ESRF	**Experiment title:** Study of inversion domain boundaries in AlGaN/GaN heterostructures	**Experiment number**: ME956
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Shifts: 18	**Local contact(s)**: Gema Martínez-Criado	
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Report:

In the present proposal, on spatially selective invserion domain boundaries (IDBs) grown in AlGaN/GaN lateral polarity heterostructures (LPHs), a complementary study to previous reports carried out by Raman scattering and photoluminescence spectroscopy is performed by hard x-ray microprobe. One of the most interesting findings was that the IDBs can be not only optically active, but are more than an order of magnitude brighter than the surrounding lattice. The luminescence suggested that such IDBs are characterized by a high local order reconstruction, where excitons are attracted because of local strain and/or electric fields. However, up to now no direct experimental evidence has been provided to support the above structural order.

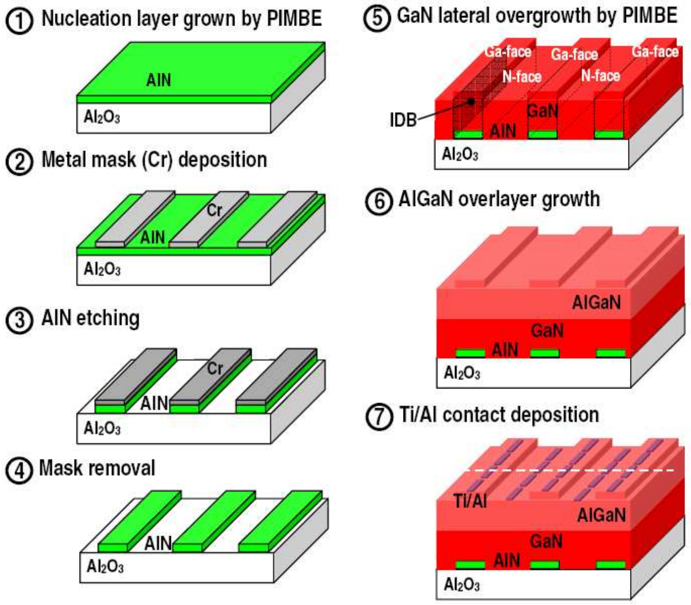

Fig. 1: Major steps involved in the sample preparation

Figure 1 represents the major steps involved in the preparation of the LPHs. The sample was scanned with the x-ray microbeam perpendicular to these IDBs (see the horizontal dashed while line on the last step). In order to study the incorporation of the chemical species, Fig. 2 displays the average x-ray fluorescence (XRF) spectra collected with an excitation energy of 13 keV from different areas (labeled Ga-rich and Ga-poor regions), accompanied with the respective fit and background lines. The XRF lines of Ga and Ti atoms from the GaN-based LPH and metallic mask respectively are shown. The statistically signifcant peaks in the considered energy range reveal the presence of several residual elements: Cr, Fe, Ni, Cu, and Zn. The profiles represent the relative intensity of the Ga and Ti Kα fluorescence lines associated to the GaN layer and to the ohmic contact, respectively. The remaining impurities do not exhibit a comparable striking variation along the line scans. However, the presence of strong electric fields, which deeply affect the electronic properties of LPHs, could give rise to a field-driven electrodiffusion of charged impurities. This might lead to, for example, the accumulation of impurities close to the IDBs. As it is expected, maxima in the Ti signal are present in the window regions of the metallic mask. The abrupt edges suggest no significant lateral interdiffusion of Ti atoms at the micrometer scale. The IDBs are characterized by alternated junctions of Ga-rich and Ga-poor areas in the Ga-related profile. In both regions, the XRF displays similar composition with

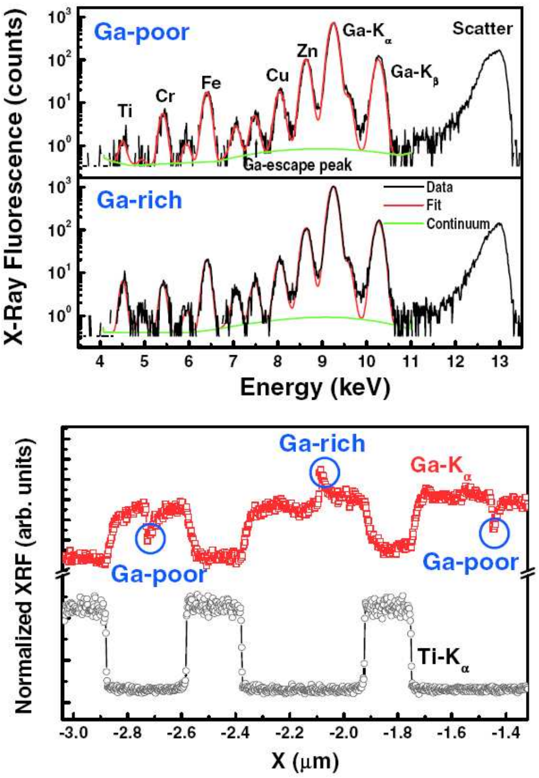

Fig. 2: XRF spectra taken on different areas.

