MS-8-P-2675 Investigation of GaAs/AlGaAs heterostructure core-shell nanowires by aberration corrected STEM

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Recently high quality GaAs/AlGaAs quantum well heterostructures based on core multishell nanowires were fabricated by metal organic vapour phase epitaxy (MOCVD) [1]. The nanowires show excellent optical properties including extremely high quantum efficiency, intense emission for extremely low submicrowatt excitation. Calculations suggest that the optical properties depend critically on the morphology and composition of the GaAs quantum wells [1]. In order to fully understand the structure-property relationship and to optimize the growth process, it is necessary to determine the local atomic arrangement and composition with high spatial resolution. In this work we use aberration corrected scanning transmission electron microscopy (STEM) to investigate the cross-sectional structure and morphology of the nanowires [2]. Several structural features, including the width of the quantum well were found to have a 3-fold rotational symmetry about the <111> growth axis. By using atomic resolution high angle annular dark field (HAADF) STEM, the crystal polarity was determined directly from the asymmetric intensity distribution in the dumbbell structure along the [110] projection and further linked to the three-fold symmetry of the heterostructure morphology about the nanowire growth axis. These results indicate that the two-dimensional vapour-solid (VS) growth of the nanowire multishells depends strongly on the polarity of the nanowire sidewall facets, which determine the surface energies and surface reconstruction of the facets, and hence driving the anisotropic growth of the heterostructures [2].

The aluminium composition of GaAs/AlGaAs heterostructures was measured by quantitative HAADF-STEM. The intensity of HAADF images was normalized to the incident beam intensity and transferred to an absolute scale to compare with simulated HAADF image intensities. The STEM simulation uses multislice calculations incorporating thermal diffuse scattering via a frozen phonon approach. By comparing the simulated electrons intensity with the experimental results, the HAADF-STEM images were translated into aluminium composition maps with high spatial resolution as shown in Fig. 2 [3].


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Fig. 1: HAADF-STEM image of an AlGaAs/GaAs nanowire cross-section viewed along the (111) direction. Several morphological features, including the different thickness of the AlGaAs rich bands, the different size of the corners of AlGaAs QW as well as the GaAs cap layer and the tapered GaAs QW, all show three-fold rotational symmetry around the growth axis.

Fig. 2: (a) High resolution STEM-HAADF image of GaAs/AlGaAs quantum well heterostructures and (b) the corresponding Al composition mapping by quantitative STEM.