OXFORD RESEARCH FORUM JOURNAL , June 2006 , Vol. 2 No.3. Pages 45 - 49

EXPERIMENTAL STUDY OF THE I-V CHARACTERISTIC OF GAN- METAL CONTACT

Saeed S. Al-Ameer

Department of Physics, Faculty of Science, P.O Box 9028, King Abdulaziz University, Jeddah 21413, Kingdom of Saudi Arabia. E-mail: sameer@kaau.edu.sa

ABSTRACT

Wide band gap Gallium Nitride (GaN) is the most promising of the next generation semiconductor materials. It shows an excellent and high potential for a large range of technological applications in which the classical semiconductors, such as Si and GaAs, are unable to fulfill the needs of the advancing technology. In this work GaN prepared by the metal organic chemical-vapor deposition (MOCVD) techniques was used. This technique is capable of producing high quality films. However, the quality is still variable and dependant on the deposition parameters such as the substrate material, temperature sources, carrier gas pressures and other reactor conditions.

KEYWORDS: I-V reproducibility of GaN-metal contact

INTRODUCTION

Gallium Nitride (GaN) having a direct band gap of 3.45 eV has been developed with a view to extending the range of optical output to the blue region of the spectrum and is currently being used to fabricate blue Light Emitting Diodes (LED_S) and Laser Diodes. (LD_S).[1] More recently the area of research has broadened to include Aluminum Nitride (AlN) and Indium Nitride (InN) which also have direct band gaps of 6.28 eV and 1.9 eV respectively. All these nitrides crystallize in a wurtzite structure and are continuously miscible as binary or ternary alloys. The ratio of the constituents can be altered to obtain a continually variable band gap from 1.9 eV, which is the red end of the visible spectrum, to 6.28 eV which lies well into the vacuum ultraviolet.[2] The family of III-Nitrides exhibits high melting points and has potential for use in high power and high frequency devices. However, it is in the area of optoelectronics in which these materials will find large-scale application. The major impediment in the fabrication of these devices is the production of mono-crystalline materials (both as bulk and films), which are so critical in the reliable and efficient operation of semiconductor devices. These problems stem from the unavailability of native substrates over which homo-epitaxial layers may be grown. Additionally, the science of strongly bonded materials like IIII-Nitrides for hetro-epitaxial growth is not well understood.[3]

Several materials for fabrication and doping of Gallium Nitride films by epitaxial growth have been tried. They include high and low pressure, reactive ionized cluster beam epitaxy [4] and electron cyclotron resonance electron beam epitaxy [5] to mention only a few. The absence of native substrates implies that "suitable substrates" having similar lattice constants and structure can be used for what is termed "hetro-epitaxial" growth. The effect of lattice mismatch is minimized by depositing a buffer layer at a lower temperature to obtain a nucleation phase over which an active layer is deposited at relatively higher temperature. The lattice mismatch though minimized is still prevalent and gives rise to lattice imperfections and defect. Also, the process of doping these films, which produces the required n or p type layers, contributes its own distortions.[6] As the electrical and optical properties of semiconductors are crucially dependent on their structure, all aspects of GaN-based devices are affected and are studied as a function of material/device fabrication parameters. GaN grown from bulk and epitaxial techniques have been characterized by optical, electrical and structural methods .[7]

Another important technique of characterizing the material is the study of deep traps. These traps have been studied by optical transmission methods and capacitance transient methods.[8,9]

Metal contacts to GaN films have also been widely studied due to their role in reliable device operation.[10] Schottky contacts using metals of different work function have been extensively studied .[11-14] Interfaces have also been studied for ascertaining the position of the Fermi level in the band gap by determining the interface states density. The Fermi level in GaN does not appear to be pinned like silicon and exhibits a dependence on the work function of the metal.[15]

