Nuclear Instruments and Methods in Physics Research B 267 (2009) 79–82

Contents lists available at ScienceDirect

Nuclear Instruments and Methods in Physics Research B

journal homepage: www.elsevier.com/locate/nimb

Investigations on the effect of 100 MeV Ni ions irradiated chloride vapour phase epitaxy (Cl-VPE) grown GaN epilayers

P. Puviarasu [a], V. Suresh Kumar [a], D. Kanjilal [b], K. Asokan [b], J. Kumar [a,*]

[a] Crystal Growth Centre, Anna University, Sardar Patel Road, Chennai 600 025, India
[b] Inter-University Accelerator Centre, Aruna Asaf Ali Marg, New Delhi 110 067, India

ARTICLE INFO

Article history:
Received 27 May 2008
Received in revised form 16 October 2008
Available online 5 November 2008

PACS:
71.55.Eq
61.10.Jh
61.10.Nz
78.55.Cr
78.66.Hf

Keywords:
GaN
Ion irradiation
X-ray diffraction
AFM
Photoluminescence
UV-visible optical transmission spectrum

ABSTRACT

Gallium nitride (GaN) epilayers have been grown by chloride vapour phase epitaxy (Cl-VPE) technique and the grown GaN layers were irradiated with 100 MeV Ni ions at the fluences of 5×10^{12} and 2×10^{13} ions/cm^2. The pristine and 100 MeV Ni ions irradiated GaN samples were characterized using X-ray diffraction (XRD), UV-visible transmittance spectrum, photoluminescence (PL) and atomic force microscopy (AFM) analysis. XRD results indicate the presence of gallium oxide phases after Ni ion irradiation, increase in the FWHM and decrease in the intensity of the GaN (0002) peak with increasing ion fluences. The UV-visible transmittance spectrum and PL measurements show decrease in the band gap value after irradiation. AFM images show the nanocluster formation upon irradiation and the roughness value of GaN increases with increasing ion fluences.

1. Introduction

Gallium nitride (GaN) is a semiconductor material with outstanding properties, because of its potential applications in short wavelength optoelectronic devices such as high performance transistors, light emitting diodes (LEDs) and laser diodes (LDs). Recently efforts by several groups have been devoted to study the irradiation-induced defects in gallium nitride and related compounds. The study of defect stability is important from the device fabrication and device performance point of view [1]. Shift heavy ions (SHI) create point defects along its trajectory in a solid, leading to tracks because the energy of point defect creation is significantly less than the average binding energy of target electrons [2]. These defects are responsible for the modification of the physical properties of the materials [3]. The origin of the defects has been widely studied by artificial irradiation, such as electron, proton and neutron irradiation in GaN single crystals, grown by the hydride vapour phase epitaxy technique [4]. Previous reports [5], [6] and [7] have indicated that GaN is rather resistant to ion-beam-induced amorphization. This stage contains stable basal-plane dislocation loops, stacking faults and local regions of highly disordered structures [8]. Recently Suresh Kumar et al. [9] reported that the large lattice disorder has been observed by 100 MeV Au ion irradiation on GaN.

In this article, we present the effect of 100 MeV Ni ions irradiation on GaN epilayers at various ion fluences using X-ray diffraction (XRD), atomic force microscope (AFM), Photoluminescence (PL) and UV-visible optical transmittance spectroscopy.

2. Experiment

The wurtzite GaN layer used in this study was 2 μm thick epitaxially grown on c-plane sapphire substrate by chloride vapour phase epitaxy (Cl-VPE). We have employed a home built horizontal chloride vapour phase reactor for the growth of GaN. GaN has been grown through the reaction of $GaCl_3$ with ammonia. N_2 gas was used as the carrier gas to bring the Ga vapour into the reaction zone. The overall reaction of the growth process is given by following equation

* Corresponding author. Tel.: +91 44 22203569, +91 44 22352774; fax: +91 44 22352870.
E-mail address: marsjk@annauniv.edu (J. Kumar).

0168-583X/$ - see front matter © 2008 Elsevier B.V. All rights reserved.
doi:10.1016/j.nimb.2008.10.077

$GaCl_3 + NH_3 \rightarrow GaN + 3HCl$

The films have been deposited on (0001) sapphire substrate. The growth of GaN films were carried out at a growth temperature of 990 °C and at a fixed flow rate of (3 Slm) of ammonia gas. The details growth parameters are discussed elsewhere [10].

The GaN samples were cut into several number of small pieces of dimensions about 5 mm × 5 mm to be used for irradiation and were etched with diluted HCl to remove the surface oxides. The computer code Stopping Range of Ions in Matter (SRIM) calculations was used to calculate the depth distributions of the irradiated ions. For 100 MeV Ni ions irradiation on GaN, the electronic energy loss (S_e) and the nuclear energy loss (S_n) are calculated as 1.449 keV/Å and 2.852×10^{-3} keV/Å respectively. The projected ion range in GaN is ~11.12 μm. Hence, these ions lose their energy predominantly in the electronic stopping power regime throughout the entire ~2 μm thick GaN film while the ion end of range region is deep inside the sapphire substrate. 100 MeV Ni ion irradiation was carried out on the GaN epilayers at low temperature (77 K) using 16 MeV tandem pelletron accelerator of Inter University Accelerator Centre, New Delhi at the ion fluences of 5×10^{12}, 2×10^{13} ions cm^{-2} under in the vacuum range of 3×10^{-6} Torr. In order to reduce the sample heating during ion irradiation, the samples were mounted on a Cu holder with a conductive silver paste. The surface normal of the samples was at an angle of ~4° relative to the incident ion beam axis. The XRD measurements were performed using D8 Brucker AXS X-ray diffractometer with CuK source. UV-visible optical transmission spectrum for both pristine and irradiated samples were carried out using Simatzu (1601) spectrometer. The luminescence properties of the samples were investigated using PL Mechellc 900 spectrograph in the range of 1.4–3.8 eV using 325 nm He–Cd laser as the excitation source at room temperature. AFM analysis was performed on a digital nanoscope III A SPM. Surface scans over 5 mm square regions were carried out.

