SPECTRAL CHARACTERISATION OF GALLIUM NITRIDE MATERIALS APPLICABLE FOR RADIATION DETECTORS

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GaN is a promising wide band-gap material for fabrication of light-emitting diodes (LED), high-electron-mobility transistors (HEMT), high-frequency and high-power electronic devices, solar-blind photo-sensors and radiation tolerant particle detectors applied in high energy physics, radiation monitoring and other fields [1]. Wide band-gap of GaN determines a low leakage current and the proper radiation hardness of devices made of GaN. High luminescence efficiency is also an attractive characteristic of GaN in order to make the double response radiation sensors. Semi-insulating GaN bulk crystals of relevant thickness (~400 μm) and high resistivity ($\geq 10^6$ Ωcm) can also be used for manufacturing of the capacitor and Schottky diode type sensors with enhanced sensitivity. Such crystals are usually synthesised by the hydride vapour phase epitaxy (HVPE) and ammono-thermal (AT) techniques. Additionally, acceptor type dopants are intentionally introduced during growth of GaN to reach high resistivity of the material. However, the inevitable defects and impurities introduced during crystal growth affect functional characteristics of devices made of HVPE/AT GaN materials, despite these crystals contain significantly lowered densities of dislocations. Therefore, it is important to characterise these materials by identifying the prevailing defects and by evaluating their concentrations in order to produce devices of high quality and to predict their operational characteristics. The spectroscopic techniques are highly efficient tools for the investigation of defects and impurities in the materials.

In this work contactless pulsed-photo-ionization spectroscopy (PPIS) and steady-state photoluminescence (SS-PL) spectral measurements were applied for characterisation of defects and impurities introduced in bulk (~400 μm) GaN samples, grown by HVPE technology on AT-GaN seeds, and containing different carbon dopant ($N_C = 2\times10^{17}$ cm^{-3} – 10^{18} cm^{-3}) concentrations.

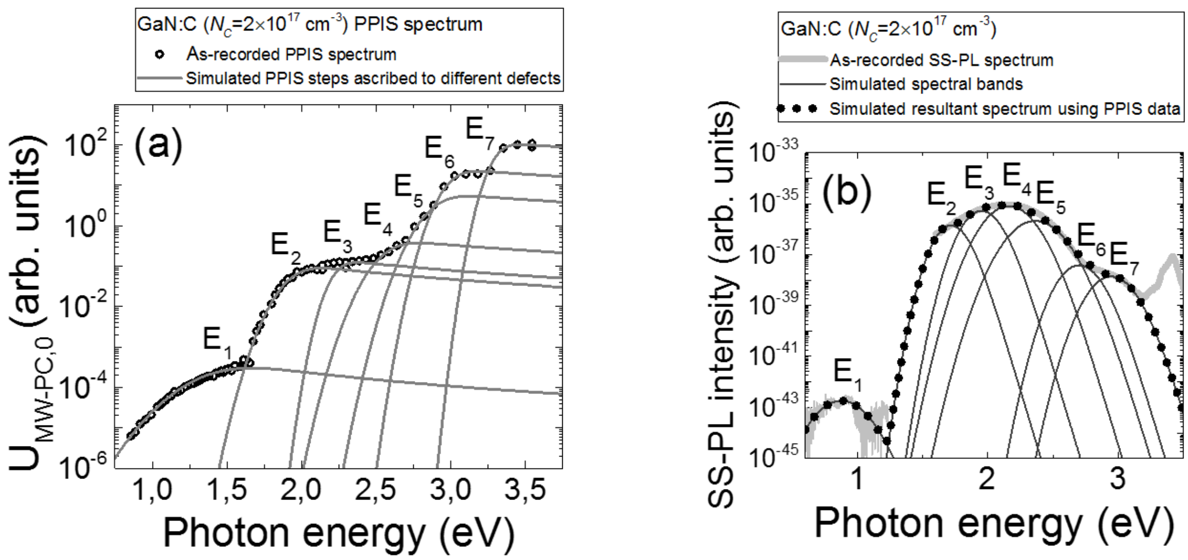

Fig. 1. (a) – Comparison of the as-recorded PPIS spectrum in lightly doped (N_C=2×10^{17} cm^{-3}) GaN:C sample (circles) with simulated (using Kopylov and Pikhtin model [2]) photon-electron coupling cross-section spectral variations attributed to different energy levels (thin solid curves), and (b) –SS-PL spectrum obtained for lightly doped (N_C=2×10^{17} cm^{-3}) GaN:C sample (grey line) compared with simulated energy levels (black dots and thin solid curves).

Combined consideration of the PPIS and SS-PL spectra allowed us to identify the dominant defects in GaN samples as well as their concentrations. The dominant defects have been identified to be the carbon interstitials (C_I), gallium vacancies (V_{Ga}), carbon substitutional atoms (C_N), carbon and oxygen complexes (C_NO_N) and two other unidentified, nevertheless carbon-related centres. The comparative analysis of the PPIS and SS-PL spectra as well as the procedure for identification of defects, impurities and calculation of their concentrations in carbon doped GaN samples grown by HVPE technique will be discussed. Operational characteristics of radiation detectors made of these materials will be demonstrated.

[1] S. J. Pearton, *GaN and related materials II*, (Gordon and Breach Science Publishers, Amsterdam, 2000).

[2] A. A. Kopylov and A. N. Pikhtin, Profiles of absorption and luminescence spectra of deep centres in semiconductors (oxygen in gallium-phosphide), Sov. Phys. Solid State **16**, 1200 (1975).