Strain engineering in core/shell nanowires

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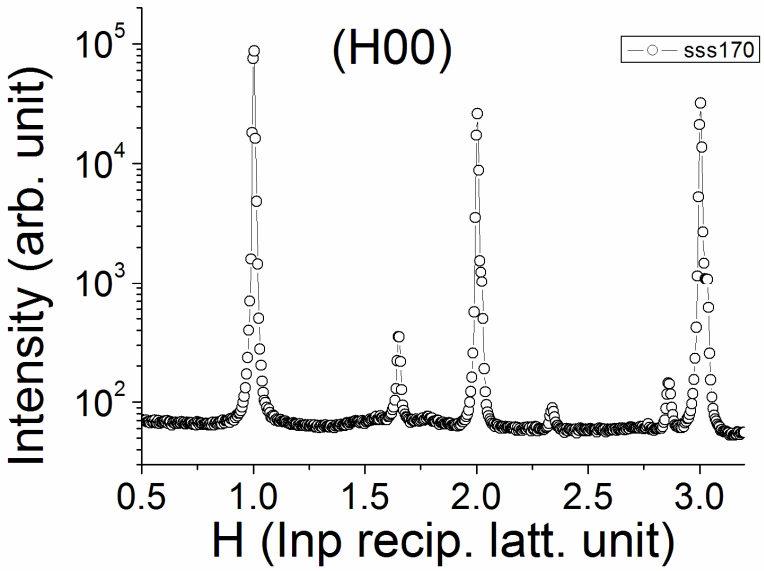
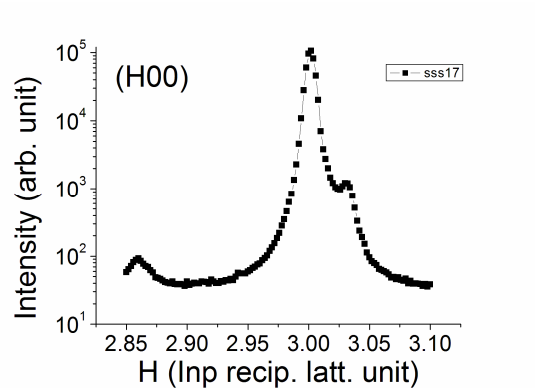
The expected results of the SI1838 proposal will be reported point by point:

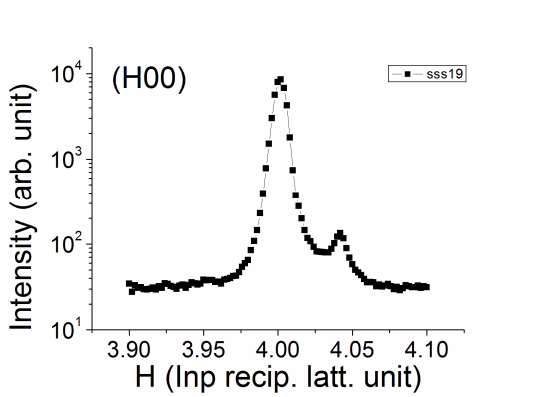
- Measurement of the strain in core/shell NW transistor and during the integration process. Estimation of growth-related defects.
A sample (called 1991A) with InAs/ InAsP (thin shell) / Al2O3 epitaxial nanowires grown on InP (111) has been measure by X-ray diffraction, both in-plane and out-of-plane.
In the plane, the InAsP shell can be clearly separated from the InAs core as shown in the following measurements.



*In-plane (H00) measurement. The peak indexation is in agreement with the paper . J. Eymery, F. Rieutord, V. Favre-Nicolin, L. Fröberg, T. Mårtensson, L. Samuelson. Nano Letters **7** (9), 2596 (2007).*

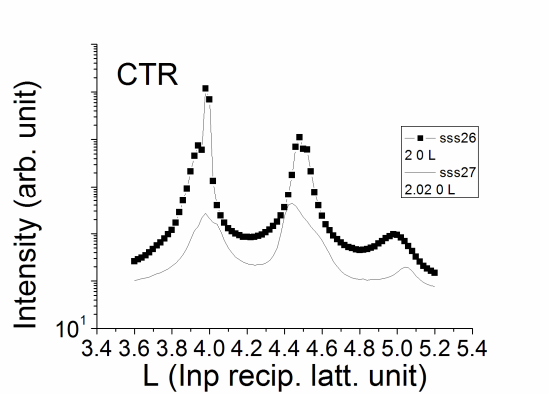


(300) peak measured with respect to the InP(111) substrate.