several differences in the relative intensities. At the Ga-rich areas, the fits yielded residual concentrations ranging from 48 % Ga, 7.5 % Zn, 3.3 % Fe, 2.1 % Cr, 1.5 % Cu, up to 1.2 % Ti, whereas at the Ga-poor areas the elemental estimations cover from 44 % Ga, 5 % Zn, 2.3 % Fe, 1.3 % Cr, 1.1 % Cu, up to 3.9 % Ti. For the remaining elements, the quantification derived concentrations below 1 %. Contrary to the ultrasharp interface previously observed by micro-Raman measurements, within the length scale determined by the probe size our investigation indicates that the IDBs accommodate laterally the incorporation of different species. As a result, the Ga concentration profile could be taken as an alternative way to identify IDBs in wurtzite GaN.

In order to study a possible influence of all these species on the local atomic structure of such IDB regions, XANES measurements have been performed around the Ga K-edge. In Fig. 3 the spectral shape of the edge reflects the distribution of the unoccupied Ga p-states in the conduction band. In the wurtzite structure, there are two distinct types of Ga-metal bonds. One π-(p_z) bond along the c axis, and another σ-(p_{xy}) bond lies in the ab plane. In our case, since $\theta = 45^o$ both contributions are combined and σ- and π-bond states dominate the first structures A - D. The spectral characteristics show the unambiguous signature of the GaN hexagonal phase. No damping effect reveals the influence of the residual impurities in any crystallographic direction.

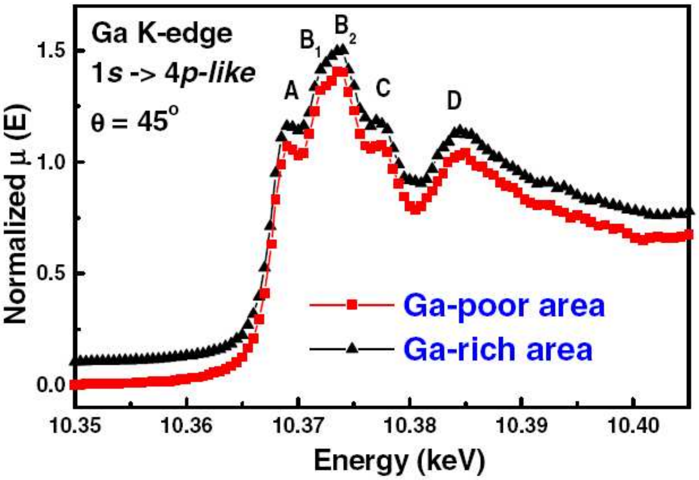

Fig. 3: XANES collected on different regions.

In order to substantiate the importance of these areas in the optical properties, we have performed XEOL based on x-ray core-level excitation with the microbeam focused on the Ga-rich and Ga-poor regions. In Fig. 4, with a noticeable difference in the relative intensity between both areas, the spectral decomposition shows nine bands located along the 1.9 - 3.5 eV energy range. Although the number of peaks in the bands could also arise from optical interference effects, we cannot exclude the possibility of several transitions involving the residual impurities detected by XRF as responsible for these radiative processes. Despite the escape depth of the x-ray excited luminescence is smaller than the information depth of the XRF, in accordance with the chemical microanalysis, the XEOL results show a higher optical effciency of the radiative centers at the Ga-rich areas than that at the Ga-poor ones. The stronger intensity at the former regions evidences a faster recombination rate (i.e., short recombination lifetime) and/or a relatively high concentration of their underlying states. The energetic positions, on the other hand, do not exhibit a significant variation, indicating no notable Ga induced strain consistent with the XANES results.

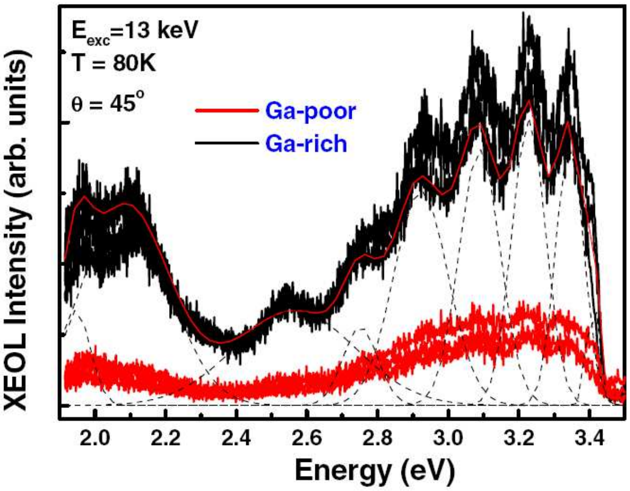

Fig. 4: XEOL measurements taken on different sample areas.