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Enhancing the Electro-Optical Properties of MOCVD GaN Structures for Radiation Sensor Applications by Chemical Surface Modification

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Gallium Nitride (GaN) and its alloys with In or Al are widely utilized in the production of light-emitting diodes, lasers, and sensors for chemical, gas, biological, and pressure detection. GaN is also critical for developing radiation-tolerant sensors used in the space industry, medical diagnostics, and high-energy physics applications. Direct-bandgap binary compounds like GaN are effective for creating dual-response devices that generate both electrical and optical signals.
GaN crystals can be grown using several methods, including metal-organic chemical vapor deposition (MOCVD) and ammonothermal (AT) techniques, which yield crystals with varying qualities. For example, AT GaN crystals exhibit a dislocation density as low as 100 cm^{-2}, while MOCVD GaN crystals typically reach higher dislocation densities. However, AT GaN often contains more homogeneously distributed vacancy-related defects throughout the crystal bulk. These dislocations create strain fields and space charge regions, affecting the electrical and optical properties of devices such as radiation detectors. Understanding the recombination dynamics of free carriers within the crystal bulk, surface, and dislocation networks is essential for optimizing device performance.
This study focuses on investigation of highly dislocated MOCVD GaN:Si wafers grown on sapphire substrates for radiation sensor fabrication. Variations in electro-optical properties between the center and edge of the wafer were analyzed. An increased yellow luminescence band in the photoluminescence spectrum was observed after etching of samples in potassium hydroxide (KOH) and orthophosphoric acid (H_3PO_4). Proton-induced luminescence was measured in situ on both pristine and etched MOCVD GaN:Si samples. Investigation revealed a stretched-exponential relaxation (SER) component within excess carrier decay transients, which highlighted differences in carrier lifetimes within the bulk of highly dislocated MOCVD and AT GaN crystals. These results indicate that dislocations attract point defects, forming regions of higher quality GaN within inter-dislocation volumes.
This research provides insights into enhancing the electro-optical characteristics of MOCVD GaN-based radiation sensors through chemical surface modifications.

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