Reactive sputtering of gallium nitride thin films and the electrical characterisation of GaN/GaAs metal insulator semiconductor diode structures.

Thesis submitted in partial fulfillment of the requirement

of the degree of

DOCTOR OF PHILOSOPHY

by

Lakshmi Enjeti

to the

INDIAN INSTITUTE OF TECHNOLOGY, DELHI

CERTIFICATE

This is to certify that the dissertation entitled "Reactive sputtering of gallium nitride thin films and the electrical characterisation of GaN/GaAs metal insulator semiconductor diode structures", which is being submitted by Mrs. Lakshmi Enjeti to the Indian Institute of Technology, Delhi, is a record of bonafide research work carried out by her under my guidance and supervision.

In my opinion this dissertation has reached the standard fulfilling the requirements of all the regulations relating to the degree. The results contained in it have not been submitted in part or in full to any other University or Institute for the award of any degree or diploma.

(Professor A.B.Bhattacharyya)
Centre for Applied Research
in Electronics,
Indian Institute of Technology,
Delhi.

Date:

ACKNOWLEDGEMENTS

I would like to express my sincere gratitude to Professor A. B. Bhattacharyya for his constant encouragement and excellent and stimulating guidance throughout the course of this research work. But for his ability, enthusiasm, and keen interest in the work, the completion of this dissertation would have been an impossible task. Many thanks are also due to Dr. J.Vasi, for his very valuable discussions and critical comments on some of the aspects of this work. I would like to thank Dr. B. Mathur for his guidance in the initial portions of the work.

My thanks are due to Professor K.V. Ramanathan of the Tata Institute of Fundamental Research for making available some of the facilities for carrying out this work and Shri V.P. Bhargava and Ms. A. Patel for their help in the growth of the films. I would also like to thank Professor S. Guha and Dr. B. M. Arora for their useful discussions and their help in the deposition of ohmic contacts over gallium arsenide.

I would like to thank all the scientific and technical staff of the I.C. Group,,Centre for Applied Research in Electronics, whose goodwill and readiness to extend any possible help went a long way in making my task much easier.

I would like to thank the Department of Physics, IIT whose flexible attitude enabled me to pursue this research work in an interdisciplinary area. I am thankful to the National Council of Educational Research and Training for its financial assistance during a major portion of this work and the Department of Eleetronics for financially supporting the remaining portion of this research.

I would also like to thank all my family members, my husband, my parents and my brother whose help and constant encouragement contributed significantly to the completion of my thesis. Last, but not the least, I am greatly indebted to my little daughter, Kavita, who has silently put up with a lot of inconvenience at a tender age, while I was busy in my academic pursuits.

Finally I would like to thank Shri H.C. Bhatia for his excellent typing of the manuscript and Shri N. S. Gupta for drafting the figures. I do not know whether my responsibility ends by saying just this.

ABSTRACT

Reactive sputtering of gallium nitride films and the electrical characteristics of the gallium nitride gallium arsenide MIS diode structures

This work aims at conducting an investigation into the fabrication and characterization of the gallium nitride-gallium arsenide metal insulator semiconductor diode structure.

Gallium nitride thin films were grown by the reactive sputtering of pure gallium in a nitrogen argon atmosphere. By suitable optimization of the various sputtering conditions in an r.f. sputtering chamber, stoichiometric gallium nitride films were deposited having an as deposited resistivity of 10^{13}-10^{14} ohm cm.

The insulator characteristics were determined from the detailed study of the gallium nitride silicon MIS capacitor. The properties studied include etch rate, dielectric constant and its frequency dependence, the d.c. and a.c. insulator loss resistances and the dielectric breakdown field strength.

Detailed study of the capacitance voltage and conductance voltage characteristics of the GaN/GaAs MIS structure in the frequency range from 10 hz to 1 Mhz revealed a significant dependence of the same on the growth conditions of gallium nitride films and post growth annealing treatments. Best results were obtained when GaN is deposited at 350^{o}C

and N_2 annealed for 1/2 hr at 450°c. H.f. Terman's method and the conductance technique were used to determine interface state density, its distribution in the band gap and their capture cross section.

The interface state density distribution was found to be a two peaked one with a small peak at 0.35eV below the conduction band edge and a much more pronounced one at 0.5eV above the valence band edge. The minimum interface state density was $8x10^{10}/cm^2eV$. The capture cross section, of the interface states determined over a small portion of the band gap was found to be in the range of 10^{-12} cm^2.

The indepth Auger electron analysis of the GaN/GaAs MIS structures showed that the significant improvement in the interface state characteristics on N_2 annealing was due to the fact that the latter was found to be effective in reducing the oxygen content of the interface, while simultaneously increasing its nitrogen content.

The minority carrier lifetime in GaAs was determined from the transient capacitance plots of the GaN/p GaAs MIS structure. Zerbst's technique has been modified to includethe the effect of finite leakage currents through the insulator. It was found that these leakage currents produce significant changes in the slope and shape of the resultant Zerbst plots. The effect of various other modifications to the Zerbst analysis, as developed over silicon, namely surface state effect, lateral edge effect and the effect of using a modified value of the generation width, over GaAs MIS structure have also been discussed.

TABLE OF CONTENTS