ESRF	**Experiment title:** Nanowires embedded into dielectric layers for multi-junction solar cells	**Experiment number**: MA-822
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Report:

We have investigated III-V nanowires for multi-junction solar cell applications. Several series of samples have been prepared by MOCVD in Lund, Sweden. Aim of the experiment was to evaluate the influence of a passivating oxide shell on the nanowire properties. Furthermore, we also continued a study on the influence on growth mode when the wires are doped. All samples are grown on Si(111) substrates, already the final target substrate to combine III-V solar cells with a Si solar cell. For each sample except AX2544#1, we had two pieces, with and without a SiO_2 deposition step to embed the wires. The nominal sample parameters are listed in Tab. I.

sample	growth sequence (µm)	comment/result
EP5734#1	In(Ga)P nucleation, long (In)GaP segment	statistical ensemble control on Ga/In amount in InGaP segments influence of oxide (strain)
EP5736#1	In(Ga)P nucleation, short InP section, Ga(In)P section and long InGaP section	
EP5738#1	same as EP5736#1 except 1.5× TMI flow for InGaP section	
EP5740#2	same as EP5736#1 except 2.25× TMI flow for InGaP section	
AX2347#1	ordered InP wires, n-doped	oxide strain? ZB/WZ amount
AX2349#1	ordered InP wires, p-doped	
AX2351#1	ordered InP wires, p^+-doped	
AX2451#1	ordered InP wires, p-i-n structure	
AX2544#1	ordered InP wires, p-i-n structure	with electrical contacts, has undergone electrical tests, measurement on/aside contact pads

Table I: nominal parameters of the investigated samples and issues to be clarified by XRD from the different series.

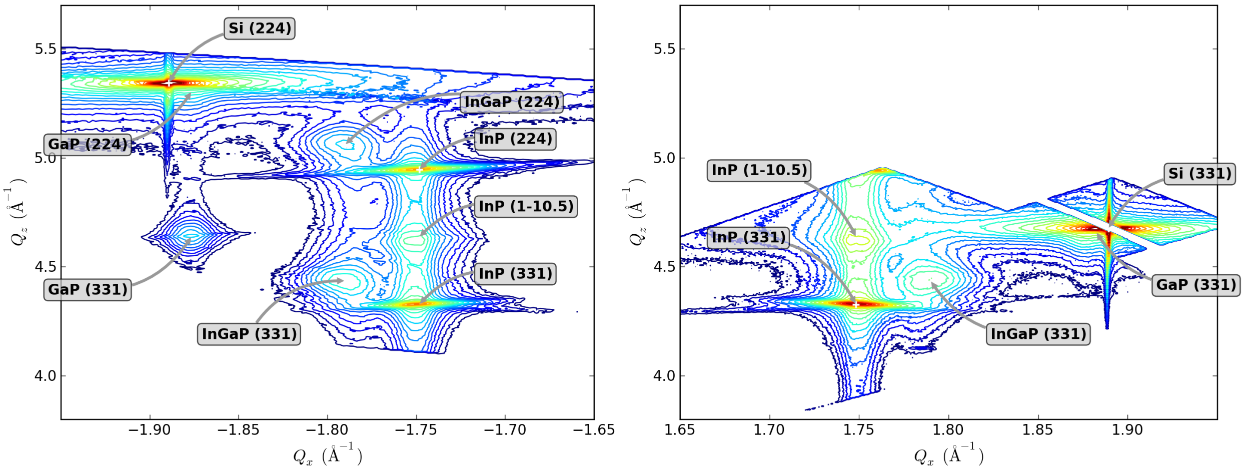

Fig. 1: Asymmetrical RSMs around InP nanowires grown on Si(111) and p-doped with Zn, in the as-grown state without oxide shell. While in the high incidence map (right) the GaP (331) peak is blurred by the Si(331) peak, on the low incidence side (left), the Si(331) is absent and GaP(331) position can be determined .

For the InGaP segments, one problem is that for high Ga content, the lattice parameter gets very similar to that of the substrate (Si: 5.431 Å, GaP: 5.451 Å), and the weak scattering from the nanowires is blurred by the substrate peak. This problem is circumvented exploiting the defect structure of nanowires: beside polytypism between zincblende (ZB) and wurtzite (WZ), stacking faults and twin planes occur, so that the ZB segments of the NWs exist both in the same orientation than the substrate, as well as with 180° rotation. In Fig. 1 reciprocal space maps (RSMs) over a rather large range in reciprocal space are shown, with the observed NW peaks indicated. The left panel shows the map recorded in low incidence geometry, the right panel those in high incidence geometry: changing the geometry has the same effect than rotating the sample azimuth by 180°. In both reflection, all peaks due to the different (twinned) NW segments can be seen, but on each side only the (224) or the (331) substrate reflection is present, so that in total all NW peaks can be measured without overlap with the substrate. From the measurements the WZ amount will be determined, and the lattice strains and In and Ga contents determined.

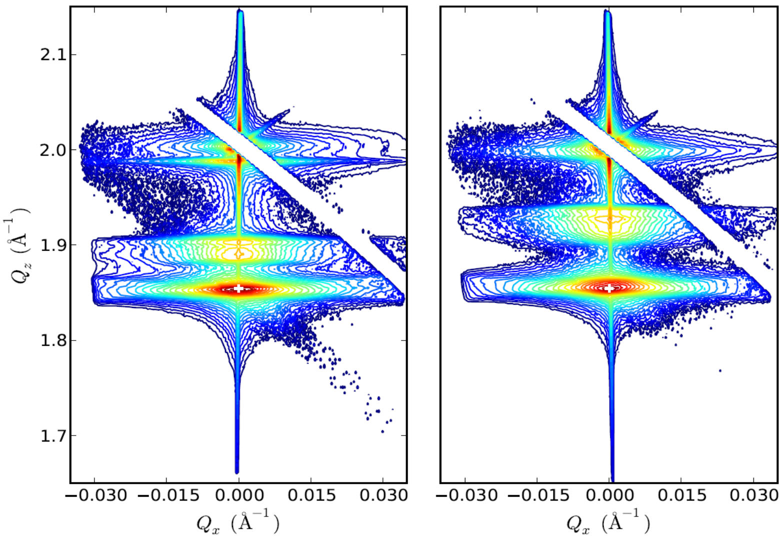

Fig. 2: (111) Bragg peaks of InP/InGaP/GaP heterostructure nanowires (EP5736#1) grown on Si(111), with (right) and without (left) a passivating SiO_2 shell. While the InP peak at Q_z=1.85 Å^{-1} shows only a slight shift due to the oxide shell, the multiple peaks due to InGaP around Q_z=1.9 Å^{-1} significantly shifts. Also the GaP peak at Q_z=1.98 Å^{-1} exhibits considerable shape change and slightly shifts in position.

Concerning the influence of the oxide shell, RSMs have been measured for the same samples before and after oxide deposition. An example is shown in Fig. 2. Obviously the peak positions especially of the InGaP segments shift considerably when the oxide is deposited, corresponding to rather unexpectedly large strain changes in these wires. Interestingly, this affects the shorter Ga(In)P sections much more than the longer Ga(In)P ones. The InP nucleation segment close to the substrate produces a rather “bulky” pyramid at the NW bottom, compared to the much thinner upper part of the NW, and is hence almost unaffected by the oxide shell.