ESRF	**Experiment title:** **Strain mapping and signature of single defects in coherent diffraction patterns**	**Experiment number:** HC-892
Beamline: ID01	**Date of experiment:** from: 06/11/2013 to: 12/11/2013	**Date of report:** 1 March 2014
Shifts: 18	**Local contact(s):** Dr. Marie-Ingrid Richard	*Received at ESRF:*

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Report:

Coherent X-ray diffraction (CXD) has been shown to be very powerful to investigate mechanical properties at the nanoscale. Combined with phase retrieval algorithms, it yields non destructive elastic strain mapping with a resolution of less than 10 nm [1,2]. However plastically deformed crystals display complex diffraction patterns that are still impossible to analyse quantitatively. This spurs interest in the study of single isolated defects in model nanostructures. In a recent experiment (see Experimental Report SI-2423, ESRF-ID01), we performed coherent X-ray diffraction imaging of single isolated defects in single GaN nanowires grown on **c**-sapphire at one Bragg position. Some diffraction patterns (see Fig. 1) have been successfully inverted by iterative algorithms revealing inversion domain boundaries (pure phase objects - where the phase corresponds to a displacement field in the object, relative to an undistorted lattice) in GaN nanowires and their corresponding lattice shifts Δ*d* between the Ga and N lattices along <0001>. These first results are promising and demonstrate the possibility to image nanostructures in Bragg geometry even in the presence of defects.

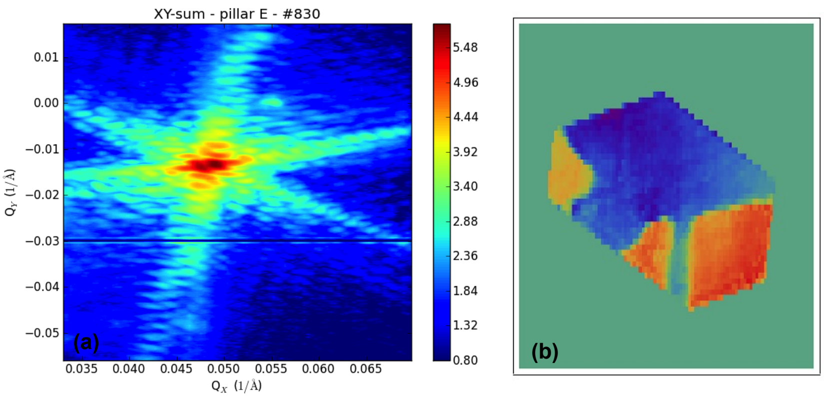

Fig. 1 (a) CXD pattern of the 004 reflection from a GaN nanowire. (b) reconstructed phase, evidencing antiphase domains (the phase shift between the blue and the orange regions is ~ 2.8 rad, the green region is outside the nanowire; the nanowire section is almost hexagonal, with main diameter 660 nm).

In this new experiment, nano-focused coherent X-ray diffraction was performed on single and isolated GaN nanowires/whiskers grown on sapphire. Coherent X-ray diffraction experiments were performed using a nano-focused X-ray beam at the ID01 beamline. The nano-beam was focused to a 430 x 700 nm^2 (vertical x

horizontal) spot size using a Fresnel Zone-plate (FZP) of 300 μm diameter and 80 nm outer-most zone width. The nano-diffraction experiments were carried out at a beam energy of 9 keV (wavelength of 1.378 λ). The diffracted beam was recorded with a two-dimensional (2D) MAXIPIX photon-counting detector, characterized by 516 x 516 pixels and 55 μm pixel size, at a distance of 1.3 m from the sample.

We succeeded to record coherent diffraction patterns in Bragg geometry at five non-coplanar Bragg reflections on a unique GaN nano-whisker (see Fig. 2). Phase retrieval on the five different patterns reveals inversion domains inside the GaN nano-whisker and allows to recover all the three components of the displacement vector $\boldsymbol{u}_i$, as well as the strain field around the observed single planar defects: ***inversion domain boundaries.***

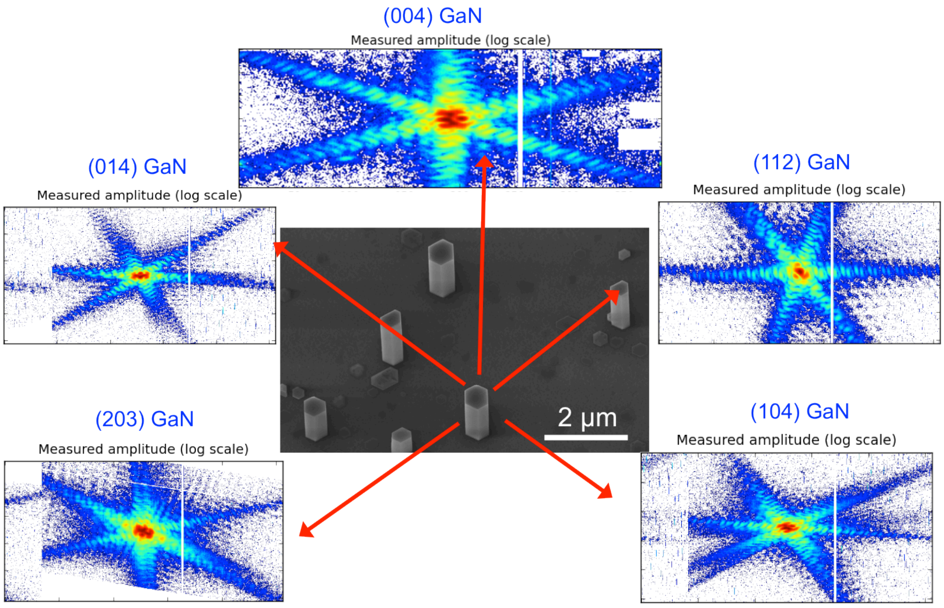

Fig. 2: Middle: scanning electron microscope (SEM) of GaN nano-whiskers on a **c**-sapphire substrate. CXD patterns of five non-coplanar reflections measured on a unique GaN nano-whisker: (004), (014), (112), (203) and (104) GaN reflections.

Three-dimensional coherent X-ray diffraction images were also collected at different positions along the GaN pillar and at the (014) and (004) GaN Bragg reflections to determine how defects evolve along the nano-whisker (see Fig. 3).

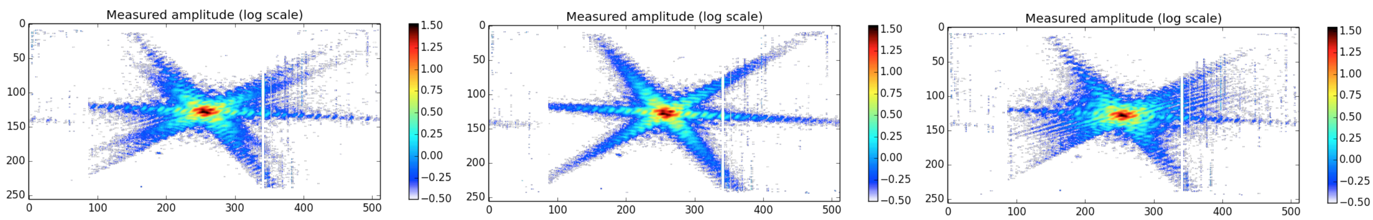

Fig. 3: CXD patterns of the (014) GaN Bragg reflection at three different positions along the nano-whiskers

References:

[1] A. Diaz, C. Mocuta, J. Stangl, B. Mandl, C. David *et al.,* Phys. Rev. B **79** (2009) 125324.

[2] I. Robinson, R. Harder, Nat. Mat. **8**, 291 (2009).