GaAs/AlGaAs 共鳴トンネル双量子井戸におけるスピン緩和時間の温度依存性

Temperature dependence of spin relaxation time in GaAs/AlGaAs resonant tunneling bi-quantum-well

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The tunneling bi-quantum-well (TBQ) is a kind of coupled quantum well. Since the ground electron state energy in the narrow well is higher than that in the wide well, photoexcited electrons in the narrow well can tunnel to the wide well. This tunneling reduces the recovery time of the excitonic absorption. Under resonant tunneling condition, the further reduction of the tunneling time was reported.[1] In this study, we report the electron spin relaxation in GaAs/AlGaAs TBQ structures including resonant tunneling case.

The TBQ structures we studied consisted of 50 periods of narrow GaAs quantum wells, each 4.5 nm thick, and $Al_{0.51}Ga_{0.49}As$ barriers, each 4.0 nm thick, and wide GaAs quantum wells. We prepared four TBQ samples in which the thickness, L_w, of wide quantum wells is varied from 9.0 nm to 13.0 nm (Fig.1). From the absorption spectra of TBQ of L_w = 10.7 nm, the ground electron level, e1, in the narrow well and the second electron level in the wide well, e2, are considered to be resonant.[1] Therefore, the ground state in the narrow well is lower (higher) than the first excited state in the wide well for the sample of L_w < 10.7 nm (L_w > 10.7 nm). We also measured the spin relaxation of multiple quantum wells (MQW) which has 120 periods of 4.5 nm thick GaAs wells and 4.0 nm thick AlGaAs barriers. All structures were grown on a semi-insulating (100) GaAs substrate by molecular beam epitaxy. The spin relaxation times were measured by time-resolved spin-dependent pump and probe reflectance measurement.[2] A Ti-sapphire laser was used as the optical source for the pump and probe experiment. The time resolution in this system is sub-picosecond.

Figure 2 shows the time evolution of the reflection intensity for the sample of L_w = 10.7 nm at 15 K for an excitation power of 30 mW. I^+ and I^- indicate the cocircular and anticircular polarizations, respectively. The time evolution on the spin polarization is plotted in the inset of figure 2. We can observe the spin relaxation time of 6.2 ps by a single exponential fitting. Figure 3 shows temperature dependence of the spin relaxation time in narrow well. We observed the shorter spin relaxation in TBQ structures than that in MQW. Particularly, the spin relaxation time in the samples of L_w ≧ 10.7 nm are fastest. This result indicates that the spin relaxation in narrow wells is affected heavily by the tunneling between the ground state of narrow well and the first excited state of wide well.[3]

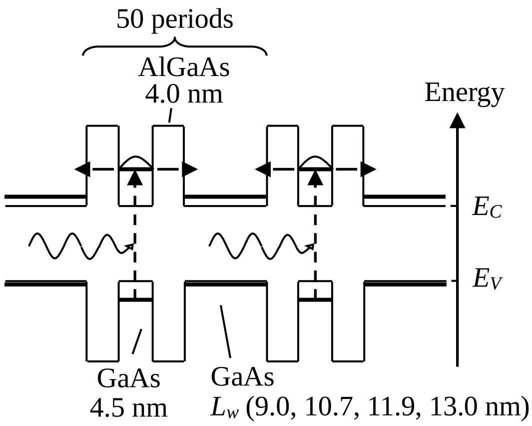

Fig.1 Energy band diagrams of the GaAs/AlGaAs tunneling bi-quantum-well.

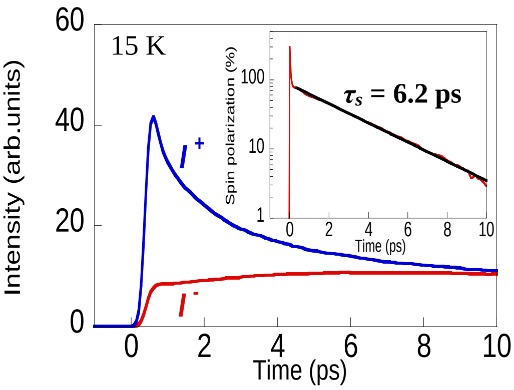

Fig.2 Time evolutions of cocircular (I^+) and anticircular (I^-) polarization at 15 K for the excitation power of 30 mW. The inset shows the time evolution of spin polarization.

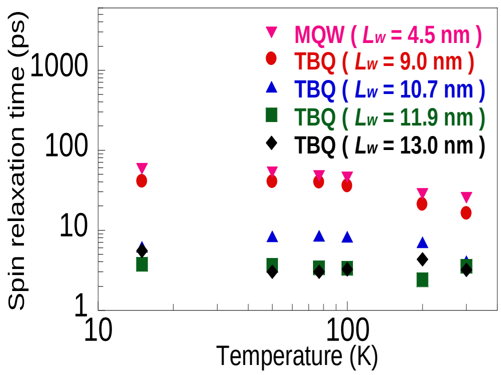

Fig.3 Temperature dependence of the spin relaxation time in narrow well.

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[3] H. Sasakura et al., Jpn. J. Appl. Phys. **43**, 2110 (2004).