As mentioned earlier, GaN has a band gap of 3.45eV and finds wide application in high efficiency blue and green Light Emitting Diodes (LED_S) and Laser Diodes (LD_S). This has made it possible to make full color solid-state displays. Blue and violet emitting lasers at 417 nm have also been fabricated and attempts are being made to push the limit into the ultraviolet region.[16] The high efficiency (9%) of GaN LED_S has enabled the fabrication of a hybrid GaN/ phosphor white lamp LED.[17]

The brief survey presented above is sufficient to emphasize the importance of GaN as a potential material for the next stage of development in the semiconductor industry. Apart from its most obvious applications in blue/green/UV LED_S and LD_S it may well find large-scale applications in high power, high frequency devices operating at elevated temperatures.

EXPERIMENTAL WORK

VACUUM SYSTEM

This consists of a diffusion pump that has a combination liquid nitrogen trap bakable valve and is connected to a backing rotary pump. Such a combination is capable of coping with extremely high gas loads whilst at the same time offering a chamber pressure of 10^{-5} mbar. Several types of pumps are used in the high vacuum system. An Edwards -5 two stage rotary pump connected to the main chamber and used to rough the chamber before use of an E04- liquid Nitrogen baffled oil diffusing pump starts pumping.

SAMPLE CLEANING PROCEDURES

All the substrates used in this work were n-type GaN, which were chemically cleaned according to the procedure detailed in Figure 1.

RAW MATERIALS

The starting material was a 2-inch diameter GaN wafer with typical purity equal to 99%. This material was selected for its advantages due to its compatibility with high vacuum systems i.e. in terms of the fabrication as well as the oxidation process, in which it's not easy to oxidize by metal contacts.

Utilising a chamber base pressure of 10^{-5} mbar, the GaN was degassed several times, the pressure rising to 10^{-4} mbar. These degassing procedures were done successively until the pressure gradually returned to 10^{-5} mbar with degassing still running. Next, the substrate carrier was placed on its position in the chamber under the desired evaporation angle. The mechanical shutter was then opened and the molybdenum boat that was loaded with the desired materials (Au and Cr) to make the contact on the top of the GaN films, was heated (50 to 80 Ampere D.C. current was used) under the predetermined optimum conditions.

CONTACT DEPOSITION

This step is crucial for formation of continuous ulta-thin films. In order to confirm this, several Au, Cr film evaporation runs, ranging in thickness from 2000 to 3000 angstroms, were deposited and examined by an optical electron microscope. Nearly smooth surface with no discontinuity was observed all over the films. A little contamination on the surface of the film is expected during the metal deposition, but not very serious since the pressure during the deposition of the film was held at less then 10^{-5} mbar.

EXPERIMENTAL SET-UP FOR DC MEASUREMENTS

Detailed measurements of I-V characteristics of the GaN- Cr/Au contact were performed under room temperature conditions. The experimental set-up mainly consisted of power supply (HP4140B meter used as power supply), RCL meter and programmable evacuated oven.

The quality assessment of the GaN- device in which Au and Cr single layered films evaporated on the top of GaN film is presented D.C. I-V measurements of the contact were carried out at room temperature. Accurate measurements were undertaken using the appropriate DC system. However, as the applied voltage has to be in the range of a few volts, special arrangements were made to secure minimum effects of noise pick-up. Consequently, the connections between various parts of the circuit were made by coaxial cable and shielded wires with the shields earthed to a single point to avoid earth loop problems. The electronics circuit was housed in a closed die cast metal box with cables connected to the circuit through coaxial sockets attached to the box.

CHARACTERISTICS FOR THE GaN/Au AND GaN/Cr

Electrical contact to the films was made by connecting 0.25 mm copper wires using air-dried silver paint. These contacts were used for both two and four terminal specimens. The voltage contacts were spaced about 0.2 cm inward from the current contacts with at least 1.2 cm of film between them. The I-V characteristics were measured at room temperature. Measurements were carried out on several devices, which were prepared using various areas. The I-V curves of this device are shown in Figures 2-6. Clearly from these curves there was no change on I-V curves even with different sizes of contact area. Also these measurements were repeated several times and no changes on the I-V behaviors were observed.

