GaSb/AlSb 多重量子井戸におけるスピン緩和時間の観測（Ⅲ）

Spin relaxation time of GaSb/AlSb multiple quantum wells (III)

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In recent years, antimony-based III–V semiconductor materials have attracted growing interests in the development of optoelectronics devices because the band gap is tunable to a 1.55 μm optical transmission system. Previously, we reported the spin relaxation of GaSb/AlSb multiple quantum wells (MQWs) with 48-nm-wide wells at 10-100 K. In this paper, we report the spin relaxation in two GaSb/AlSb MQWs at wider range of temperature, between 10 and 200 K, observed by time-resolved pump and probe reflection measurements [1].

The samples were grown on GaAs substrate by molecular beam epitaxy. Sample A has 25 periods of 48 nm thick GaSb quantum wells, and sample B has 10 periods of 13.4-nm-thick quantum wells.

A Ti-sapphire laser with an optical parametric oscillator was used as the optical source for a pump and probe measurements. To suppress the low-frequency optical noise, an electro-optic modulator was used with lock-in amplifier to induce 1.9 MHz optical intensity modulation into the pump beam. The excitation wavelength was adjusted between 1.48-1.53 μm at 10-200 K.

The time evolution of spin-dependent reflection intensity of sample A for the excitation power of 30 mW at 10 K is shown in Fig. 1. I^+ (I^-) corresponds to a right circularly polarized excitation with a right (left) circularly polarized probe. The abrupt signal changes at ±12 ps are due to the reflection at the back side of the substrate [2]. The inset of Fig. 1 shows the time transition of spin polarization, obtained by $(I^+ - I^-)/(I^+ + I^-)$. The spin relaxation time τ_s, which is twice the relaxation time of the spin polarization, of sample A is obtained to be 164 ps at 10 K using a single exponential fitting. The spin relaxation can be assigned to electron spin relaxation.

Figure 2 shows the temperatures dependences of the spin relaxation time of sample A (quantum confinement energy: E_{1e}=3 meV), sample B (E_{1e}= 28 meV) and InGaAs/InP MQWs (E_{1e}= 60 meV) which has the bandgap energy of 1.5 μm we measured before.

At higher temperature (77-200 K) in sample A, the spin relaxation time decreases depending on the temperature according to $T^{-2.07}$, which is stronger negative temperature dependence than that in sample B ($T^{-1.18}$) and InGaAs/InP MQWs ($T^{-0.67}$). This result explained by D'yakonov-Perel (DP) process through the thickness of the quantum well (QW) [3-5]. In bulk material and QW with lower E_{1e} than Boltzmann energy $k_B T$, the spin relaxation time scales as $\tau_p^{-1}T^{-3}$ (τ_p: momentum relaxation time). In QW with higher E_{1e}(> $k_B T$), the spin relaxation time is proportional to $\tau_p^{-1}T^{-1}E_{1e}^{-2}$. This difference of the two dependences due to DP process may contribute to the results.

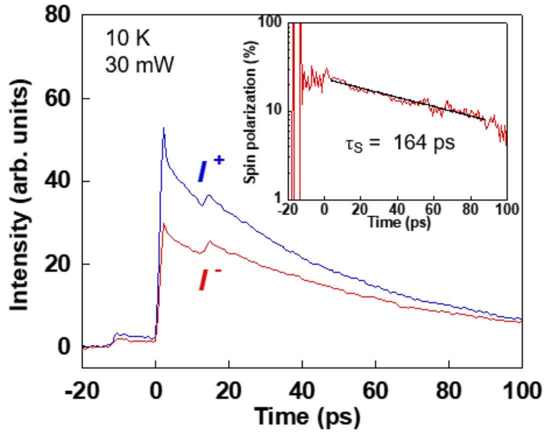

Fig.1 Time evolutions of spin-dependent reflection intensity for excitation power of 30 mW at 10 K in sample A. The inset shows the time evolutions of spin polarization.

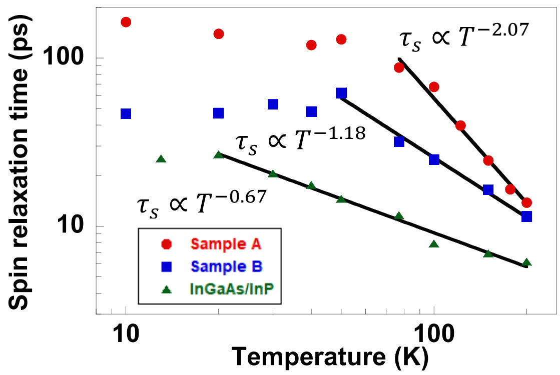

Fig. 2 Temperature dependences of the spin relaxation time for sample A (circle dots), sample B (square dots) and InGaAs/InP MQWs (triangle dots) at 30 mW.

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