CHAPTER 7

CONCLUSION

Systematic studies were conducted to extract the high power capability of GaN based High Electron Mobility Transistor (HEMT). High voltage blocking capabilities enhancement in forward and reverse drain bias were the focus of investigation in this work. This leads to many level of operation and development in the device. Along with device simulation a novel capacitive model for the GaN based device has done to evaluate the characteristics performance of the design.

The device was developed and analysed in Synopsys Sentaurus Technology CAD tool (TCAD). The simulation tool was efficiently used throughout the entire work for device geometry design, epitaxial layers design and analysis of dynamic physical properties also used in GaN-based HEMTs during their operation. The TCAD tool was employed in this work to predict the device performance, to understand device physics and operation mechanisms, and to gain insight into device design. The parameters in the TCAD model were calibrated in order to accurately reproduce the measured data. The internal electron concentration, electric potential and electric field obtained from the simulation for the device biased at different conditions were discussed.

The simulations results along with analytical data revealed the nature of the device’s breakdown and paved the way for understanding the lack of blocking capability in GaN-based HEMTs. In addition the simulation gave good indication to practice innovative concepts such as the Schottky Source drain
Contact HEMT (SSD HEMT), field-plated HEMT and High-k passivated HEMT configurations.

AlGaN/GaN HEMTs are of particular interest because of their advantages for high power density, high frequency and high temperature applications. These benefits are a result of the high sheet charge density in these hetero-structures, the high carrier mobility and saturation velocity in the channel, and the high breakdown voltage inherent in the GaN material.

A discussion of AlGaN/GaN HEMT device design and optimization was also presented in this work. Various device structure optimization methods, polarization charge control methods and passivation methods were discussed along with the means to improve the performance of AlGaN/GaN HEMTs. From the TCAD simulation results, it is suggested that an asymmetric device design with long gate-to-drain spacing can be used to improve the high power capability of the device.

Different technique including processing methods, field engineering methods and schottky contact method can be employed to decrease the effect of leakage current and reliability problems: (1) high-k Passivation can be employed to reduce or immobilize the surface states. (2) Gate Field plates can be applied to decrease the electric field at the gate edge and to reduce the reverse tunnelling current, but the application of field plates also degrades the frequency performance of the device. (3) Schottky source drain contact can further reduce the reverse leakage current and increase the speed of the device.

Finally, it is suggested that our methods can be applied for AlGaN/GaN HEMT modelling, the new capacitive model is effective to identify the sheet carrier density and drain current variation in the device.

The goals defined for this work to improve the breakdown voltage were completely achieved. Deep understanding of the premature breakdown mechanisms led to design and development of concepts for breakdown voltage
enhancement in GaN-based HEMTs for power switching and regulation application. The design and development of normally on high power device with breakdown voltage larger than 1500 V is achieved. Long term reliability test results are expected in the very near future.