown GaN epilayers for ion fluences of $1 \times 10^{12}$ ions/cm$^2$ and $1 \times 10^{13}$ ions/cm$^2$. Irradiated samples have been characterized using XRD, UV, PL and AFM. Comparing these three ions, it is observed that 100 MeV intermediate Ni ions create more structural damage in the irradiated GaN epilayers.
The study of current transport mechanism in Ni/Au- GaN schottky diodes have been carried out. Both capacitance–voltage (C-V) and current-voltage (I-V) measurements have been carried out to gain insight into the processes involved in current conduction. The diode parameters such as ideality factor, series resistance, barrier height are determined.

The results of these investigations have been published in International Journals and also presented in several International conferences.