3. Results and discussion

3.1. Atomic force microscopy

The ability of the AFM to create three dimensional micrographs with resolution down to nanometer scale has made it as an essential tool for imaging surfaces before and after swift heavy ion irradiation. It is a non destructive characterization technique for quantitative surface roughness measurements. The passage of SHI induces very rapidly developing processes, which are difficult to observe during or immediately after their occurrence. The formation about these processes is stored in the resulting damage such as size, shape and structure of defects. Fig. 1 shows the two dimensional AFM images of pristine and 100 MeV Ni ion irradiated GaN epilayers. The surface of as grown pattern does not show any special features. The surface roughness value of as grown GaN layer is 1.096 nm. 3.1 and 7.3 nm is the surface roughness for samples irradiated at a fluence of 5×10^{12} and 2×10^{13} ions/cm^2 respectively. Fig. 1(a–c) shows the AFM images of pristine and Ni ion irradiated GaN. Track formation was observed in both the samples. The total number of the tracks increases with increasing ion fluences. The dimensions of the tracks are around 185.5 nm.

3.2. X-ray diffraction

Fig. 2 shows the XRD spectrum of the as grown and Ni ion irradiated GaN epilayers Fig. 2(a) shows the XRD pattern of pristine GaN, which exhibits a wurtzite GaN (0002) peak at $2\theta = 34.5°$. Pure GaN exhibits c-plane texture its full width half maximum (FWHM) is 0.424°. After irradiation, it was found that the GaN

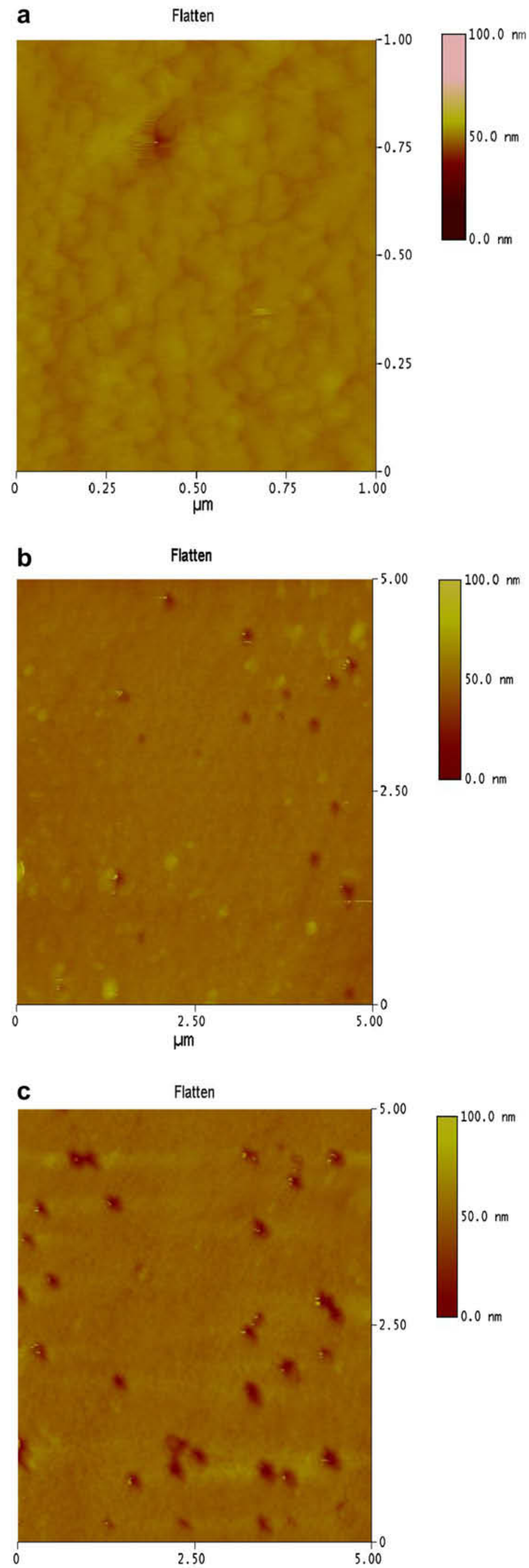

Fig. 1. (a) AFM image of Cl-VPE grown pristine GaN, (b) AFM image of 100 MeV Ni ion irradiated GaN at the fluence of 5×10^{12} ions/cm^2 and (c) AFM image of 100 MeV Ni ion irradiated GaN at the fluence of 2×10^{13} ions/cm^2.

XRD peak intensities were decreased [9]. The FWHM of irradiated GaN is increases with increasing ion fluences. The formation of Ga_2O_3 may be due to the interface mixing between the GaN/