Growth approaches for GaAs/(Al,Ga)As core-shell nanowires in molecular beam epitaxy and their impact on the luminescence

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Nanowires enable the epitaxial combination of dissimilar materials, because strain induced by lattice mismatch can elastically relax at the free nanowire sidewalls. Thus, the formation of dislocations that exist in analogous planar samples can be avoided. Possibly the technologically most important implementation of this conceptual advantage is the monolithic integration of III-V semiconductors on Si, which could lead to the integration of III-V optoelectronic devices on the mature Si platform. In this framework, the growth of GaAs nanowires on Si can be considered the prototypical example.

GaAs nanowires can be grown by molecular beam epitaxy (MBE) in the self-assisted vapor-liquid-solid mode on Si substrates covered by an oxide layer [1-3]. However, the luminescence efficiency of these structures suffers from the high surface recombination velocity of GaAs. Therefore, surface passivation is necessary and epitaxial (Al,Ga)As shells were grown which exhibit interfaces of highest quality and minimal strain. In this study we discuss two different approaches for the growth of (Al,Ga)As shells and their effect on the energy and intensity of radiative transitions as observed by photoluminescence (PL) and cathodoluminescence (CL) spectroscopy:

(1) After growth of the GaAs core, the liquid Ga droplet is crystallized under a high As flux. Then an (Al,Ga)As shell is grown at growth conditions that correspond to optimized growth of planar heterostructures. At 10 K the nanowire PL spectra exhibit transitions lying at energies significantly above the GaAs bandgap. These transitions become more prominent with increasing growth temperature, which we attribute to compositional fluctuations in the (Al,Ga)As shell [4]. Low temperature CL experiments show that the luminescence intensity and peak energy from the GaAs core is constant over the nanowire length.

(2) After growth of the GaAs core, a shell is grown by supplying Al without any previous interruption of the Ga and As fluxes. The lower diffusivity of Al on the nanowire sidewalls then enables the radial growth of (Al,Ga)As [3,5]. At 10 K the PL spectra for these samples also exhibit high energy transitions lying above the GaAs bandgap. CL line scans show that in contrast to the samples grown with approach (1) there are two distinct segments with different emission energies, where the high energy luminescence is coming from the upper half of the wire. In addition, scanning electron micrographs indicate that the upper segment forms during shell growth. These results suggest that the supply of Al leads to the growth of an (Al,Ga)As shell and continued VLS growth of an (Al,Ga)As segment.

These results show that the growth of an (Al,Ga)As shell without crystallizing the Ga droplet may lead to undesired axial segments of the nanowire.

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