ESRF	**Experiment title:** **Study of Strain Relaxation in Indium Nitride Nanostructures**	**Experiment number**: SI-1086
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Shifts:	**Local contact(s)**: Dr. Sean O'FLAHERTY	*Received at ESRF:*

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Report:

Indium Nitride (InN) is currently the subject of intense research, as a new promising semiconductor for optoelectronic applications in the 1.55 µm range. In particular, nanosructures based on InN/GaN combinations could have a huge potential for applications since the bandgap difference between both material allow for a strong electron and holes confinement, and would permit to cover a broad wavelength range, from infrared to near UV.

However, the growth of these material systems is very complicated, and this is the main reason for the lack of precise data concerning them. By comparison with other semiconductors system, one may expect that the lattice mismatch between GaN and InN will induce a Stranski-Krastanov growth mode. Although our team was succesfull to produce InN quantum dots (Applied Physics Letters 83 (2003) 2919), we have collected several experimental indications (mainly Transmission Electron Microscopy) that these dots may not be fully strained to the surrounding GaN. Due to the small size of the InN dots (typically 12 nm height), synchrotron radiation was necessary to collect signal from the nanostructures. The samples of unburried and burried quantum dots were grown by the MOCVD technique at the University of Montpellier, and studied at the ESRF ID10B beamline. Extremely thin films of InN grown onto sapphire substrates (8 to 75 nm in thickness) were also studied to obtain information in the growth mechanisms and evaluate the critical thickness for plastic relaxation of InN. Regarding nanostructures, our goal was to probe the strain gradient in the InN quantum dots, in order to determine its mean value and distribution along the dot growth axis.

Surface diffraction experiments were performed, mainly around the (100) Bragg peak of InN, using a linear detector, in order to be depth sensitive.

The important results obtained through this experiments are :

1 – All the InN thin films that were studied showed evidence of a large lattice relaxation, leading to almost unstrained material in all cases, even for the 8 nm film.

2 – We observed the occurrence of a (101) In peak for the thinner films (figure 1), indicating that during the first stages of the growth, metallic In was embedded in the films. This point, has been the subject of many discussions in the literature, is made very clear here. These experiments were performed close to the InN critical angle, in order to probe only the first nanometers of the layers.

3 – The a lattice parameter, measured in the InN quantum dots demonstrate that a large amount of relaxation occurs in the dots, leading to few residual stress. The lattice parameters reported in figure 2 correspond to 0.3% residual strain (unburried dots), and 0.6% of residual strain for burried dots. This difference is clearly linked to the fact that unburried dot are free to relax elastically, thus further reducing the residual strain.

4 – In figure 2, the PSD channel is directly linked to the exit angle α_f , ranging around the critical angle for InN. This allow us to probe the strain within the dots on a nanometer scale. Although a quantitaive analysis require further modeling of the data, one can deduce that the residual strain is higher in burried dots, and is almost constant within the dots. On the other hand, for unburried dots, the strain decreases from the bottom of the dots, close to the substrate, to their tops, demonstrating that an elastic relaxation mechanism is active.

In conclusion, we have been able to analyze the strain state on a naometer scale in InN/GaN quantum dots, and we observed that this residual strain is very low. Indium inclusions were clearly evidenced in the first stage of growth for InN. These results will be further analyzed quantitatively and a paper, with supporting microscopy observations is under preparation.

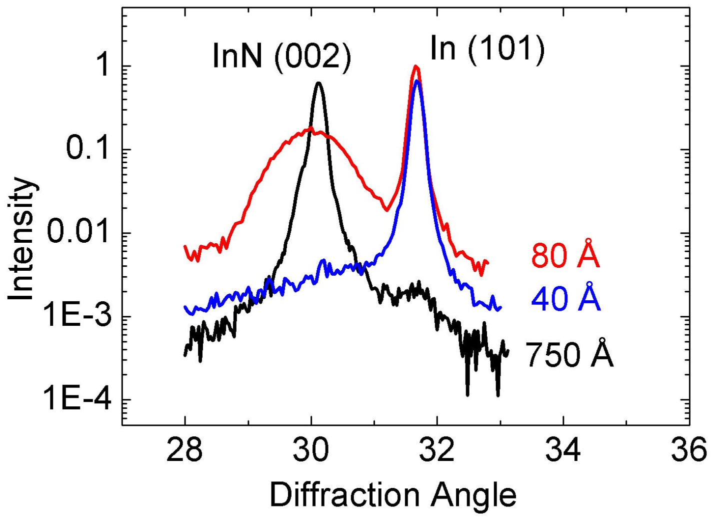

Figure 1 :

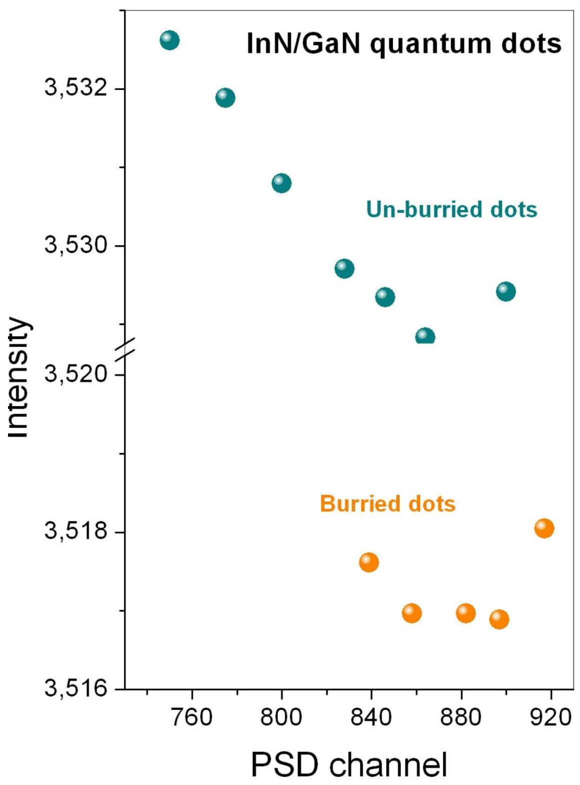

Figure 2: