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Free excitons in strained MOCVD-grown GaN layers

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GaN layers grown on sapphire substrates were characterized using high resolution optical reflectivity and absorption spectroscopy in the region of ground and excited exciton states. The main exciton parameters are deduced from calculations of reflectivity contours for A and B exciton S-states. The parameters of the Γ_5 state of the A-exciton as well as those of the Γ_5 and Γ_1 states of the B-exciton are determined from a comparative analysis of reflectivity and absorption spectra in thin layers. The influence of strains inherent to MOCVD-grown GaN layers on the exciton parameters including effective masses and longitudinal-transverse splitting is discussed. Electron transitions from the three (Γ_9, Γ_7, Γ_7) upper valence bands to the second E_{c2} conduction band of Γ_3 symmetry were evidenced.

1 Introduction

Gallium nitride and related alloys are attractive materials for various high-temperature high-power electronic applications [1] [2] [3] [4]. Advances in the technology of low temperature epitaxial growth allow one to grow GaN layers of 2 – 10 nm thickness with the smoothness of hetero-interfaces at the order of one atomic layer [3] [4]. When the layer thickness is comparable with the de-Broglie wavelength, the electron and hole energy spectrum depends on the layer thickness due to quantum confinement effects. These effects open new possibilities to control the wavelength of the emitted light through the variation of the quantum well width.

In spite of a great deal of interest in these materials, many features of strained GaN layers, such as the influence of strains on the electron and hole effective masses, longitudinal-transverse exciton splitting, etc., are poorly explored. The study of the impact of strain upon material characteristics is important since the growth of GaN layers on sapphire and 6H-SiC substrates is a common practice due to the lack of suitable GaN substrates. Strains in GaN layers are caused by large lattice and thermal mismatches between GaN and the substrate materials.

In this work, we investigate optical properties of GaN layers grown on sapphire substrates and compare optical parameters of these strained layers with the data published on non-stressed material.

2 Experimental

The GaN layers used in our experiments were grown by low-pressure MOCVD on (0001) c-plane sapphire using trimethylgallium (TMGa) and ammonia (NH_3) as source materials [5]. The carrier gas was Pd-cell purified hydrogen (H_2). Heating was accomplished by RF induction of the graphite susceptor. A buffer layer of about 25-nm thick GaN was first grown at 510 °C. Subsequently n-GaN layers were grown at 1100 °C. The concentration of free electrons in the top n-GaN layer was 1.7 x 10^{17} cm^{-3}.

Photoreflectivity and absorption spectra were measured using the light from a halogen lamp. The white light reflected from the sample (in reflectivity experiments) or passed through the sample (in absorption experiments) was analysed through a double spectrometer with 1200 lines/mm gratings assuring a linear dispersion of 0.8 nm/mm. The signal from an FEU-106 photomultiplier with SbKNaCs photocathode working in a photon counting mode was introduced in an IBM computer via the IEEE-488 interface for further data processing. The spectral resolution was better than 0.5 meV. The samples were mounted on the cold station of a LTS-22-C-330 workhorse-type optical cryogenic system.