ß´

ESRF	Experiment title: **"X-ray investigation of strain-accommodation in the initial stage of MBE GaAs nanorod growth onto Si [111] using a micro-focussed X-ray beam "**	**Experiment number**: SI-2020
Beamline: ID 1	**Date of experiment**: from: 07.04.10 to: 13.04.10	**Date of report**: 18. 08.2010
Shifts: 18	Local contact(s)**:** Vincent Jacques	*Received at ESRF:*

U. Pietsch , A. Biermanns, A. Davydok

1. Solid State Physics, University of Siegen, D- 57068 Siegen, Germany

Compared to thin film technology, the growth of semiconductor nanowires (NWs) offers the possibility to form heterostructures between highly lattice-mismatched materials, because strain energy can be released at the free NWs sidewalls without introducing defects. In particular, this is a promising route to combine III-V properties with Si technology. Although the growth of III-V NWs on Si has been demonstrated experimentally for many different materials, little is known about the details of the strain accommodation at the interface between NW and substrate.
The aim of this experiment was to study the strain accommodation during the initial stage of GaAs nanowire (NW) growth on a Si (111) substrate, using a nanometre sized x-ray beam in order to determine individual nanowire-properties.

The experiment at ID1 was performed using the nanofocus setup installed at the beamline. The 8keV X-ray beam was focussed down to a spot size of 300x300 nm² (FWHM vertical and horizontal, respectively) using a Fresnel zone plate (FZP) placed 130mm in front of the sample. A central beamstop and an order-sorting aperture were placed in front and behind the FZP, respectively, to block all but the first diffraction orders produced by the FZP. The sample was mounted horizontally on a piezo stage allowing for a reproducible sample positioning below the incident beam in the order of 50nm.
To determine average properties of the grown NWs, the FZP was removed from the optical axis. In this case, a beam size of 200x200µm² was defined by a set of apertures in front of the sample. For the detection of the diffracted beam we used a 2 dimensional MAXIPIX pixel detector.

In order to monitor the initial stage of NW growth, a set of samples was investigated where the growth was stopped at different times between 60s and 1800s (figure 1). All samples were grown using a self-induced growth mechanism in MBE, leading to inter-wire distances in the order of a few micron, ideally suited for single-NW inspections. In a first step, the whole NW ensembles were characterized using the broad x-ray beam described above. As the NWs grow along the [111] crystallographic direction, their structure is usually found to be either hexagonal wurtzite or cubic zinc-blende, differing only in the stacking of hexagonal close packed planes. From the data (not shown) we deduce that for the used growth conditions, NW growth starts with a large amount of wurtzite phase units separated by stacking faults whereas at later times growth occurs mainly in the (bulk) zinc-blende phase units of GaAs. Compared to the zinc-blende phase, the wurtzite phase always show a slightly larger vertical lattice spacing.

Using the focused x-ray beam, diffraction patterns of single NWs could be obtained. Figure 2 shows an example of reciprocal space maps around the symmetric (111) reflection. As this reflection only depends on the vertical lattice spacing, it is allowed for both zinc-blende and wurtzite type structures. Whereas the ensemble average (left) shows a broad Brag peak at the GaAs position, thickness fringes and a strong variation in peak position can be observed for single NWs (right). In particular, the intensity distributions from single wires show a pronounced strain effect, visible in an asymmetry of the diffraction peaks along q_z, shown in the upper panel in figure 3. Based on simulation the data could be fitted by a vertical displacement field within the nanowire (solid lines in fig. 3) revealing the appearance of a vertical strain gradient at the NW - substrate interface.

Similar measurements could be performed at the asymmetric GaAs (331) reflection which is only sensitive to the zinc-blende phase units within the nanowire. Examples of the intensity distribution of single NWs along q_z at this reflection are shown in the lower panel in fig. 3 together with simulations. Preliminary analysis shows that compared to the complete NW including all stacking faults and wurtzite phases, the pure zinc-blende part of the wire shows a smaller residual strain.

