Nanostructuring induced enhancement of radiation hardness in GaN epilayers

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The radiation hardness of as-grown and electrochemically nanostructured GaN epilayers against heavy ion irradiation was studied by means of photoluminescence (PL) and resonant Raman scattering (RRS) spectroscopy. A nanostructuring induced enhancement of the GaN radiation hardness by more than one order of magnitude was derived from the PL and RRS analyses. These findings show that electrochemical nanostructuring of GaN layers is a potentially attractive technology for the development of radiation hard devices. © *2007 American Institute of Physics*. [DOI: 10.1063/1.2723076]

Gallium nitride (GaN) is a promising radiation hard semiconductor material for the development of optical and high-power high-frequency electronic devices. From the point of view of optical properties, the material is some two orders of magnitude less sensitive to the proton irradiation than gallium arsenide (GaAs).[1,2] In order to attain many advantages of GaN, controllable doping and formation of semi-insulating regions, among others, must be achieved. Ion implantation is widely used for planar selective area doping of GaN.[3] In order to minimize the ion bombardment induced damage, it is important to characterize the features of lattice disorder caused by ion damage and ion implanted material provides a good opportunity for this purpose. While photoluminescence (PL) can be used for characterization of the materials at low implantation doses, Raman scattering (RS) is a powerful, nondestructive tool to assess the lattice disorder at high implantation doses.[4–9] The purpose of this work is to compare the damage introduced by high energy heavy ion implantation in as-grown and electrochemically nanostructured GaN epilayers and to evaluate a possible contribution of electronic stopping power in damage production. To date, only a few information about structural response of GaN to swift heavy ion irradiation is known.[10,11]

It was previously demonstrated[12,13] that electrochemical etching produces fully relaxed from strain columnar nanostructures in GaN which are suitable for the development of selective methane gas sensors in environments containing ethanol vapor. In this letter, we show that these nanostructures also exhibit radiation hardness more than one order higher in magnitude than that inherent to as-grown layers.

The GaN layers used in our experiments were grown by low-pressure metalorganic chemical-vapor deposition on (0001) *c*-plane sapphire using a modified EMCORE GS-3200 system and trimethylgallium and ammonia as source materials. A buffer layer of about 25 nm thick GaN was first grown at 510 °C followed by a 2.0 μm thick *n*-GaN layer grown at 1100 °C. The concentration of free electrons in the *n*-GaN layer was 1.7×10^{17} cm^{-3}. Anodic etching of samples was carried out at a current density of 5 mA/cm^{-2} in 0.1 mol aqueous solution of KOH under *in situ* UV illumination provided by focused radiation from a 250 W Hg lamp on the GaN surface which was also in contact with the electrolyte. The duration of anodization was 6 min, leading to the formation of pyramidal GaN nanostructures illustrated by the scanning electron microscope (SEM) image in the inset of Fig. 1. The as-grown and electrochemically treated samples were irradiated at room temperature by 85 MeV Kr^{+15} ions (10^{12} and 10^{13} cm^{-2}) or by 130 MeV Xe^{+23} ions (5×10^{11} and 5×10^{12} cm^{-2}). The irradiation was carried out on the IC-100 cyclotron at FLNR, JINR, Dubna.

PL was excited by the 351.1 nm line of an Ar^+ Spectra Physics laser and analyzed through a double spectrometer. The resolution was better than 0.5 meV. The samples were mounted on the cold station of a LTS-22-C-330 optical cryogenic system.

The energy of the 351.1 nm laser radiation (3.530 eV) is in resonance with the GaN band gap (3.503) at 10 K. Under these excitation conditions, the emission consists of two components: PL and RRS. The emission from the sample is dominated by strong near band gap luminescence in the case of high quality samples, while RRS becomes observable in the emission spectra of samples with low PL intensity. Note that RRS from solids can be observed if the energy of the incoming or scattered photons matches the real electronic states in the material. One refers to incoming and outgoing resonances, respectively (see, e.g., Ref. 14). The resonance of the 351.1 nm laser radiation with the GaN band gap at 10 K ensures good conditions for incoming resonant Raman scattering.

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