Effect of growth conditions on carrier and spin lifetimes in (001) GaAs/AlGaAs quantum wells

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Spin-polarized light-emitting diode (spin-LED), which consists of a ferromagnetic (FM) contact and semiconductor quantum well (QW), is one of the important building blocks for future spin-optical devices such as spin laser [1]. So far, the FM contact has attracted much attention in order to achieve a highly circular-polarized electroluminescence (EL) from the spin-LED. However, it is also important to study carrier and spin dynamics in the QW part because the polarizability strongly depends on those properties [1]. In this study, we systematically investigated the effect of growth conditions on the carrier and the spin lifetimes in the (001) GaAs/AlGaAs QWs.

All the undoped samples, which consists of 20 periods of 10-nm-thick GaAs QW layers separated by 20-nm-thick $Al_{0.3}Ga_{0.7}As$ barriers, were grown on semi-insulating GaAs(001) substrates by molecular beam epitaxy (MBE) under the different V/III (As_4/Ga) flux ratios and growth temperature conditions. The carrier and the spin lifetimes were evaluated at room temperature (RT) by polarization- and time-resolved photoluminescence (PL) measurements. Mode-locked Ti: Sapphire laser and the streak camera were respectively used as the pump laser and the PL detector. Excitation wavelength of the pump laser was fixed at 780 nm to keep a constant value of the electron spin polarization (P_s) created in the QWs.

The measured carrier lifetimes (τ_c) and spin relaxation times (τ_s) at RT are summarized in Figs. 1(a) and 1(b), respectively. It should be noted that the carrier lifetime strongly depends on both the V/III ratio and the growth temperature (0.4-9 ns) whereas the spin relaxation time is almost constant at about 0.2 ns. These results suggest that the circular polarization of the PL (P_{PL}) is largely affected by the growth conditions because the P_{PL} is given by $\tau_s/(\tau_c + \tau_s)P_s$, where the P_s is constant in our measurements. As plotted in Fig. 1(c), the P_{PL} values depend considerably on growth conditions as expected from the obtained τ_c and τ_s values. Hence, choosing the appropriate growth condition of the QW part is indispensable to obtaining a high EL polarization from the spin-LED.

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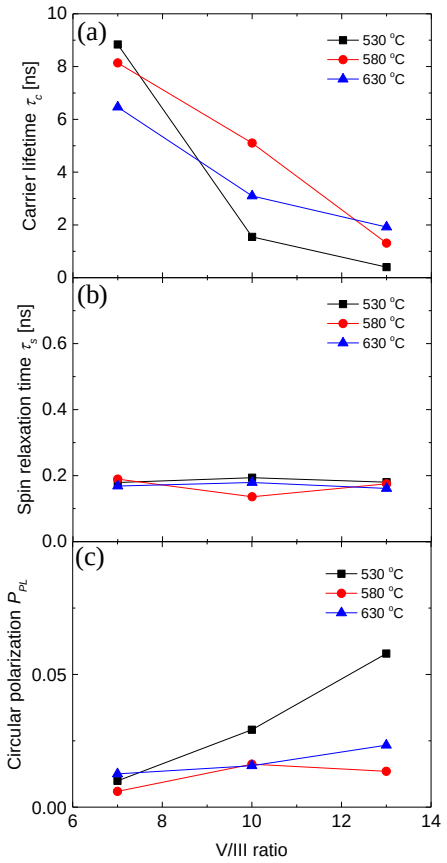

Figure 1(a) carrier lifetime (b) spin relaxation time (c) circular polarization of the PL at RT in (001) GaAs/AlGaAs QWs grown at different growth conditions.

Reference

[1] M. Holub and P. Bhattacharya, J. Phys. D: Appl. Phys. 40 R179 (2007).