Three-dimensional mapping of the strain anisotropy in self- assembled quantum-wires by grazing incidence x-ray diffraction

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Introduction

The strain distribution is one of the significant factors that determine the shape, size, and facet formation in self-assembled nanostructures obtained from strained heteroepitaxial growth. For coherently strained islands, the continuous variation of the lattice parameter inside the nanostructure (from bottom to top) makes it energetically stable against the formation of a uniform (flat) strained layer. In this work, we report the study of strain distribution of InAs self-assembled nanowires on an InP(001) substrate

Methods and Materials

InAs self-assembled nanowires were grown by chemical beam epitaxy [1] on (001) InP substrates, misoriented by 2° toward [011]. Grazing incidence X-ray diffration (GID)was used to map the strain distribution both parallel and perpendicular to the wire directions [2].

Results

We have mapped three different X-ray reflections to be able to reconstruct the cristalline structure of thes ewires. We first maped both the 220 and -220 reflection and determined the relationship between wire size and lattice parameter measureing angular scanns at a fixed 2θ angle [3]. However, our InAs nanowires are very asymmetric in shape and exhibit significant strain anisotropy. In this case, two problems are encountered: (i) we cannot determine the length of the wires since the lower measurable full width at half maximum (FWHM) of the angular scans is limited by experimental error and (ii) the assumption of iso-strain planes parallel to the substrate surface for each value of *z*cannot be made, and must be extended to the case in which the in-plane lattice constants are different due to anisotropic strain relaxation. To solve these problems, we found a relationship between the interatomic distances along [220] and [-220] directions (*d*220 and *d*–220, respectively) using the (004) reflection (see fig. 1).

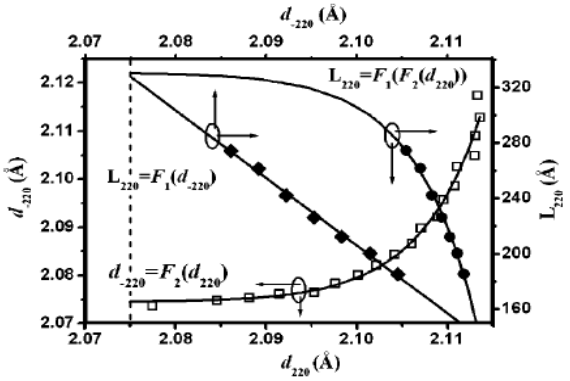

Fig.1. Relationship between lattice spacings and wire size in different crystallographic directions[2].

Discussion

RHEED and HRTEM (fig.2a) results have shown that the InAs nanowires present (114) and (−1−14) facets parallel to the (−220) direction. Taking in account the shape of the wire cross section and the average base width measured by GID, we obtained a direct relationship between the strain and the height of the nanowire. Figure 2(b) shows the strain maps of the wires along directions [220] and [−220]. Clearly there is a much larger strain relaxation across the wires than along them, as expected. The large relaxation of the elastic energy across the wires could justify the formation of these strained nanostructures instead of a flat and strained InAs layer. In summary, we have studied the strain relaxation of self assembled InAs/InPs001d nanowires using grazing incidence x-ray diffraction. A remarkable strain anisotropy was observed and quantified by mapping out the x-ray intensity near reciprocal lattice points of the substrate in two crystalline directions parallel to the substrate surface.

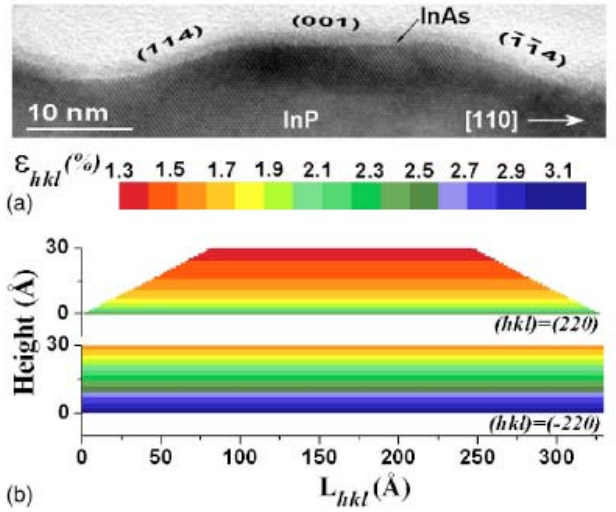

Fig.2. Comparison between TEM measuremetns of the wires (2a) and the strain results obtained from grazing incidence X-ray diffration from the same wires (2b) [2].

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