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Photoreflectance study of GaN grown on SiN treated sapphire substrate by MOVPE

M. Bouzidi *, Z. Benzarti, I. Halidou, Z. Chine, A. Bchetnia, B. El Jani

Université de Monastir, Faculté des Sciences, Unité de recherche sur les Hétéro-Epitaxies et Applications (URHEA), 5000 Monastir, Tunisia

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GaN films were grown on silicon nitride (SiN) treated *c*-plane sapphire substrates in a home-made vertical reactor by atmospheric pressure metalorganic vapor phase epitaxy (MOVPE). In order to obtain different thickness layers, the growth procedure was interrupted at diverse stages using in-situ laser reflectometry. The structural and optical properties of obtained samples were investigated by high resolution X-ray diffraction (HRXRD) and photoreflectance (PR). In the 0.7–2 μm epilayer thickness range, the dislocation density decreases and remains roughly constant above this range. For fully coalesced layers, PR measurements at 11 K reveal the presence of well resolved excitonic transitions related to A, B and C excitons. A strong correlation between dislocation density and exciton linewidths is observed. Based on theoretical approaches and experimental results, the electronic band structure modification of GaN films due to isotropic biaxial strain was investigated. The valence band deformation potentials D_3 and D_4, interband hydrostatic deformation potentials a_1 and a_2, spin–orbit Δ_{so} and crystal field Δ_{cr} parameters were re-examined and found to be 8.2 eV, −4.1 eV, −3.8 eV, −12 eV, 15.6 meV and 16.5 meV, respectively.

* Corresponding author.
E-mail address: elbouzidimed16@yahoo.com (M. Bouzidi).

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1. Introduction

Because of its large direct band-gap energy and good thermal stability, GaN and related materials have attracted tremendous interest owing to a large variety of potential applications covering optical, optoelectronic, and electronic devices [1,2]. Extensive research and development efforts have been expended in III-nitrides materials over the past decades. These efforts were crowned by the fabrication and commercialization of a variety of devices such as lasers and light-emitting diodes, modulation-doped field-effect transistors and solar-blind ultraviolet photodetectors [3–6]. Despite all of this, the full potential of GaN-based devices has yet to be achieved due to the GaN material itself suffering from a high density of defects inherent to heteroepitaxy on foreign substrates necessitated by the lack of bulk GaN substrates. Further improvements in high performance devices call for the reduction of dislocation densities which are known to affect optical and electrical properties of GaN-based devices by trapping point defects or forming complexes with them [6–8]. In this regard, various strategies were employed and many methods have been developed to reduce the dislocation density such as epitaxial lateral overgrowth (ELOG) [9–12], pendeo-epitaxy (PENDO) [13,14], facet controlled epitaxial lateral overgrowth (FACELO) [15,16], and SiN treatment [17–22]. In contrast to the overgrowth techniques which have shown a high degree of complication, the SiN treatment procedure is simpler and has been proven to significantly reduce threading dislocation density in GaN. The threading dislocation reduction mechanism is based on the change in growth mode to 3D island formation on the SiN treated GaN surface and the half-loop formation between the bent-over threading dislocations that occurs during the lateral overgrowth [21]. Different growth parameters were shown to influence the final quality of the GaN films, such as growth temperature, V/III ratio, carrier gas and film thickness [17–27]. In this context, many authors have studied the thickness effect on the structural, electrical and luminescence properties of GaN layers and they have shown a large influence on such physical properties [22–25]. However, few reports have been devoted to investigate the evolution of free exciton transitions during the smoothing process and their progress with dislocation density.

In this paper, the structural and optical properties of GaN layers grown by MOVPE on SiN treated (0001) sapphire substrate at different stages of the growth process are investigated using HRXRD and low temperature PR spectroscopy. A strong correlation between structural defects and excitonic properties during the coalescence process is observed.

2. Experiment

GaN epilayers were grown on (0001) sapphire substrate in atmospheric MOVPE home-made vertical reactor. Trimethylgallium (TMG) and NH_3 were used as the precursors of gallium and nitrogen. The carrier gas was a mixture of N_2 and H_2. After a cleaning procedure of the sapphire substrate, the growth started by a nitridation step under $NH_3 + N_2 + H_2$ atmosphere for 10 min at 1080 °C. Then, the SiN treatment was carried out by in-situ deposition of a thin SiN mask on the sapphire. SiN coating is obtained by introducing silane (SiH_4) in the vapor phase at the end of the nitridation step of the sapphire substrate. Afterward, the temperature was decreased to 600 °C in order to deposit 30 nm GaN buffer layer. GaN epilayer was finally grown after a temperature ramp from 600 to 1120 °C. Details of the process and optimum growth conditions can be found in references [18,20]. The samples used in the present work were grown under nominally identical conditions except for the thickness which was chosen in such a way that it covers all the different stages of film coalescence, i.e., samples S1 (0.1 μm), S2 (0.3 μm), S3 (0.7 μm), S4 (0.8 μm), S5 (1.7 μm), S6 (2 μm), S7 (3 μm) and S8 (5 μm). A Brucker X-ray diffractometer with Cu Kα radiation was used to determine the crystal quality of GaN films. PR measurements were carried out by employing a standard setup with the 325 nm line of He–Cd laser as the pump light which was mechanically chopped at 280 Hz. The probe light was obtained from a 75 W Xe lamp dispersed with a 275 mm focal length monochromator. The reflected light was dispersed by a 500 mm focal length grating monochromator and was detected using Hamamatsu R-928 photomultiplier.