Schottky barrier diode fabrication on n-GaN for ultraviolet detection

by

Mmantsae Moche Diale

Submitted in partial fulfillment of the requirements for the degree

PHILOSOPHIAE DOCTOR

In the Faculty of Natural & Agricultural Sciences

Department of Physics

University of Pretoria

PRETORIA

September 2009

Supervisor: Prof. F. D. Auret

TO MY SON

LEBOGANG ONKGOPOTSE

DIALE

Brain Child

ACKNOWLEDGMENTS

The opportunity to be at one of the foremost research universities in the world and pioneer GaN research in South Africa is one I will always be grateful for, and there are many people who have inspired, guided and assisted me. I want to thank my supervisor, Professor F. Danie Auret, for accepting me as his student. Thank you for all your support and guidance during my time at the University of Pretoria. It has been both an educational and an emotional experience to work with the Thin Films and Electronic Materials group. The atmosphere was not always enjoyable, but the willingness to learn and apply emotional intelligence has helped me to pull through. I thank Andre Botha and all the members of the microscopy unit for their helpful discussions that led to my first presentation at an international conference as regards this thesis. I wish to express special thanks to Professor Johan Brink for helpful discussions and advice in the experiments that involved the use of optical equipment. I wish to thank Professor Johan Malherbe, the head of the Department of Physics, for his encouragement and interventions during difficult times. I am so glad to have shared this experience with my fellow students in this Department. Gunther Kassier was the first student who worked very closely with me in the endeavour to set-up the optoelectronic station, which was finalized by Louwrens van Schalkwyk. Special thanks to my fellow students and colleagues for answering important questions of the moment: Hannes de Meyer, Machesa Legodi, Claudia Zander, Johan Janse van Rensburg, Sergio Coelho, Cloud Nyamhere, Wilbert Matangi, Albert Chawanda, Rik van Laarhoven, Quinton Odendaal, Walter Meyer, and Augusto Machatine.

Finally I thank my husband Dr OPPP Diale for financial and emotional support.

The financial support of the project stemmed from the National Research Foundation and the University of Pretoria.

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

Schottky barrier diode fabrication on n-GaN for ultraviolet detection

by

Mmantsae Moche Diale

Submitted in partial fulfillment for the degree PhD (Physics) in the Faculty of Natural and Agricultural Science, University of Pretoria

Supervisor: Prof. F. D. Auret

There are many potential areas for the utilization of GaN-based nitride materials, including ultraviolet photodetectors. Ultraviolet photodetectors are used in the military for missile plume detection and space communications. Medically, ultraviolet photodiodes are used in monitoring skin cancer. Schottky barrier metal-semiconductor contacts are choice devices for the manufacture of ultraviolet photodiodes due to higher short wavelength sensitivity and fast response. They also require simple fabrication technology; suffer lower breakdown voltages, and record larger leakage currents at lower voltages as compared to p-n structures of the same semiconductor material. Thus the formation of a Schottky contact with high barrier height, low leakage current, and good thermal stability in order to withstand high temperature processing and operation are some of the most important factors in improving the performance of Schottky barrier photodiodes to be used for ultraviolet detection. The first stage of this study was to establish a chemical cleaning and etching technique. It was found that KOH was suitable in reducing C from the surface and that $(NH_4)_2S$ further reduced the surface oxides. The next phase of the work was to select a metal that will allow UV light to pass through at a high transmission percentage: a combination of annealed Ni/Au was found to be ideal. The transmission percentage of this alloy was found to be above 80%. The next phase was the fabrication of Ni/Au Schottky barrier diodes on GaN to study the electrical characteristics of the diodes. Electrical

characterization of the diodes showed that the dominant current transport mechanism was thermionic emission, masked by the effects of series resistance, which resulted from the condition of the GaN surface. Finally, we fabricated GaN UV photodiodes and characterized them in the optoelectronic station designed and produced during this research. Device responsivity as high as 31.8 mA/W for GaN and 3.8 mA/W for AlGaN were recorded. The calculated quantum efficiencies of the photodiodes were 11 % for GaN and 1.7 % for AlGaN respectively

Keywords: Al(GaN), Schottky, photodiodes, Ultraviolet, responsivity, quantum efficiency.

TABLE OF CONTENTS