ESRF	**Experiment title:** Strain-induced dopant segregation in nanowire hetero-structures investigated by multi-angle Bragg ptychography	**Experiment number**: HC-3807
Beamline: ID13	**Date of experiment**: from: 17 Nov 2018 to: 20 Nov 2018	**Date of report**: 19 Feb 2019
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Report:

In multijunction solar cells, highly doped tunnel diodes are used to connect the individual p-n junctions. The different band gaps are bridged by inducing dopants to form a tunnel diode junction at the interface. The mismatch in lattice constant at the heterostructure causes the material to strain. How the strain from the interface affects the incorporation of dopants is an open question, and it is possible that the strain can induce segregation to the surface. Both doping and strain influence the electronic properties of the nanowire. In this experiment, we aimed to study the strain at the junction of nanowire tunnel diodes [1].

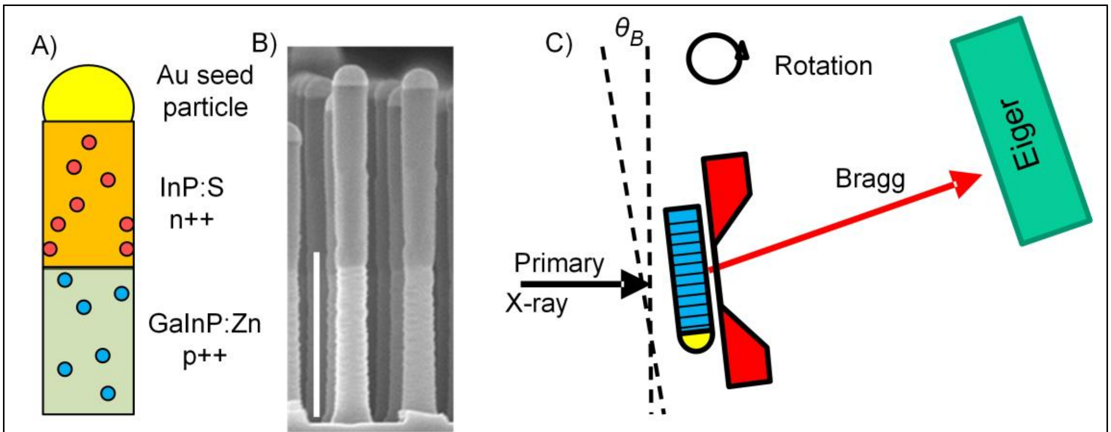

Figure 1. a) Drawing, and b) Scanning electron microscope image, of InP:Sn (n++) /GaInP:Zn (p++) heterostructured nanowire tunnel diode, showing the distribution of dopants. Scale bar 1 µm. c) Drawing of the experimental setup

GaInP:Zn (p++) / InP:Sn (n++) tunnel diodes (Fig. 1 a and b) were grown of the group of Magnus Borgström at Lund University, by vapor-liquid solid growth from a gold droplet. The nanowires were deposited on a Si_3N_4 membrane, transparent to the hard x-rays. We scanned single nanowires with a 15.2 keV beam focused down to around 100 nm. Compound refractive lenses were used for focusing, and the focus size was found by transmission ptychography of a test sample. The diffraction signal from the NWs was measured with an Eiger detector in Bragg geometry, see setup in Fig. 1 c). Our nanowires were oriented in a random fashion on the substrate. Single nanowires were located with the in-line microscope. The fluorescence signal from Ga K_α Au was used to aligne the NW in the focus. Full rocking curves were collected by small rotations of the NW, with angular steps of 0.05 deg. We measured the InP and GaInP Bragg peaks of both the two WZ/ZB equivalent peaks of (2-1-10)/(20-2) and the (0002)/(111) reflections.

From the Bragg diffraction patterns we could single out the Bragg peak from the InP and the GaInP repectively, and produce maps of the summed intensity as well as the q-vector length and tilt. The length of the q-vector is related to the strain of the material. Preliminary analysis from the (2-1-10)/(20-2) reflections can be seen in Fig. 2. From the summed intensity maps in Fig.2 a-b, the origin of the scattered intensity, for the InP and GaInP Bragg peak respectively, is visible. Fig. 2 b-c) shows the length of the q-vector in each scanning postion, for InP and GaInP respectively. The values fit reasonably well with the expected values. A separate Bragg peak, attributed to the p-doped region of the junction was also visible in the measurements.

