Spin relaxation of neutral excitons in InAs/AlAs QDs: effect of the dot size

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Abstract

Investigation of long spin relaxation times of excitons in quantum dots (QDs) is often limited by relatively short (of few nanoseconds) exciton recombination. This problem can be solved in (In,Al)As/AlAs QDs where the type-I band alignment is combined with the indirect band gap (electron belongs to X valley). In these QDs the exciton lifetime reaches several hundreds of microseconds. Here, we present the direct experimental measurements of the long exciton spin relaxation time in these QDs. Spin relaxation was studied by analysis of the longitudinal magnetic-field-induced circular polarization degree of photoluminescence (PL), ρ_c. Since the shape of the PL emission (Fig.1a) reflects the distribution of QD sizes, different detection energies provides information on the exciton recombination in QDs with different characteristic sizes in the ensemble.

Spin relaxation time is evaluated from the evolution of ρ_c calculated from dynamics of σ^+ and σ^- circular polarized PL, as shown in Figs. 1(b) and 1(c). In all QDs the dynamics have common feature - almost constant polarization degree of 0.20 (20%) immediately after the excitation pulse up to approximately 1 μs that is a result of hot electron spin relaxation in AlAs matrix before capture in QDs. However for times >1 μs $\rho_c(t)$ unexpectedly transforms qualitatively with QD size ($\rho_c(t)$ monotonically rises with saturation for small QDs and $\rho_c(t)$ changes nonmonotonically for large QDs), while the sign of longitudinal exciton g factor measured by spin-flip Raman scattering technique does not change. Thus, the relaxation process cannot be described by a single spin lifetime, and a four-level system with states of bright and dark excitons has to be taken into account. Mechanisms responsible for the exciton spin relaxation in different size QDs will be discussed.

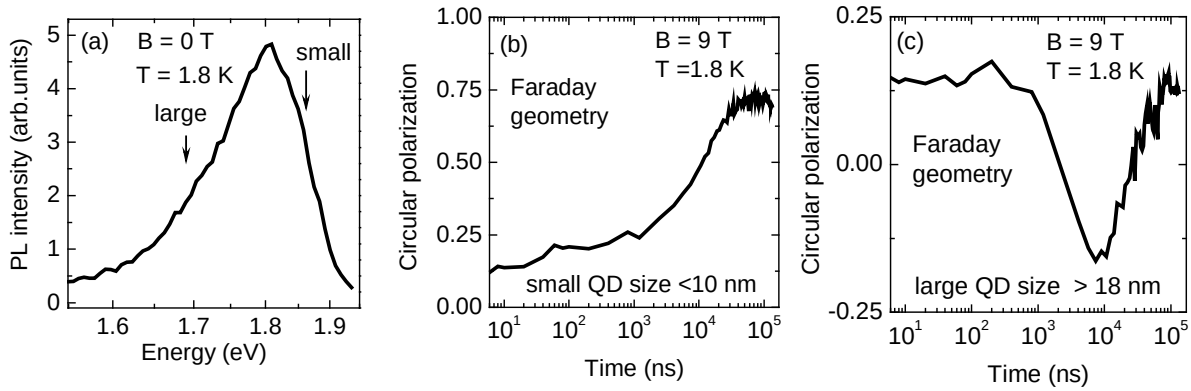

Figure 1. Photoluminescence spectrum of QDs (a) and ρ_c dynamics for QDs with small (b) and large (c) sizes.