

## Strain relaxation of graded InGaN and AlGaN

Reem E. Alhelais<sup>1,2</sup>, Fernando Maia de Oliveira<sup>3</sup>, Hryhorii V. Stanchu<sup>3</sup>, Mohammad Zamani-Alavijeh<sup>4</sup>, Mirsaeid Sarollahi<sup>6</sup>, Yuriy I. Mazur<sup>3</sup>, Najm Al-Hosainy<sup>2</sup>, Morgan E. Ware<sup>1,3,5</sup>

<sup>1</sup> Department of Materials Science and Engineering, University of Arkansas, Fayetteville, AR, 72701, USA

<sup>2</sup> Department of Physics, Taif University, Taif, 21944, Saudi Arabia

<sup>3</sup> Institute for Nanoscience and Engineering, University of Arkansas, Fayetteville, AR 72701, USA

<sup>4</sup> Department of Physics, University of Arkansas, Fayetteville, AR, 72701, USA

<sup>5</sup> Department of Electrical Engineering, University of Arkansas, Fayetteville, AR, 72701, USA

<sup>6</sup> Department of Physics, University of Idaho, Moscow, 83843, USA

E-mail: [meware@uark.edu](mailto:meware@uark.edu), [realhela@uark.edu](mailto:realhela@uark.edu)

III-nitride semiconductor materials have proved to be ideal materials for high-power, high-frequency, and high-temperature applications because of their tunable direct band gaps, high breakdown voltage, high absorption coefficient, resistance to defects, lattice match, and polarization characteristics. These materials form a continuous alloy system with direct bandgaps from 6.2 eV (AlN) through 3.4 eV (GaN) to 0.7 eV (InN). The compositionally graded Group III-nitride alloy enables access to large range of energies through varying the bandgap. This change in bandgap is achieved through varying the indium and aluminum composition during growth, which yields excellent compatibility for various optoelectronic applications.

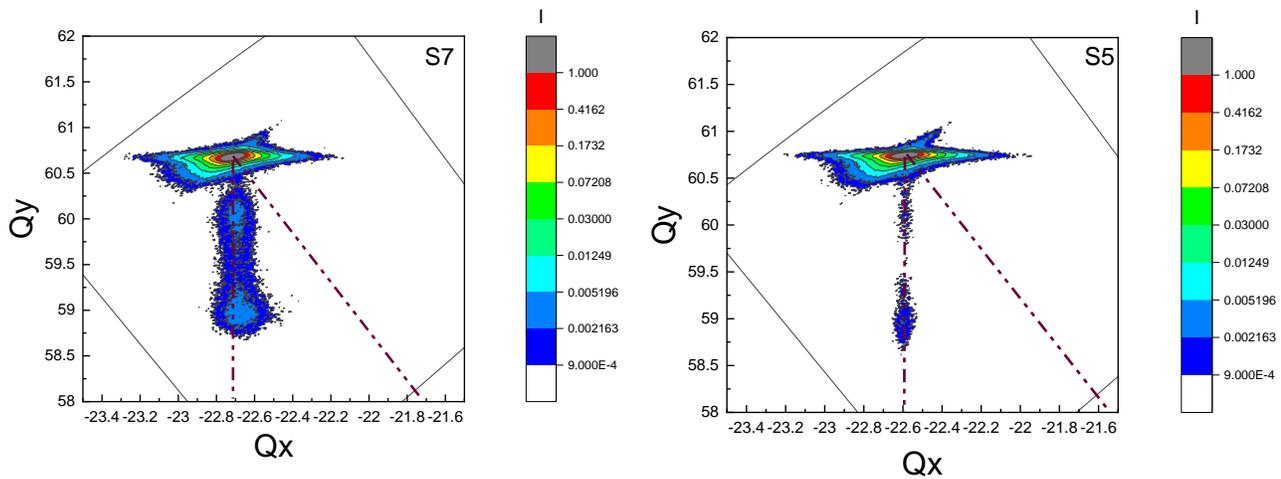
The growth and quality of mismatched heteroepitaxial III-Nitrides layers are generally influenced by strain relaxation mechanisms that release the accumulated strain energy. Plastic relaxation is generally started by the formation of misfit dislocations above the critical thickness. This has been well studied and is generally understood for heteroepitaxial films with fixed composition. Graded composition films have been investigated recently for potential incorporation into semiconductor devices, however the issue of plastic relaxation for graded III-Nitride semiconductors has not been thoroughly investigated.

Graded InGaN and AlGaN can be grown pseudomorphically strained to its substrate until some critical amount of strain energy is built up. This can happen either as a result of reaching a maximum composition or a maximum growth thickness. These two parameters are not independent in terms of their contribution to the buildup of strain energy, and the goal of this study is to determine both the range over which these alloy layers can be grown without relaxation and the mechanisms by which they exhibit relaxation.

In the present work, we have grown both graded InGaN and AlGaN layers with 30 % of In and Al composition of increasing thicknesses for 15 min, 30 min, and 60 min on GaN substrates. We investigated their properties through X-ray diffraction reciprocal space mapping (RSM). With increasing the thickness of these graded layers, the InGaN or AlGaN signature in the RSM shifts from a fully strained position. Atomic force microscopy will be also used to characterize the

sample surface of interest, including dislocation density, while transmission electron microscopy will be used to understand the nature of relaxing defects that is formed in these layers. How these introduced dislocations impact the electrical and optical properties will be demonstrated through photoluminescence and Raman spectroscopy.

- X-ray diffraction reciprocal space mapping (RSM)



With increasing the thickness of these graded layers, the InGaN or AlGaIn signature in the RSM shifts from a fully strained position.