Asymmetrical Reciprocal Space Mapping using X-ray Diffraction: a Technique for Structural Characterization of III-nitride Nanostructures

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Group III nitride-based heterostructures have been widely studied for power- and opto-electronics applications. The structure and composition are the crucial characteristics for various designs of nanostructures. The precise characterization of these properties is of crucial importance for explaining the structure-properties relationship. The high-resolution X-ray diffraction (HRXRD) is one of the main tool to determine the parameters of III-nitride nanostructures.

In this work, we report on a new approach for the structural characterization of GaN/AlN superlattices (SLs) based on asymmetrical reciprocal space mapping (RSM) using X-ray diffraction. The considered method directly provides the SL period, thickness, and strain state of quantum well/barrier from RSM of an asymmetrical reflection; it can be applied to any (strained or relaxed) III-nitride SLs heteroepitaxially grown on the substrate. A good correlation of parameters obtained from the proposed method and currently preferred approach of the $\omega/2\theta$ X-ray diffraction profile measurements and simulation is demonstrated. Furthermore, by performing a simulation of the reciprocal lattice point broadening for an asymmetrical reflection, we additionally determined the density of threading dislocations (TDs) in GaN substrate and GaN/AlN SL. The comparison of the density of TDs in the substrate and SL allows analyzing the relaxation mechanism and developing a technique to improve the structural quality of the SL. A method based on a laboratory X-ray diffraction for nondestructive diagnostic would be useful for design and precise growth of III-nitride superlattice-based devices. This approach is not limited for solely III-nitride and can be applied for variety of materials.