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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.

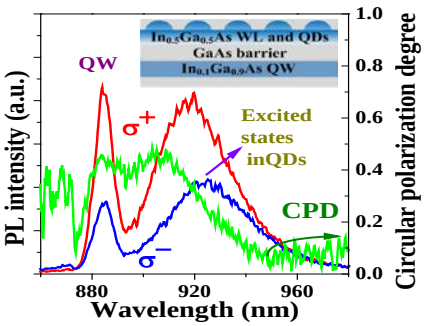

Fig.1 PL spectra and the circular polarization degree of the coupled InGaAs QW-QDs structure with the 5 nm-thick barrier under circularly polarized and pulsed excitation at 20 K. Solid lines are rate equation calculations

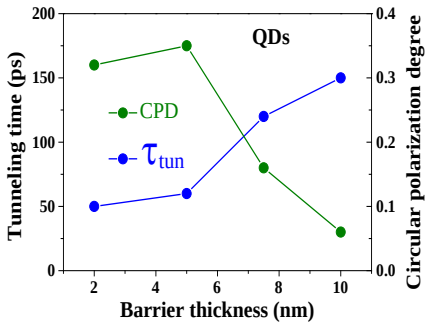

Fig.2 Barrier thickness dependences of the spin-tunneling time and the circular polarization degree (CPD) of PL at excited states in QDs

[1] M. Syperek et al, Appl. Phys. Lett. 96, 011901 (2010)