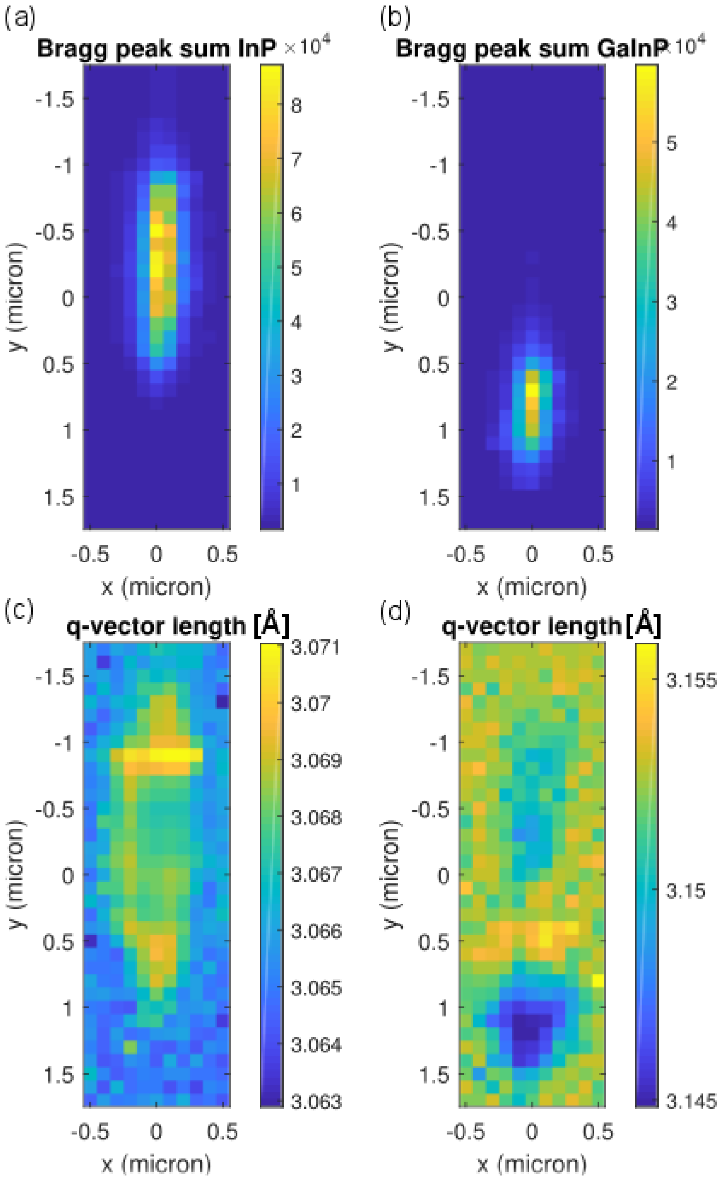

Figure 2: Scanning XRD of doped InP/GaInP nanowires: The summated intenisty of the Bragg peak in each scanning position for a) InP and b) GaInP. q-vector length map for c) InP and d) GaInP.

From the data collected at ID13, we can perform q-vector maps, mapping the strain in single tunnel junctions, for two different reflections. We can answer questions about the crystalline structure, like if wurtzite or zinc blende is the more prominent structure. From the p-doped region of the junction, we not only see smearing of the Bragg peak, but a separate peak. This observation will be further investigated.

Real space drift is one major difficulty in Bragg ptychography. From the preliminary analysis done here, we find that the sample drift between rotations was small. The in-line microscope made the location of single wires in real space very easy. Since our NWs are randomly orienteded on the substrate, it would be benificial if we could rotate the sample in the plane perpendicular to the beam. In that way we can choose any given NW, and align it to the sought reflection.
The real space resolution in these measurements is limited by the beam size. Ptychographic reconstruction could give us a much better real space resolution, but it will probably not be possible for this dataset since the intensity of the diffraction patterns is too low to resolve fringes.
From the inproved brilliance after the ESRF upgrade, we believe that with the increased number of coherent photons we will be able to perform Bragg ptychography and/or multiangle Bragg projection ptychography.

Referenses

[1] X. Zeng, G. Otnes, M. Heurlin, R. T. Mourão, M. T. Borgström, *Nano Res.* **2017**