Excitation power dependence of spin relaxation time in GaAs/AlGaAs/AlAs type-II tunneling bi-quantum wells

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The GaAs/AlGaAs/AlAs type-II tunneling bi-quantum well (TBQ) is composed of GaAs wells, AlGaAs barriers, and AlAs layers. The recovery time from excitonic absorption bleaching in the GaAs wells is governed by tunneling of electrons out of the wells through AlGaAs barriers into the X states in the AlAs layers. Comparing with GaAs/AlGaAs type-I TBQ, the absorption in type-II TBQ is reduced since the lowest direct transition energy in AlAs layers is larger than that of the GaAs wells. [1] The recovery time also can be made faster using thinner AlGaAs barriers.[1] Previously we have reported the temperature dependence of spin relaxation time in type-II TBQ sample.[2] In this study, we have investigated the excitation power dependence of spin relaxation time in GaAs/AlGaAs/AlAs type-II TBQ with different barrier thickness by time-resolved pump and probe measurements.

The investigated samples were grown on a GaAs substrate by molecular beam epitaxy. The structures of these samples consist of 50 periods of GaAs (2.8 nm)/$Al_{0.51}Ga_{0.49}As$ (L_b nm)/AlAs (7.1 nm) type-II TBQ, as shown in Fig. 1. The values of L_b nm in each sample were 4.0, 3.4 and 2.3 nm, respectively. Time-resolved spin-dependent pump and probe reflection measurement[3] was used for obtaining the spin relaxation time. The excitation wavelength was tuned to the energy between the ground state in GaAs well.

Figure 2 shows the results of time-resolved pump and probe reflection measurements of the sample of L_b = 4.0 nm, at 50 K with an excitation power of 30 mW. In the figure, I^+(I^-) indicates the time evolution of the down(up) spin polarization which is observed by co(anti)-circularly polarization of pump and probe pulse, respectively. The inset of Fig. 2 shows the temporal evolution of spin polarization, which is obtained by dividing the subtraction of I- from I^+ by the sum I^+ and I^-. The fast and slow components of spin relaxation time τ_{s1} and τ_{s2} are obtained to be 3 ps and 87 ps by double exponential fitting. These fast and slow spin relaxations can be attributed to the hole and electron spin relaxation, respectively.

Figure 3 shows the excitation power dependence of electron spin relaxation time in three type-II TBQ samples at 50 K. The negative excitation power dependence of spin relaxation time was observed only in sample with 4.0-nm-thick barriers. The tunneling time, evaluated from I^+ and I^-, were 8, 6 and 2 ps in 4.0-, 3.4- and 2.3-nm barriers samples, respectively. This dependence indicates that the contribution of the Bir-Aronov-Pikus (BAP) process[4] is suppressed with the decrease of the tunneling time. During the BAP process, electron spins flip by the exchange interaction between electrons and holes. However, in type-II TBQ, the number of remaining electrons in GaAs QWs decreases faster for the thinner barrier thickness, resulting in the suppression of BAP process.

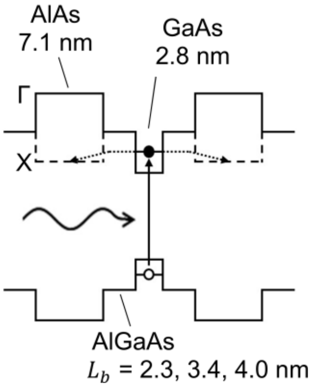

Fig. 1 Structure of energy band in the GaAs/AlGaAs/AlAs type-II tunneling bi-quantum wells.

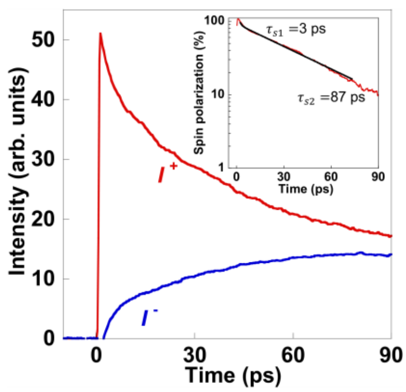

Fig. 2 Temporal evolutions of reflection intensity and (inset) spin polarization at 50 K, 30 mW in sample with 4.0-nm-thick barriers.

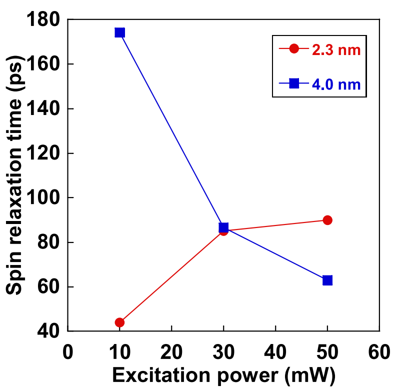

Fig. 3 Excitation power dependence of spin relaxation time in type-II TBQ samples at 50 K.

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