GaAs single quantum dot embedded into AlGaAs nanowire

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We report on study of the photoluminescence spectra (PL) taken from quasi one-dimensional and quasi zero-dimensional semiconductor heterostructures. The structures were grown by molecular-beam epitaxy in (111) direction and are cylindrical nanowires based on $Al_{0.3}Ga_{0.7}As$, of 20 – 50 nm in diameter and 0.5 – 1 mkm in length. Inside the nanowires there were one or two GaAs quantum dots, of 2 nm thick and 20 – 50 nm in diameter. We studied a single nanowire, several (3 - 4) nanowires and arrays of many nanowires as well. The PL spectra were registered as a function of the intensity of optical excitation and external magnetic fields.

In the spectra of the array of nanowires we observed two PL bands extending from 1.8 to 1.95 eV and from 1.65 to 1.8 eV. These bands are connected with carrier recombination in a large array of nanowires and quantum dots respectively. In the PL spectra of several nanowires in these spectral ranges we observe several irregular distributed very sharp lines. The line-width of these lines was lower than our spectral resolution.

In the spectra of a single nanowire at very low optical excitation we observed a doublet of very narrow lines which should be related to recombination processes in a single quantum dot. We relate these lines to the annihilation of exciton and biexciton in a single dot. The biexciton binding energy has been found to be ~ 8 meV. The validity of the interpretation of this line as the biexciton recombination is supported by intensity dependence of these spectra and by calculation of the biexciton binding energy.

The intensity of the exciton and biexciton lines saturates at very small excitation densities (<10 mkW/cm^2). Biexciton line intensity grows superlinearly at low excitation densites, and at further increase of the excitation intensity all lines in this spectrum are saturate, at very higher excitation intensity (> 1 mW/cm^2) all lines begin to broaden. In several samples a line of trion recombination in the quantum dot was observed at nearly 1 meV below the exciton line. In magnetic fields we observed diamagnetic shift of all the lines and their Zeeman splitting. The biexciton line shows a fine structure.

At very small excitation intensities in the structures containing two quantum dots, we observed spontaneous jumps of the exciton PL line position. The magnitude of the jumps reached ±0.5 meV. As the intensity of the excitation increases the frequency of the jumps increases, and at sufficiently high excitation intensities these jumps manifested as a broadening of the exciton line.

Additionally, we observed a linear polarization of the exciton emission line in (110) direction that reaches 30-50%. The nature of this polarization is puzzling, since the spectra were observed in the (111) direction. We discuss the possible causes of the effect, including spontaneous deformation of the nanowires and giant piezoelectric effect.