ICOP 2009 - International Conference on Optics and Photonics
Chandigarh, India, 30 Oct. - 1 Nov. 2009

REACTIVE ION ETCHING OF n-GaN USING Cl_2/BCl_3 FOR LED APPLICATIONS

Manish Mathew, Kuldip Singh, B.C. Joshi, Ashok Kumar Sharma and C. Dhanavantri.
Optoelectronic Devices Group, Central Electronics Engineering Research Institute (CEERI),
Council of Scientific and Industrial Research (CSIR), Pilani, 333031, India,
Email: manish@ceeri.ernet.in

Abstract: Reactive ion etching (RIE) of n-GaN using Cl_2/BCl_3 plasma under a high self-bias voltage was carried out. The effects of BCl_3 flow rate with respect to Cl_2 on the etch rate were investigated. An etch rate as high as 50nm/min for n-GaN was obtained under an RF power of 75 W, BCl_3 flow rate of 4 sccm, Cl_2 flow rate of 20 sccm and a pressure of 5 Pa. The root-mean-square (rms) roughness of the etched surface was between 0.32 and 0.46 nm as determined by atomic force microscopy.

1. INTRODUCTION

GaN and related compounds are promising materials in UV-blue-green optoelectronic devices [1], high temperature electronic devices [2], negative-electron-affinity (NEA) electron emitters [3] and solid-state lightings (SSLs).

Over the last few years, excellent progress has been made in the growth of these materials. In order to realize their potentials, it is important to develop an etching technology for device fabrication. A reliable and effective etching method is needed for device fabrication. However, the inertness of the III-nitrides to harsh chemical environment makes most wet etching extremely difficult. Even in a hot alkali solution GaN is etched at a very low rate. Dry etching is presently a more viable way for the processing of these materials. However, dry-etching-induced defects may serve as local non-radiative recombination centres for electron-hole pairs reducing the radiative lifetimes and luminescence efficiencies of optical devices [4]. Thus, study of etching-induced damage effects on the optical properties are important.

In this report, the RIE etching process of high quality n-GaN films using BCl_3/Cl_2 discharges are present. An etching rate as high as 50nm/min has been achieved. We used an atomic force microscope (AFM) to observe the difference in roughness between a native and an etched surface of n-GaN.

2. EXPERIMENTAL

The epitaxial n-GaN films etched in this study were grown by Metal Organic Chemical Vapor Deposition (MOCVD) system. First a low temperature GaN of 30 nm was deposited on c-plane (0001) sapphire substrate followed by a 2 μm undoped GaN. A 2 μm n-GaN layer was deposited over undoped GaN. The carrier concentration of n-GaN was found to be 3×10^{18} cm^{-3}. Five samples have been examined in this study. The n-GaN wafer was cut into 2 cm x 1 cm pieces and cleaned in acetone and methanol with ultrasonic agitation, rinsed in flowing deionized water, and was dried with N_2. Photoresist (Shipley-1818) was used as the etching mask to etch n-GaN. The load locked RIE system (Sentech SI591) was used for the etching of n-GaN. The plasma was generated by a radio frequency (13.56 MHz) glow discharge. Electronic grade BCl_3 and Cl_2 were injected into the chamber through mass flow controllers. The surface morphology of selected n-GaN samples was examined with atomic force microscopy (AFM)

3. RESULTS AND DISCUSSION

Concentration of BCl_3 was varied with respect to Cl_2 at 75 Watt RF power and a chamber pressure of 5 Pa. Different etch rates were obtained when the concentration of BCl_3 was varied from 5% to 20% of Cl_2. The maximum etch rate obtained in this case was 50 nm/min at 16% of Cl_2. Above 16% the etch rate reduced drastically. In the lower flow rate regime, the reactive radicals can fully react with n-GaN reaching maximum with 16% of Cl_2, and then decrease with increase in BCl_3 flow rate. As the flow increases, some of the etchant species were pumped away before surface reaction could take place, in other words the resident time of the reactive radicals were more shorter than their life time. Fig.1 shows the n-GaN etch rates as a function of $\%BCl_3$ flow rate in Cl_2. The surface roughness of the sample was improved after the etching of the wafer.

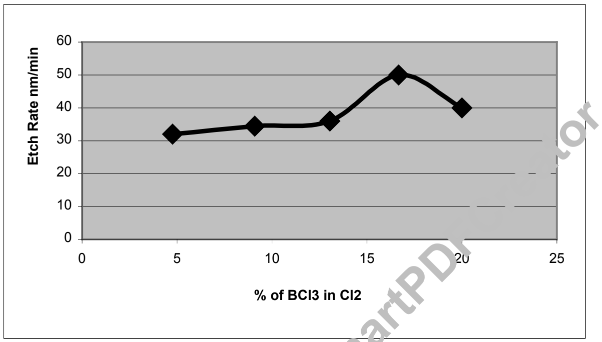

Fig. 1. n-GaN etch rates as a function of $\%BCl_3$ plasma condition.

