Electric-field control of spin transport property into InGaAs quantum dots from a tunnel-coupled quantum well

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Remarkable advances of self-assembled semiconductor quantum dots (QDs) have been received significant attention as an ideal platform for strong confinements of the electronic and spin states. InGaAs-based QD-quantum well (QW) tunnel-coupled structures have been proposed to capture electron spin efficiently in layered device structures [1,2]. In this research, external electric-field effects on spin injection of optically excited carriers in a QW into QDs are investigated. Spin-polarized electrons and holes in the QW are injected into the QDs through a GaAs barrier layer. We report time-resolved circularly polarized photoluminescence (PL) from QDs after optical generation of spins in the QW as a function of applied electrical field.

A QD-QW coupled sample composed of a 20 nm-thick $In_{0.1}Ga_{0.9}As$ QW with a 4 nm-thick GaAs barrier and an $In_{0.5}Ga_{0.5}As$ QD layer sandwiched by AlGaAs barrier layers were grown on (001) a *p*-GaAs substrate by using molecular beam epitaxy. The top AlGaAs layer was capped with a GaAs layer on which Ti/Au electrode was deposited. Growth conditions for QD layers were discussed in our previous work [1]. We estimated the areal QD density as 5.5×10^{10} cm^{-2} based on our SEM analysis. A mode-locked Ti: Sapphire laser with a wavelength of 840 nm was used as an excitation source, which energy was tuned just above the bandgap of QW. The circular polarization characteristics of PL were discriminated by using a circular polarizer, and spin dynamics was studied by using time-dependence circular polarization degree (CPD) at 4 K. Here, we calculated the CPD, i.e., CPD = $(I_{\sigma+} - I_{\sigma-}) / (I_{\sigma+} + I_{\sigma-})$, where $I_{\sigma+}$ and $I_{\sigma-}$ were σ^+ and σ^- polarized PL intensities with σ^+ excitation.

Figure 1 shows circular polarized transient PL and the corresponding CPD measured with the applied bias voltage of $V_b = 0$ (a) and 1.0 V. A drastic change of CPD polarity is observed depending on the bias voltages. At $V_b = 0$ V, significant negative (cross circular to the initial QW spin state) CPD values are developed up to −7% after 0.5 ns, while strong positive (co circular) ones are observed at $V_b = 1.0$ V and relax to be zero at 0.8 ns. The negative CPD can be explained by the negative trion formation with excess electrons in QDs [3], which can depend on V_b resulting from the different injection probabilities between the electron and hole in bias-dependent coupled QD-QW band diagram (shown as insets).

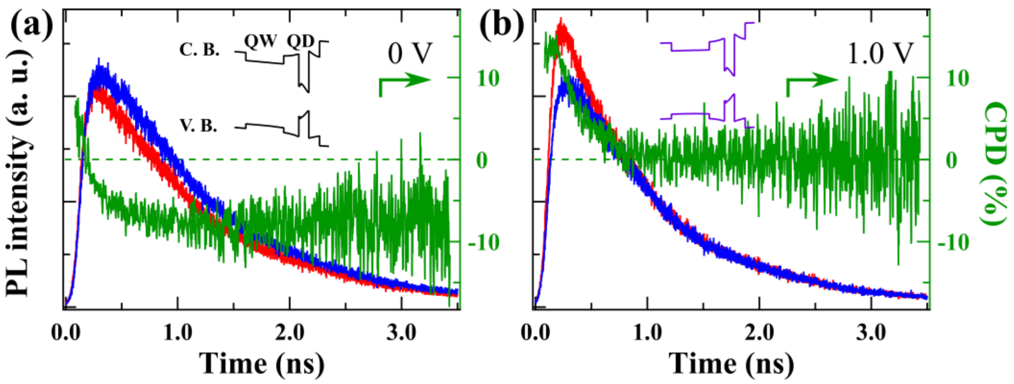

Fig. 1 Circularly polarized transient PL and the corresponding CPD vs time measured at 4 K with the bias voltages of (a) 0 V and (b) 1.0 V. The corresponding CPD is given as green lines. Three-dimensional calculations of band line-up are shown in the upper inset.

References:
[1] X. J. Yang et al., Appl. Phys. Lett. **104**, 012406 (2014).
[2] S. L. Chen et al., J. Appl. Phys. **119**, 115701 (2016).
[3] Y. Puttisong et al., Appl. Phys. Lett. **105**, 132106 (2014).