Monolayer splitting for InAs/GaAs quantum dots

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InAs/GaAs quantum dots (QDs) with well−defined shape and composition have been grown in MOCVD using the alternative precursor tertiarybutylarsine. Low−excitation photoluminescence spectra of such QD layers, recorded at low temperature, exhibit a series of clearly separated peaks (figure 1). It is concluded from photoluminescence excitation spectroscopy that these peaks originate from a multimodal distribution of QD ground state transition energies. The different peaks are assigned to ground state transitions in QDs for which the heights differ by integer numbers of atomic monolayers. The pronounced monolayer splitting indicates clearly defined planar upper and lower interfaces between QDs and matrix. Eight−band k·p calculations suggest that the QD height varies between 4 and 10 ML, and correspondingly that the aspect ratio of the QDs is low.

The observed monolayer splitting provides access to the microscopic structure of QD ensembles and thus allows keeping track of the variation of the structural distribution resulting from changes of the growth parameters. It was found, for example, that upon antimony supply during a short growth interruption after the deposition of the QD material, the number of peaks on the low−energy side of the transition multiplet increases, indicating the formation of larger QDs. This finding is discussed in view of surfactant−like properties of antimony, lowering the surface energy and thus favouring the formation of larger QDs (figure 2).

Furthermore, the temporal evolution of the island formation was studied by variation of the growth interruption after the deposition of the QD material. With increasing duration of the growth interruption, the mean transition energy of the QDs shifts to lower energies, and the peak multiplet disappears (figure 3). The disappearance is ascribed to an increase of the QD aspect ratio, leading to a larger impact of lateral carrier confinement, so that the distribution of QD lateral sizes starts to broaden the QD transition lines.

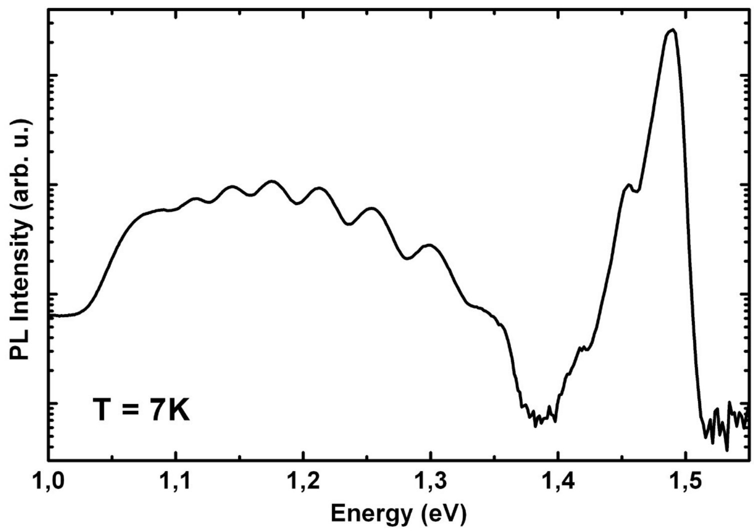

Figure 1) Low temperature PL spectra of QD sample, recorded at low excitation density. Eight peaks can be distinguished.

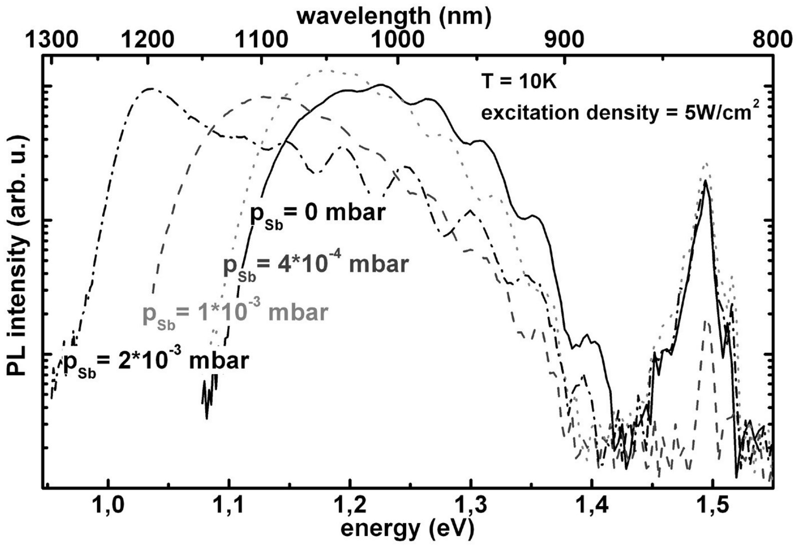

Figure 2) PL spectra of InAs QDs with different Sb−flux during 5s growing interruption, recorded at 10K with low excitation density.

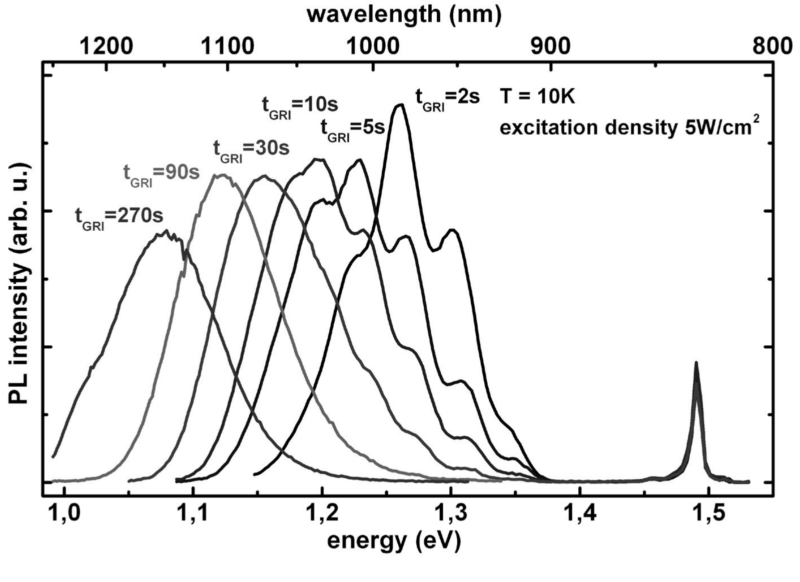

Figure 3) PL spectra of InAs QDs with different durations of growing interruption after depositing QD−layer, recorded at 10K with low excitation density. For longer growing interruption maxima at lower energies appear, maxima at higher energy disappear.