Persistent photoconductivity and optical quenching of photocurrent in GaN layers under dual excitation

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(Received 28 January 2003; accepted 10 July 2003)

Persistent photoconductivity (PPC) and optical quenching (OQ) of photoconductivity (PC) were investigated in a variety of *n*-GaN layers characterized by different carrier concentrations, luminescence characteristics, and strains. The relation between PPC and OQ of PC was studied by exciting the samples with two beams of monochromatic radiation of various wavelengths and intensities. The PPC was found to be excited by the first beam with a threshold at 2.0 eV, while the second beam induces OQ of PC in a wide range of photon energies with a threshold at 1.0 eV. The obtained results are explained on the basis of a model combining two previously put forward schemes with electron traps playing the main role in PPC and hole traps inducing OQ of PC. The possible nature of the defects responsible for optical metastability of GaN is discussed. © *2003 American Institute of Physics.* [DOI: 10.1063/1.1604950]

I. INTRODUCTION

Over the last years, spectacular progress was achieved in fabrication of GaN based short-wavelength light-emitting devices[1–4]. Besides that, GaN and related compounds offer great potential for applications in ultraviolet detectors[5,6] and field effect transistors.[7,8] The existence of metastable defects in GaN does not seem to have a negative impact on light emitters, while the PPC behavior associated with these defects can have a significant effect on the characteristics of FET and UV detectors based on AlGaN/GaN heterostructures, including sensitivity, noise properties, dark level, and response speed.[7,9] Persistent photoconductivity (PPC) proves to be inherent to wurtzite-type GaN epitaxial layers.[10] Different mechanisms were considered as the origin of PPC, such as defects with bistable character,[10,11] AX, [12] or DX (Refs. 13 and 14) centers, random potential fluctuations due to nonstoichiometry and heterointerfaces,[15,16] and unintentionally incorporated cubic-phase crystallites in the hexagonal matrix.[17] Other effects related to the PPC, such as yellow luminescence (YL),[10,18,19] time dependent luminescence,[20,21] quenching of photocurrent,[21,22] and optical quenching (OQ) of photoconductivity (PC)[23,24] indicate that bistable defects are the most probable source of the optical metastability. Recently, the OQ phenomena were pointed out to be closely related to the defects responsible for the PPC effects[24].

In spite of considerable efforts in investigating optical metastability in GaN, the explanation of the phenomenon is still contradictory. Particularly, the microscopic nature of the centers responsible for the effect involved remains uncertain, gallium vacancy (V_{Ga}), [11,24,25] nitrogen antisite (N_{Ga}), [10,18,19,24] and gallium antisite (Ga_N)[21] being the preferable candidates. The issue concerning the major role of electron[18,19,22] or hole[23–25] trapping processes in optical metastability of GaN is also under discussion.

The goal of this article is to investigate the relation between PPC and PC quenching phenomena in n-type GaN epilayers. For this purpose, PPC and OQ of PC were studied in a series of GaN epilayers with different carrier concentrations, luminescence characteristics, and strains. Sample characterization was carried out in the temperature interval from 10 to 300 K under simultaneous excitation by two monochromatic light beams of various wavelengths and intensities.

II. EXPERIMENT

The GaN layers investigated in this study were grown by low-pressure metalorganic chemical vapor deposition on (0001) *c*-plane sapphire or 6H–SiC substrates using trimethylgallium and ammonia as source materials.[26] 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 thickness of the layers varies from several hundreds of nanometers to several tens of micrometers. According to Hall effect measurements, the room-temperature electron concentration in specially undoped layers is $\sim 10^{17}\,\mathrm{cm}^{-3}$. Si-doped samples with electron concentration ranging from 10^{18} to $10^{19}\,\mathrm{cm}^{-3}$ were also used in our experiments. For PC measurements, ohmic contacts were formed by depositing in-

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