

TUTORIAL

Growth and Characterization of Structural and Optical Properties of Polar and Non Polar GaN Quantum Dots

Although being the last member of the family of self-organizing semiconductor materials, GaN and GaInN quantum dots are of huge interest from both device and basic research point of view.

Actually, among the various hypotheses invoked to account for the remarkable efficiency of nitride-based light emitting diodes despite the huge density of dislocations (10^{10} to 10^{11} /cm²), the existence of In-rich regions in InGaN quantum wells (QWs) acting as quantum dots (QDs) has been postulated. Whatever the exact nature of localization centres eventually be, these speculations have concomitantly increased the interest in the intentional growth of GaN and InGaN QDs.

Considered from basic research side, the GaN/AlN system, being free of interdiffusion, can be viewed as a model system, making it of general interest for dot-grower community.

The tutorial will provide an overview of GaN QD growth and of the various characterization techniques used to extract quantitative information, with a special emphasis on the determination of QD strain state by anomalous Xrays diffraction. The optical properties of undoped QDs and those of rare earth-doped QDs will be described, as an opening towards applications.

More specifically, the growth mode of GaN and its dependence on various parameters allowing one to grow either quantum wires, quantum dots or quantum wells will be described. The effect of surfactant will be examined, as well as the role of parameters controlling the formation of polar and nonpolar GaN QDs.

Next, restricting ourselves to the case of QD formation, we will present their morphological and structural properties, with a special emphasis on the issue of capping and of vertical correlation of successive planes of dots, both being of interest for applications.

The characterization of GaN QDs by atomic force microscopy (AFM), high resolution transmission electron microscopy (HRTEM), Raman spectroscopy will be presented. The relatively new Medium Energy Ion Scattering (MEIS) method, which allows one to extract a strain profile at the monolayer scale in nanostructures will also be described.

The use of anomalous X rays diffraction for extracting quantitative information on the strain state of dots will be described at length. X-ray diffraction is known to be a powerful tool for measuring strain fields and correlations. The combination of Multiwavelength-Anomalous-Diffraction (MAD), that allows one to extract the scattering amplitude of the resonant and the non resonant atoms (chemical mapping in the reciprocal space), and DAFS spectroscopy, that allows one to determine the local environment of atoms located in an iso-strain volume selected by diffraction, is a particularly relevant approach to disentangle strain and composition. A MAD or a DAFS experiment consists of recording the scattered intensity as a function of the incoming x-ray beam energy in the vicinity of absorption edges. Like x-ray Absorption Fine Structure (XAFS) spectroscopy, DAFS provides information about the empty electronic states and the local environment of the resonant atom (also known as the anomalous atom). DAFS is a spectroscopic tool that records data in diffraction condition. We will give a brief insight on the basic theoretical principles of the MAD technique and the DAFS spectroscopy and we will describe the first order approach to Extended DAFS (EDAFS) formalism. Then we will report examples of grazing incidence MAD and grazing incidence DAFS studies of the structural properties of GaN Quantum Dots and InAs Quantum Wires (embedded or not). We will also give a comparison with glancing angle XAFS studies.

As a whole, based on the model case of GaN QDs, the tutorial is expected to illustrate the capabilities of most important techniques commonly used to study nanostructure structural properties.

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