CHAPTER 6

SUMMARY AND SUGGESTIONS FOR FUTURE WORK

6.1 SUMMARY

The necessity of vapour growth of GaN thin films is discussed and the growth difficulties are analysed. Necessary infrastructure facilities to grow GaN thin films from vapour phase were developed and essential growth parameters to grow good quality epilayers have been optimized. The Cl-VPE is distinguished by the simplicity of design, relatively low process pressure and cost effectiveness. GaN epilayers are grown on sapphire substrate at three different ammonia flow rates of 3, 4 and 5 slm. XRD analysis confirmed the wurtzite structure of GaN epilayers. When the flow rate is increased above 3 slm, intensity of the peak decreases. X-ray absorption spectral features are very much similar to that of the hexagonal GaN. The UV transmission spectrum of the GaN epilayers grown at different flow rates of ammonia is analyzed. The sharp transmission edge located at a wavelength of 364.7 nm is assigned to the band gap of GaN. When the flow rate increases to 5slm, the interference pattern in the transmittance spectrum gets affected and also the percentage of transmission decreases with no shift in band gap energy. The decrease in the poor transmission percentage indicates that the quality of grown epilayer is affected with the increase of ammonia flow rate. PL spectrum of GaN layers have been recorded at room temperature for different flow rates of ammonia. For 3 slm flow rate, strong band edge emission peak
corresponding to GaN is observed, while the intensity of the emission peak decreases as the flow rate is increased to 4 slm. When the flow rate is increased to 5 slm, there is no shift in band edge emission but a strong yellow luminescence centered at 550 nm is observed due to the increase in defects during the growth process. AFM is used to analyze the surface morphology of the grown films. Thus we conclude that among the three flow rates of ammonia used for the growth, the 3 slm flow rate yields good crystalline GaN layers.

Raman scattering, ellipsometry studies are performed to characterize the structural properties of the GaN film. The raman spectrum of the grown layers show two characteristic Raman modes of GaN, $E_2$ (high) and $A_1$ (TO) at frequencies 569 and 737 cm$^{-1}$ respectively along with the sapphire substrate peak at 748 cm$^{-1}$. From the ellipsometry the refractive index and extinction co-efficient of GaN epilayers are found to be 2.58, 0.654 at room temperature. Thickness of the grown layers is also estimated in ellipsometry studies. GaN samples are investigated by wet etching in hot phosphoric acid ($H_3PO_4$) and molten potassium hydroxide (KOH). Etched samples are characterized by plane view and cross section SEM to investigate the nature of the etch pits. Hexagonal etch pits are formed on the etched sample surfaces. Results showed that both phosphoric acid and molten potassium hydroxide are good wet etchants for GaN and the pits created by molten KOH etching are numerous when compared to the pits created by phosphoric acid. Three types of etch pits are observed on GaN in using both the etchants. The results shows acid etching is an effective method for evaluating the type and density of dislocations in GaN.

The effects of high energy irradiation on the CI-VPE grown layers have been analyzed. The Li$^{3+}$ ion irradiation has been made at 40 MeV while the Au$^{7+}$ and Ni$^{9+}$ ion irradiations have been made at energies of 100 MeV
with fluences of $1 \times 10^{12}$ ions/cm$^2$ and $1 \times 10^{13}$ ions/cm$^2$. The structural and optical properties of the irradiated GaN epilayers are evaluated by using XRD, UV-Visible transmittance, PL and AFM. Considerable changes have been observed in the optical properties of the layers with the increase of doses. The band gap value and the peak intensities are decreased with increase of ion fluences. AFM results show that the rms roughness value increases with increasing ion fluences. Nanotrack formation is observed upon 100 MeV Ni ions irradiation. The total number of tracks increases with increasing ion fluences. Irradiation of the semiconductors changes the property of the material at the surface or deep into the surface depending upon the energy and the species of ion.

Experimental investigations of the fabricated Ni/Au-GaN Schottky diodes have been carried out. Both current–voltage and capacitance–voltage measurements have shown interesting characteristics. An analysis has been carried out to understand the physical mechanisms underlying the anomalous current–voltage characteristics. The diode parameters of the samples are calculated based on Cheung and Cheung model. The effect of image-force lowering has been taken into account while determining the barrier height. Out of three sample diode fabricated, two of them (diodes A and B) show reasonable barrier height and the other parameters. One of the diode (sample C) shows soft diode behaviour due to the presence of the surface defects, which is expected to modify its surface charge density and enhance the tunneling property. The measured current leakage diode also indicates the presence of traps at the interface or the defects at the surface.

### 6.2 SUGGESTIONS FOR FUTURE WORK

Growth of thick GaN epitaxial films on different substrate materials (Si and SiC) can be performed from Cl-VPE method. The influence of
implantation parameters and concentration of defects produced plays an important role in the performance of GaN based devices. Detailed investigations can be carried out on the damage production rate with various ion energy, ion mass and ion flux of GaN using Rutherford back scattering spectroscopy. However, detailed investigations are necessary to thoroughly understand the defect production and its electrical behavior with respect to ion mass, ion dose and ion energy through various structural, optical and electrical characterization techniques.

Detailed annealing studies are necessary to investigate the effect of annealing temperature on the irradiation induced defects which strongly influence the device performance. Metal/GaN contacts can be fabricated with different metals in order to identify the good rectifying and ohmic behavior of GaN diodes. The fabricated Schottky barrier diode can be characterized through I-V, C-V, DLTS and Hall measurements to analyze the defect formation and electrical properties.