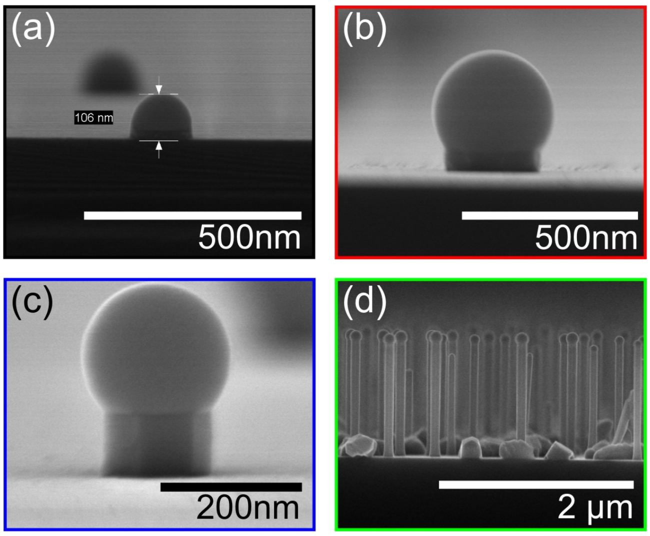

Figure 1 SEM pictures of the inspected nanowires at different stages of growth. Whereas only Ga droplets are seen after 60s (a), the wires are up to 2 µm long after 1800s (d). Their diameter is around 80nm.

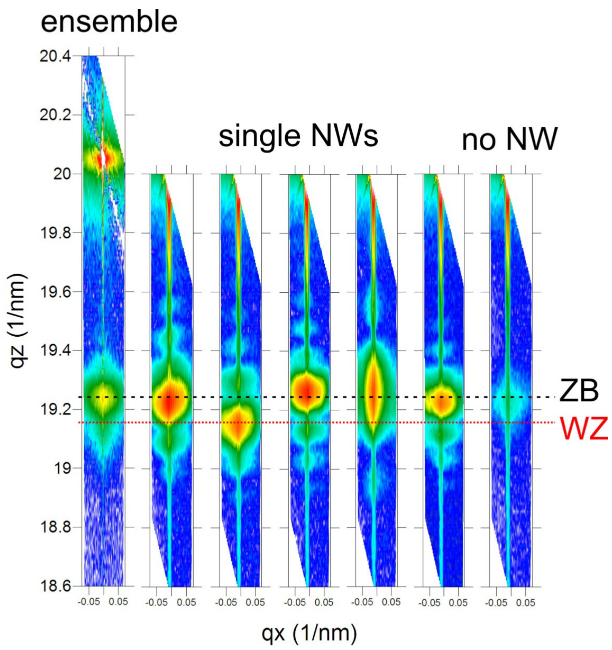

Figure 2: Reciprocal space maps around the GaAs (111) reflection from the medium hight NWs. left: Ensemble measurement,the GaAs reflection is a superposition of both ZB and WZ lattice parameters. right: measurements on single NWs with a focussed x-ray beam. NWs lattice parameters fluctuate around the average values.

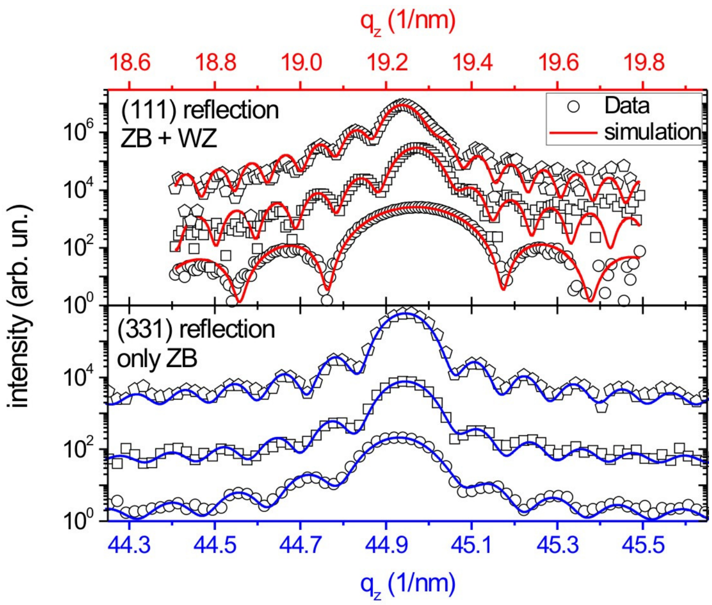

Figure 3 Intensity distribution along the qz direction (∥ [111]) of single NWs at a reflection measuring the whole NW (top) or only the zinc-blende portion (bottom), showing a reduction in size.