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Report:

III-V nanowires are promising building blocks for improved photovoltaic elements, so-called multi-junction solar cells: the NWs can be grown on Si substrates, despite the large lattice mismatch and avoiding the problem of antiphase boundaries due to the small contact area with the substrate. The NWs have larger band gaps than the Si, so that the solar spectrum can be exploited better than in Si cells. However, for this concepts to work out, a good control of NW growth is mandatory. One particular issue is the possible change in growth mode when the wires are doped. This is necessary to achieve p-n junctions, but changes the growth chemistry and might change growth results considerably. We have therefore studied a series of NWs with different levels of p and n doping, grown in this case on InAs (111) substrates. The InP wires are p-doped with Zn. For nucleation, Au aerosol particles have been used. An SEM image of this sample is shown in Fig. 1.

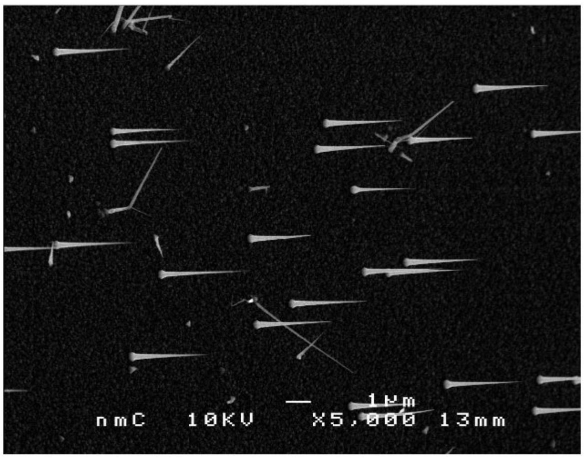

Fig. 1: InP nanowires grown on InAs(111) and p-doped with Zn.

In order to assess the wurtzite/zincblende ration, we have measured a set of grazing incidence diffraction reflections, namely the $(10\bar{1}0)$, $(20\bar{2}0)$, and $(30\bar{3}0)$ hexagonal peaks. The former two are allowed only in the hexagonal wurtzite structure, the latter is also allowed for the cubic zincblende structure, it corresponds to the cubic $(22\bar{4})$ reflection. From the intensity ratios, the wurtzite content as a function of doping has been evaluated. The results are summarized in Tab. I. Different values between about 5 and 35% have been found, however, the dependence on the growth conditions is not clear yet; certainly there is no simple relation to the type of doping or doping concentration.

sample	wire length (µm)	doping (dopant)	doping flux ×10^{-6} (molar fraction)	x_{wurtzite} (%)	x_{wurtzite} error (%)	comment
mb441	2	i	0	33.83	3.03	
mb442	2	p^- (Zn)	1	14.28	1.04	
mb444	3	p (Zn)	10	8.26	1.11	
mb445	5	p^+ (Zn)	30	4.59	0.24	
mb446	1	n^- (Sn)	1	8.48	5.51	
mb447	1.5	n (Sn)	10	24.28	3.04	
mb448	1	n (Sn)	10	30.36	3.70	no anneal

Table I: amount of wurtzite lattice for InP nanowires with different doping levels.

In addition, high-resolution reciprocal space maps have been recorded in coplanar geometry, see Fig. 2. Here, beside the InP NW peak and the substrate peak, a third reflection was detected, corresponding to interdiffused material. Here it is not completely clear, where the intermixed material is located on the sample. One possibility is that the rather thick “foot” regions of the wires contains different materials than the wires themselves. That the latter are composed of pure InP is rather clear from the fact that the InP on the sample is completely relaxed, while the intermixed material is only partially relaxed; due to the high aspect ratio, the wires relax completely according to finite element simulations, so that we assign the partially relaxed material to the more compact wire base with a low aspect ratio.

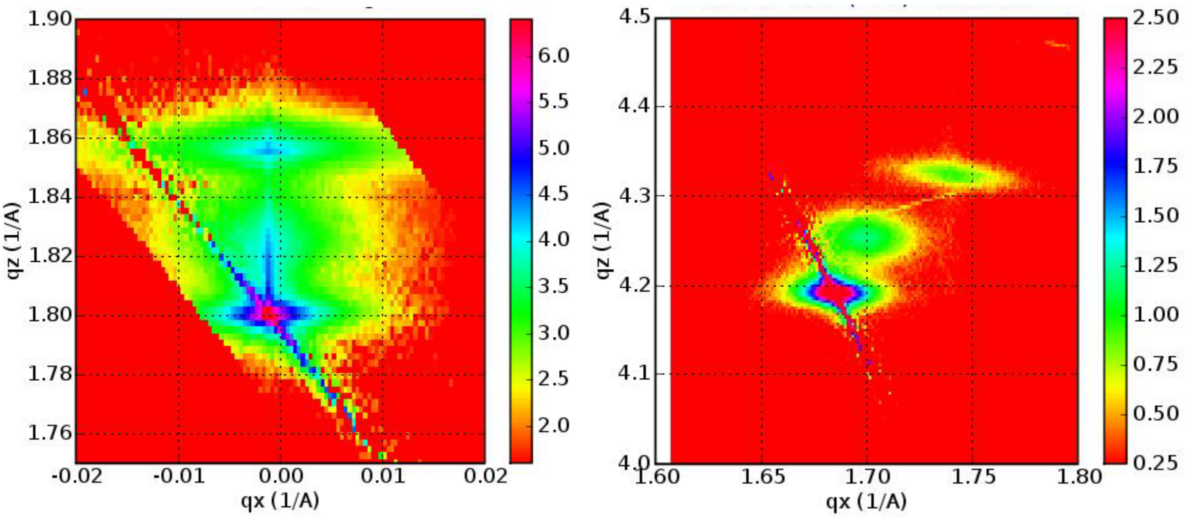

Fig. 2: symmetric (111) (left) and asymmetrical (331) (right) reciprocal space maps showing beside the InAs susbtrate peak (lower left) and the peak from relaxed InP (top right) a third reflection, corresponding to partially relaxed, intermixed material.