ESRF	**Experiment title:** Signature of single defects in coherent diffraction patterns	**Experiment number:** SI-2423
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Shifts: 18	**Local contact(s):** Dr. Vincent Jacques	*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 this way, coherent X-ray diffraction in Bragg condition has been performed at beamline ID01 of ESRF to image single isolated defects in nanostructures and to understand the infuence of a unique topological defect on the CXD pattern.
A coherent portion of the monochromatic (8.5 keV) beam was selected with high precision slits by matching their horizontal and vertical gaps with the transverse coherence lengths of the beamline (20 μm and 60 μm close to the sample position). The coherent beam was then focused to ~0.8 μm x ~0.4 μm using Fresnel zone-plate (diameter of 300 μm), in order to illuminate a single nanostructure. Diffraction was measured by a Maxipix area detector (516x516 pixels) of 55 μm placed at 1.307 m from the sample.

The wave-front of the incoming beam focused by the Fresnel zone-plate with coherent, partial and full illuminations was characterized. The retrieval of the wave-front in the different illumination conditions is still underway.

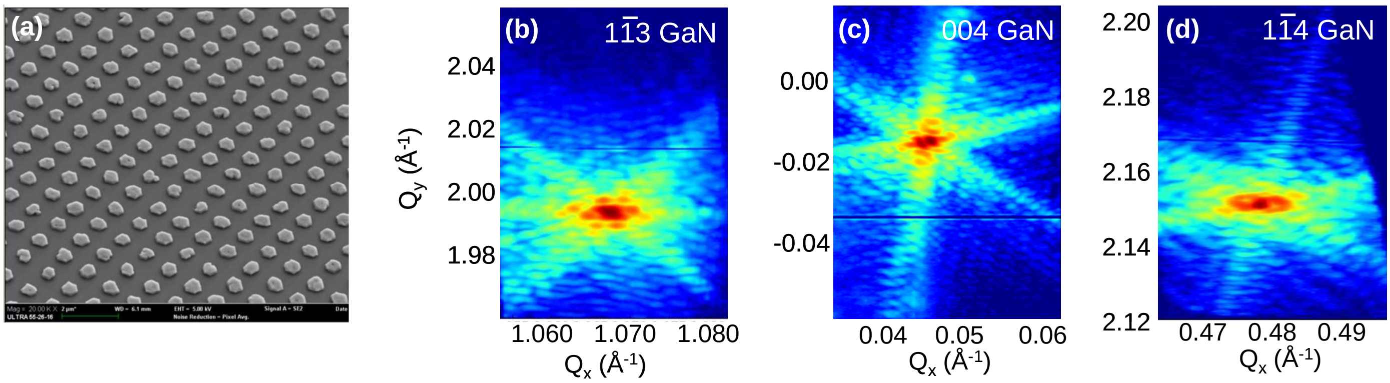

Fig. 1 (a) GaN nanowires (NWs) with a single dislocation (see black points at the center of the NWs in the scanning electron image) and/or inversion domain boundaries. (b)-(d) Two-dimensional reciprocal space images collected at different Bragg peaks for different GaN NWs.

Figure 1a displays a scanning electron microscopy (SEM) image of GaN nanowires (NWs) grown on a c-sapphire substrate. The nanowires have a hexagonal shape. Defect-free and defective nanowires with a single dislocation (see black points at the center of the NWs in the scanning electron image) coexist. Coherent X-ray diffraction measurements (not shown here) reveal that the basis of the nanowires is characterized by a disturbed pattern, which may be due to the dislocation network at the GaN/sapphire interface. Figures 1(b-d) show reciprocal space maps around the 004, 1-13 and 1-14 GaN reflections recorded at the middle (along Z) of different GaN nanowires. For each NW, only one Bragg reflection was recorded. In some cases, diffraction patterns are split into different parts (see Figs. 1(c-d)) , which may arise from defects. Figure 2a displays a three dimensional CXD pattern around the 004 GaN reflection for one chosen nanowire. The diffraction pattern has been successfully inverted by iterative algorithms revealing inversion domain boundaries [3] (see Fig. 2b) in the GaN nanowire and their corresponding lattice shifts between the Ga and N lattices along <0001>, in good agreement with literature [4]. Inversion domain boundaries are pure phase objects, where the phase corresponds to a displacement field in the object, relative to an undistorted lattice.

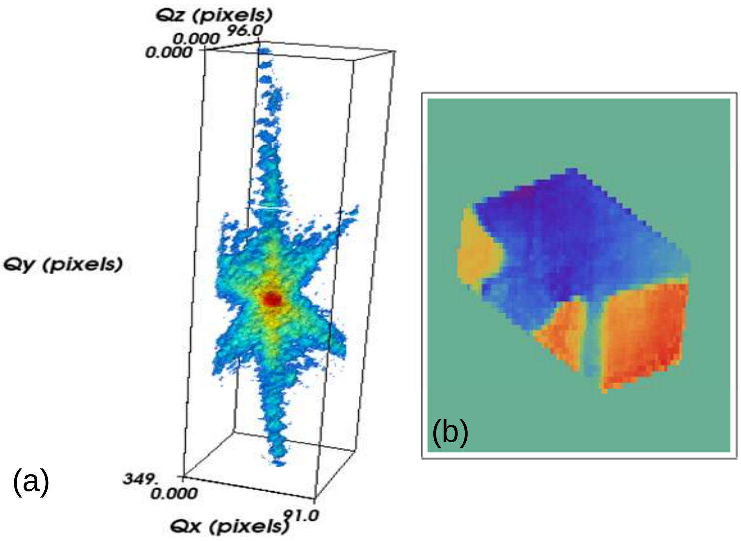

Fig.2 (a) Three-dimensional CXD pattern of the 004 reflection from a GaN nanowire. (b) Reconstructed phase, evidencing antiphase domains (the phase shift between the blue and the orange regions is ~ 2.8 rad, the green region is outside the nanowire; the nanowire section is almost hexagonal, with main diameter 660 nm)

These first results are promising and demonstrate the possibility to image nanostructures as well as defects therein in Bragg geometry. Coherent X-ray diffraction was only recorded around one Bragg positions (either 004, 1-13 or 1-14 GaN) for different GaN nanowires. To recover all the three components of the displacement vector $\boldsymbol{u}_i$ in rectilinear coordinates to access to the **strain** field around single defects, recording coherent X-ray diffraction patterns in Bragg geometry at three non-coplanar Bragg reflections is necessary.

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).
[3] J. E. Northrup, J. Neugebauer, L. T. Romano, Phys. Rev. Lett. **77**, 103 (1996).
[4] Fude Liu, Ramon Collazo, Seiji Mita, Zlatko Sitar, Stephen J. Pennycook, and Gerd Duscher , Adv. Mater. **20**, 2162–2165 (2008).