Temperature dependence of electron-spin polarization in InGaAs quantum dot opto-spintronic device applied with electric field

Faculty of Information Science and Technology, Hokkaido Univ.

○S. Park, S. Hiura, H. Chen, J. Takayama, K. Sueoka, and A. Murayama

E-mail: so_y_park.d6@elms.hokudai.ac.jp

In future optical information processing, photoelectric conversion with spin polarization of electron and photon is needed to realize opto-spintronic devices. III-V compound semiconductor quantum dots (QDs) have been expected as an optically active layer of these devices due to the suppressed carrier-spin relaxation by their strong quantum confinements. We have studied an electric field control of spin polarity in opto-spintronic devices using InGaAs QDs tunnel-coupled with a quantum well (QW) at low temperatures [1, 2]. The spin polarity during the spin injection from the QW into the QDs can be controlled by the direction and the strength of an external bias. At specific bias voltages, a large degree of negative spin polarization is obtained by an enhanced spin-flip scattering resulting from imbalance between electrons and holes injected into the QDs. However, at higher temperatures, thermal excitation and escape of carriers can affect the electron-spin polarization at QD emissive states [3]. In this study, we have focused on the temperature dependence of electron-spin polarization in InGaAs QD-QW tunnel-coupled nano-structures by applying an external bias voltage along the growth direction (z-axis), as shown in Figure 1(a).

Figures 1(b) and 1(c) show circularly polarized photoluminescence (PL) spectra of QDs at 40 and 120 K, respectively, with bias voltage of 0.2 V under σ^--polarized excitation of the GaAs barrier. Electron-spin polarization at QD emissive states corresponds to the circular polarization degree (CPD) of PL, and the CPD is defined as $(I_{\sigma-}-I_{\sigma+})/(I_{\sigma-}+I_{\sigma+})$ using circularly polarized PL intensity $I_{\sigma\pm}$. At 40 K, a negative CPD of about −10 % is observed at the QD ground state (GS). Around 0 V, the coupled QW/QD potential tilts slightly toward the QD side and then excess electron spins are injected into the QDs [1, 2]. In this case, the spin-flip scattering is enhanced due to the residual electron spins at the QD-GS. As a result, cross-circular PL increases, resulting in negative CPD [4]. By contrast, at 120 K, the negative CPD disappears at the QD-GS. This is probably due to the suppressed spin-flip scattering by thermal excitation of carrier spins.

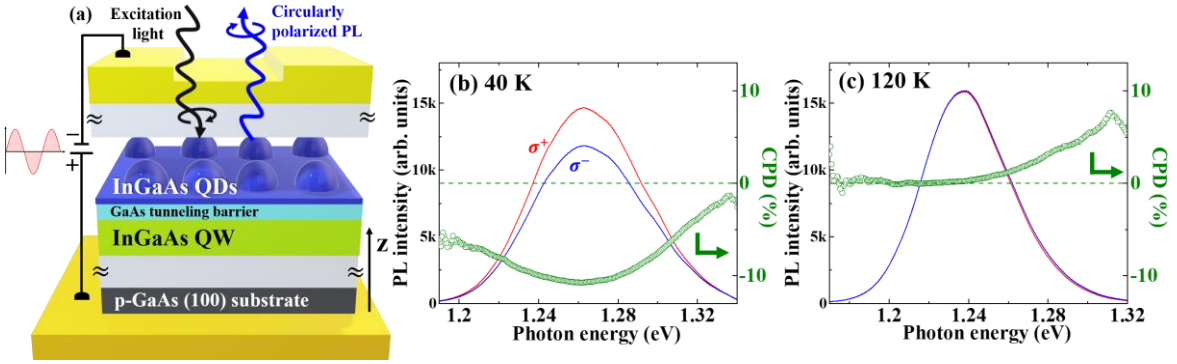

Fig. 1 (a) Schematic drawing of the electric-field-effect optical-spin device with QD/QW tunnel-coupled nanostructures. Circularly polarized PL spectra of InGaAs QDs (red line; cross-circular, blue line; co-circular polarization) and corresponding CPD (green circles) with an applied bias voltage of 0.2 V at (b) 40 K and (c) 120 K.

References:

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