Dynamics of spin-tunneling and -injection in coupled quantum dots of InGaAs with a quantum well

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Recently, an increasing interest has been attracted on tunnel-injection phenomena between a coupled QW and QDs system, where the barrier-thickness dependence of the carrier-injection dynamics on tunneling between the InGaAs QW and In(Ga)As QDs has been discussed [1]. However, the barrier-thickness dependence of spin-tunneling and spin-injection processes in these coupled nanostructures is still not well examined and understood. Therefore, we study the optical spin-injection dynamics as a function of thickness of the tunneling barrier in coupled quantum structures of 0-dimensional (0-D) InGaAs QDs with a 2-D InGaAs QW.

The coupled QW-QDs structures, which include a 20 nm-thick In$_{0.1}$Ga$_{0.9}$As QW and In$_{0.5}$Ga$_{0.5}$As QDs with 6 monolayers, were grown by molecular beam epitaxy. The spin-injection dynamics of spin-polarized carriers in the coupled QW-QDs structures was investigated by time-resolved photoluminescence (TRPL) spectra under circularly polarized excitation selectively for the QW and simulated using rate equations. Fig.1 shows the typical circularly polarized PL spectra of the coupled QW-QDs structure. The tunneling time increases while spin polarization significantly decreases with increasing the thickness of barrier between QW and QDs (Fig.2). The strongly coupled QW-QDs structures with 2-5 nm-thick barriers exhibit short tunneling times of 50-60 ps and the average degree of circular polarization around 50% in the QW and 30% at the excited state in the QDs. The fast and efficient injection of spin-polarized carriers via the tunneling process from the QW into QDs implies a promising application for semiconductor-based spintronic devices.