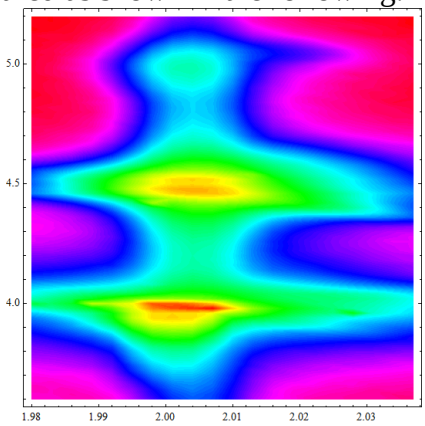


(*400) peak. The right contribution corresponds to InAsP shell.*

The crystal truncation rods (CTRs) have been also measured as shown in the following:



(2 0 L) crystal truncation rod measurement from two in-plane positions (see the figure at the right).



Reciprocal space mapping around the (20L) position.

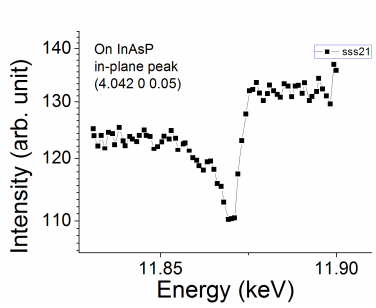
- Comparison between atomistic calculations (tight-binding calculation or simpler analytical models) giving intrinsic strain relaxation due to the nanostructure geometry and measurements giving an estimation of the structural defects (strain distribution between the different NWs).

The strain of the shell will be compared to simple calculations (as described in . J. Eymery, V. Favre-Nicolin, L. Fröberg, L. Samuelson. Appl. Phys. Lett. **94** (2009) 131911) and also to atomistic calculations taking into account the InAsP alloy at a given composition. These results will be compared to the anomalous measurements shown below.

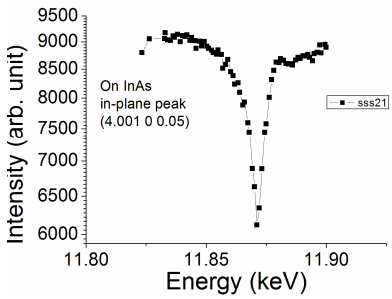
In this run, we had only one large enough sample to do the GIXRD measurements. So, we were not able to explore the process parameters and the strain relaxation effects.

- Eventually, estimation of interdiffusion with anomalous scattering in order to refine growth conditions and physical properties.

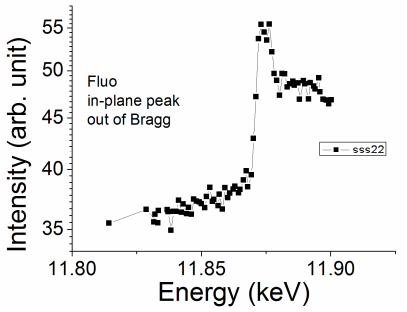
This beamline allows anomalous measurements at the As absorption edge. We select a nanowire in-plane reflection. Some examples are shown in the following figure.



Anomalous measurement on the InAsP (4.042 0 0.05) peak.



Anomalous measurement on the InAs (4.001 0 0.05) peak.



Anomalous measurement far from a diffraction peak (fluorescence measurement).

Quantitative analyses are presently under way to extract the P content in the InAsP signal.

- Complementarily with single object studies performed by electron microscopy and recently by X-rays with coherent diffraction (single insertions of InP in InAs NWs studied by our group at ESRF).

Up to now, no CDI has been performed on core/shell nanowire structures. It will be one objective of our next experiments.

- This type of experiment is very new (no published data, up to now), but also very general. For example, the Si shell / Ge core system (see Lieber's results in USA) is also a very good candidate to increase the mobility using this core/shell method. IBM (also a NODE partner) is strongly interested to explore this way. Therefore, depending on the remaining time and *substrate vailability* (epitaxy and positioning are not trivial), it could be very interesting to perform preliminary test. The interdiffusion point will be crucial in this system and anomalous measurement could be recorded at the Ge-absorption edge.

Indeed, during this experiment we have also performed very similar measurements with longitudinal nanowire heterostructures:
(i) InSb/InAs insertion/InP nanowire on InP (111) (sample 1973)
(ii) InSb/InP nanowire on InP (111) (without InAs insertion) (sample 1845)

The basic idea was to study the InAs insertion with respect to a reference.
Nice results have been obtained with in-plane, crystal truncation rod and anomalous measurements. Reciprocal space mappings have also been recorded.

These experiments are very new and not completely analyzed, but they will probably be valorized in scientific publications soon. They give a new approach for the structural characterization of nanowires.