Hole spin relaxation in type-I tunneling biquantum well

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A GaAs/AlGaAs type-I tunneling biquantum well (TBQ) is composed of GaAs narrow quantum wells, AlGaAs barriers, and GaAs wide quantum wells. In type-I TBQs, the recovery time of excitonic absorption bleaching is reduced compared with conventional GaAs/AlGaAs multiple quantum wells (MQWs) because the excited electrons in GaAs narrow wells can tunnel to the GaAs wide quantum wells.[1] In this study, we investigated the hole spin relaxation time in type-I TBQs by time-resolved spin-dependent pump and probe reflectance measurement.[2]

The sample structure consisted of 50 periods of type-I TBQs with 4.5-nm-thick GaAs narrow quantum wells, AlGaAs barriers, and 9.0-nm-thick GaAs wide quantum wells grown on a GaAs substrate by molecular beam epitaxy. Three samples with different AlGaAs barrier thicknesses (from 2.8 to 4.0 nm) were studied. Time-resolved spin-dependent pump and probe reflectance measurement was conducted to measure the spin relaxation times of the samples. The wavelength was adjusted to the excitation energy of the ground state in the GaAs narrow quantum wells. The time resolution in the measurement was subpicosecond and determined by the optical pulse width.

Figure 1(a) shows the results of time-resolved pump and probe reflectance measurement of type-I TBQ with 4.0-nm-thick barriers at 15 K. The population change without spin polarization is indicated as cross-linear polarization. The population change with spin polarization is indicated as anti-circular polarization. Figure 1(b) shows the time evolution of spin polarization which is obtained by dividing the subtraction of anti-circular polarization from cross-linear polarization by cross-linear polarization. The spin relaxation exhibits triple exponential decay. The observed second and third spin relaxation components are attributed to electron in narrow wells, and electron in wide wells spin relaxation, respectively.[3] The observed first spin relaxation component is attributed to be hole spin relaxation. The first component of spin relaxation time τ_s is obtained to be 4.1 ps at 15 K by triple exponential fitting. In a n-modulation doped GaAs/AlGaAs MQW, hole spin relaxation of 4 ps was observed at 10 K.[4]

Figure 2 shows the barrier thickness dependences of tunneling time and spin relaxation times in narrow wells. Previously, we reported that this positive dependence of the electron spin relaxation time derived from the effect of electron tunneling.[3] The observed first components of spin relaxation times in type-I TBQs are from 2.5 ps to 4.1 ps at 15K. The observed positive dependence of hole spin relaxation suggests that hole spin relaxation is also affected by electron tunneling.

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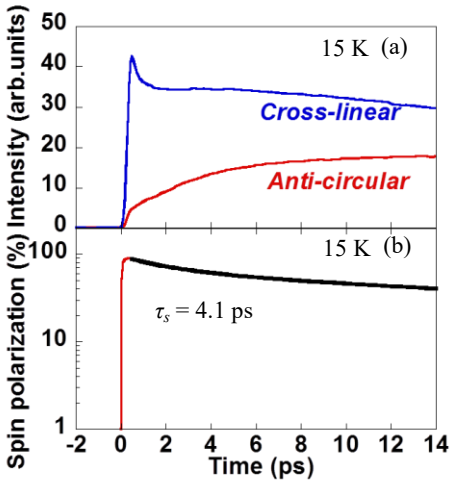

Fig.1 Time evolutions of (a) reflection intensity and (b) spin polarization at 15 K.

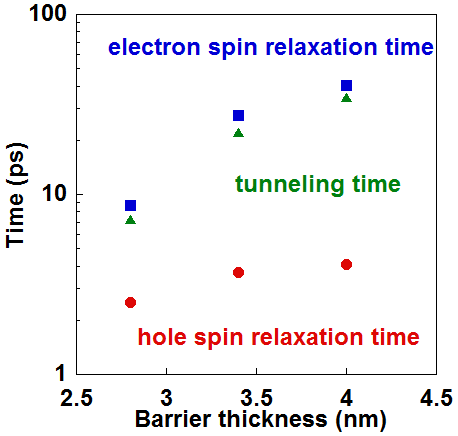

Fig.2 Barrier thickness dependences of tunneling time and spin relaxation times at 15 K.