Atomic force microscopy (AFM) was used to quantify the etched surface morphology as rms roughness for many of the plasma conditions. The surface roughness improved to 0.32 nm after etching as shown in Fig.2. The rms roughness for the grown n-GaN was 1.17 nm as shown in Fig.3.

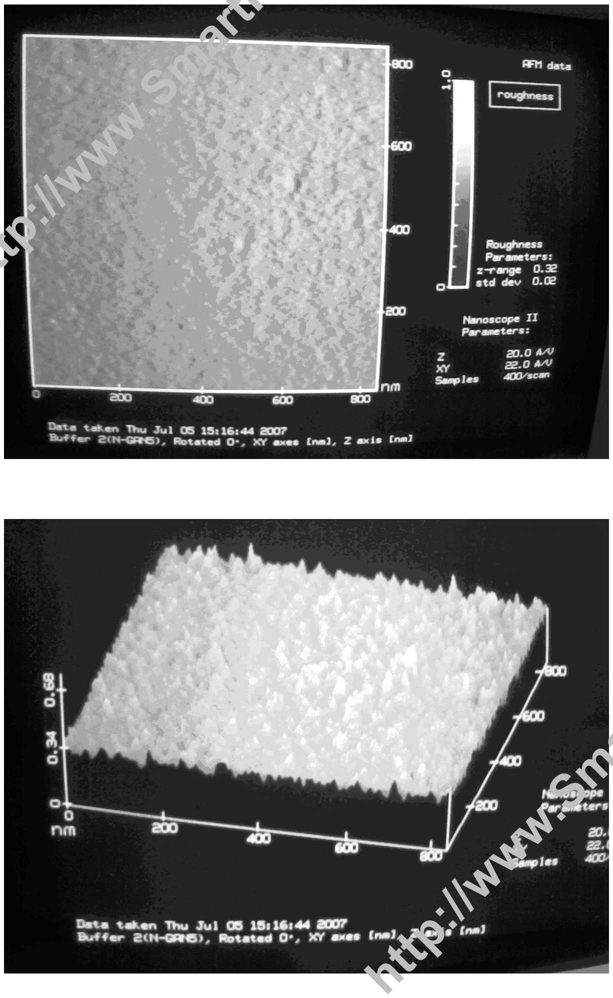

Fig. 2. Surface roughness for n-GaN after RIE

The unetched film has a root-mean-square (RMS) roughness of 1.17 nm, while the etched films exhibit a roughness between 0.32 and 0.46 nm. This implies that the surface roughness is improved by the etch.

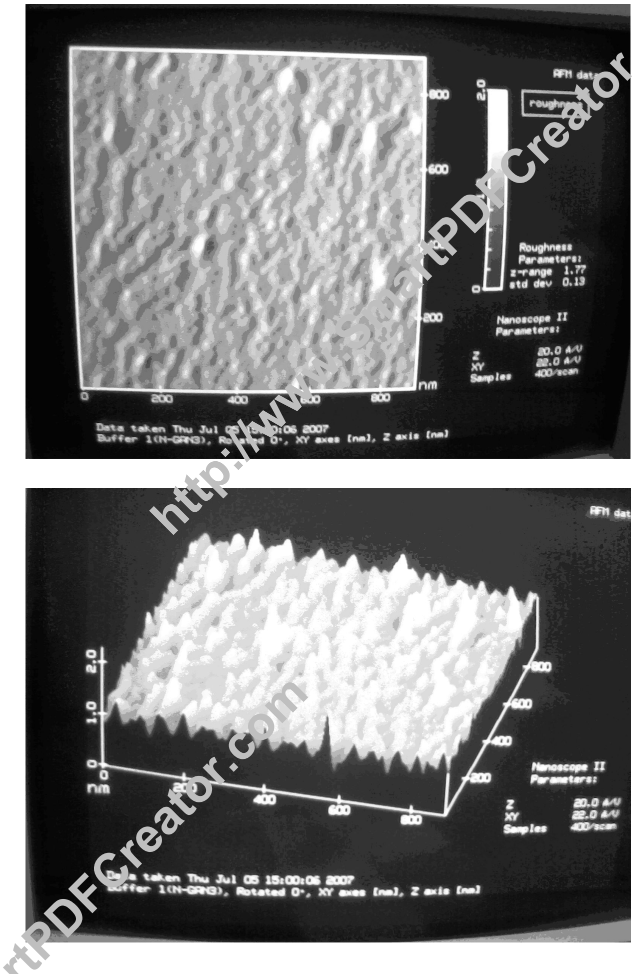

Fig. 3. Surface roughness for n-GaN before etching

ACKNOWLEDGMENT

The authors would like to thank Director, CEERI for his encouragement of this work and all the members of the opto-electronic devices group for their support.

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