CONCLUSION

The main object of this project was to study the I-V characteristics of the metal contacts on single layer crystal GaN films experimentally. Contacts were prepared by a thermal evaporation in which metals with different work functions were used. Namely Au and Cr metals on thoroughly cleaned GaN substrate.

The I-V characteristics of these devices were measured and reasonable I-V curves were obtained. These I-V curves provided basic information about the surface, barrier and many other parameters. In this work, the durability was observed as well as the repeatability of these measurements without any effect of the surrounding environments.

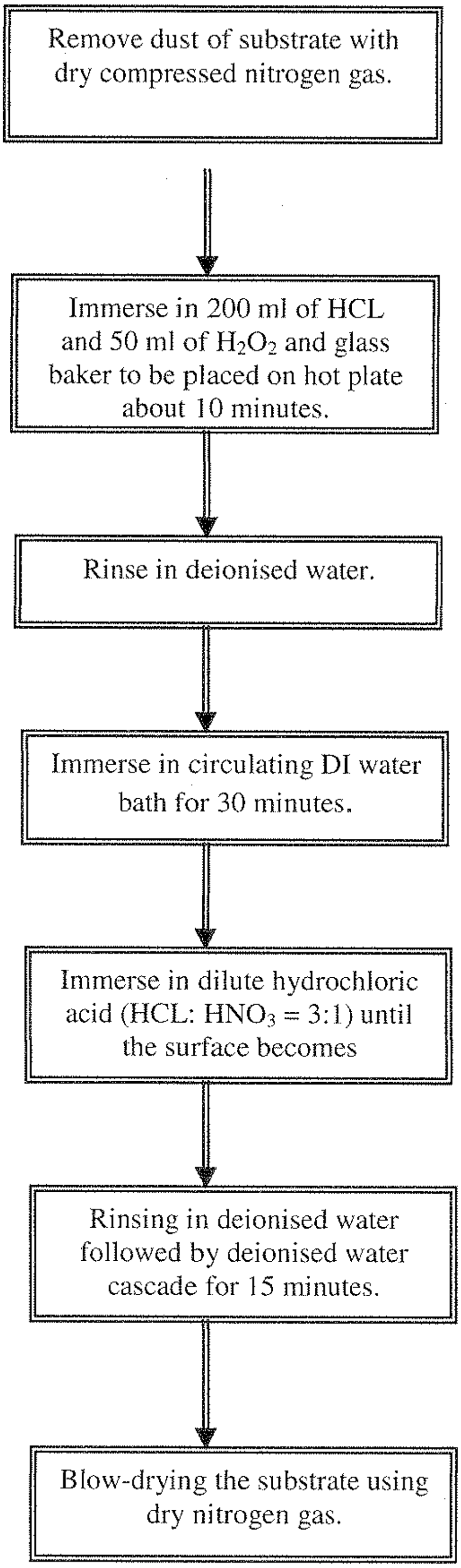

Fig 1. Standard Chemical Cleaning Procedure for the GaN substrate

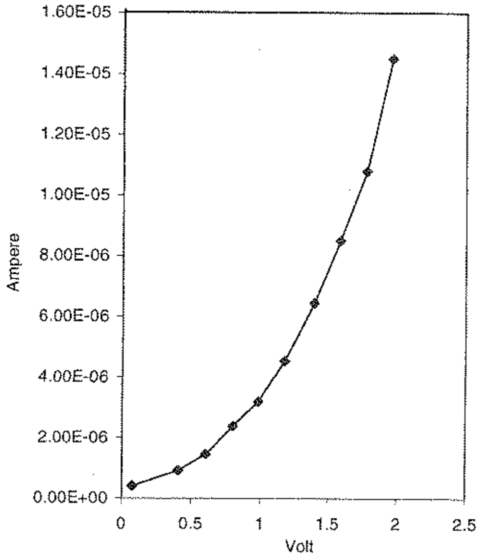

Fig 2. Electrical properties of GaN film at room

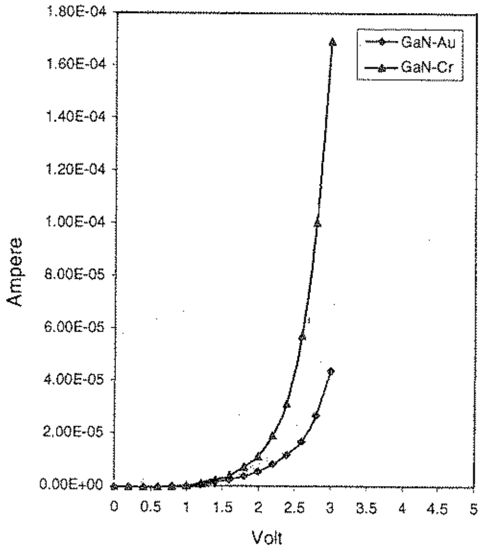

Fig 3 . Electrical properties of GaN-Au and GaN-Cr

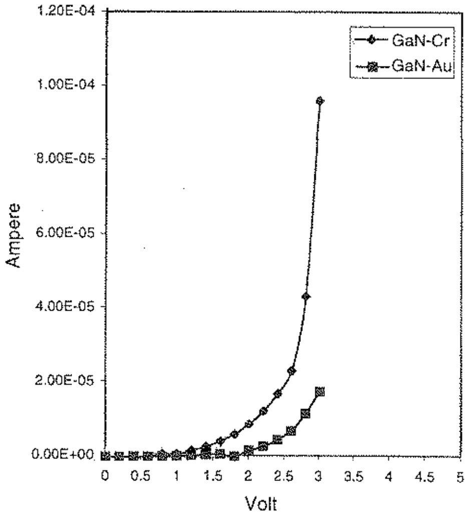

Fig 4 . Electrical properities of GaN-Au and GaN-Cr at room temperature

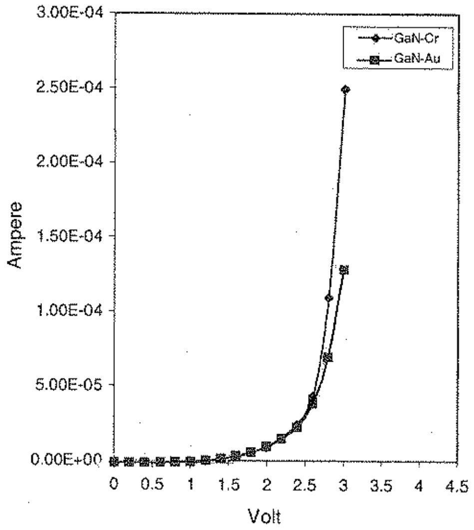

Fig 5 . Electrical properities of GaN-Au and GaN-Cr contact at room temperature

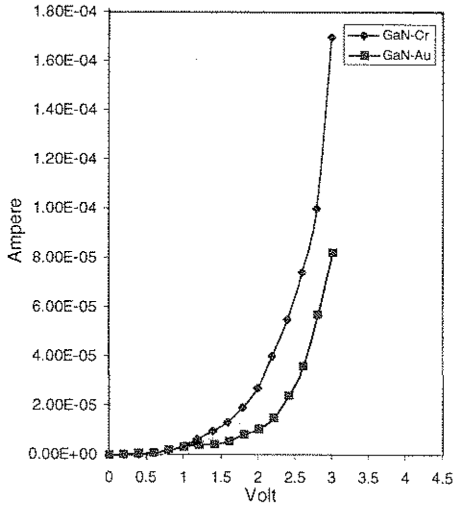

Fig 6 . Electrical properities of GaN-Au and GaN-Cr at room temperature

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