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Luminescence of GaN nanocolumns obtained by photon-assisted anodic etching

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GaN nanocolumns with transverse dimensions of about 50 nm were obtained by illumination-assisted anodic etching of epilayers grown by metalorganic chemical vapor deposition on sapphire substrates. The photoluminescence spectroscopy characterization shows that the as-grown bulk GaN layers suffer from compressive biaxial strain of 0.5 GPa. The majority of nanocolumns are fully relaxed from strain, and the room-temperature luminescence is free excitonic. The high quality of the columnar nanostructures evidenced by the enhanced intensity of the exciton luminescence and by the decrease of the yellow luminescence is explained by the peculiarities of the anodic etching processing. © *2003 American Institute of Physics.* [DOI: 10.1063/1.1605231]

GaN and related nitrides became recently the most intensively investigated semiconductor materials due to their applications for high-efficiency light-emitting devices in the ultraviolet and blue energy regions[1,2] and electronic devices capable to operate at high temperature/power and in harsh environments.[3,4] Due to the lack of suitable nitride substrate material, heteroepitaxial growth on sapphire or 6H–SiC substrates is actually common practice. The large lattice parameter and thermal expansion coefficient mismatches between GaN and these materials result in residual strain in heterostructures that can seriously influence the device quality. The common practice to reduce the strain in GaN layers is the growth of a buffer layer. In spite of that, in many cases the remaining amount of strain is considerable. It is important to understand the impact of strains on excitons in photoluminescence (PL) of GaN since the nature of the band-edge radiative recombination processes was shown to be excitonic up to room temperature.[5] The influence of biaxial strain on the exciton resonance energies and the band structure of wurtzite GaN was extensively studied (see Ref. 6, and references therein). The accumulated experimental data allow one to reliably characterize strains in GaN layers by analyzing exciton lines in optical spectra.

Unique possibilities to fabricate strain-relaxed structures and to further extend the area of practical applications of nitrides are provided by material nanostructuring. In particular, wurtzite GaN nanowire arrays are an important focus of current research, cf. Refs. 7 and 8. Nanotexturization is expected to induce a strongly enhanced nonlinear optical response that may lead to the development of fully integrated light source and frequency converter subsystems.[9] Nanostructuring is also a powerful tool for phonon engineering.[10,11]

The GaN nanowires synthesized by chemical vapor deposition on silicon substrates proved to experience significant stresses,[8] while x-ray investigation showed that porous GaN structures suffer from less residual stresses than the as-grown GaN epilayers.[12] Wurtzite GaN nanocolumns fully relaxed from strain were grown recently by molecular beam epitaxy on Si and sapphire substrates.[13]

In this work, we present the results of PL spectroscopy characterization of GaN nanocolumns obtained by illumination-assisted anodic etching of bulk epilayers. The investigated columnar nanostructures are shown to be relaxed from strain, their room-temperature luminescence being free excitonic.

The GaN layers were grown by low-pressure MOCVD techniques on (0001) c-plane sapphire. A buffer layer of 25-nm-thick GaN was grown at 510 °C. Subsequently, a 0.5-μm-thick n-GaN followed by a Si-doped n^+-GaN film and a top n-GaN layer with 2.0 μm thickness each were grown at 1100 °C. The concentration of free electrons in the top layer was 1.7×10^{17} cm^{-3}. Anodic etching was carried out at current density 5 mA/cm^{-2} in 0.1 mol aqueous solution of KOH under *in situ* UV illumination provided by focusing the radiation of a 250 W Hg lamp on the GaN surface exposed to electrolyte.

The PL was excited by the 334 nm line of an Ar$^+$ SpectraPhysics 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 cryogenic system.

A scanning electron microscope (SEM) image taken from the etched GaN sample is shown in Fig. 1. GaN columns with transverse dimensions of 50 nm or less prove to be oriented perpendicular to the initial surface. In some re-

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