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Observation of Spin Relaxation in InGaAs/AlAsSb Quantum Wells

Sotaro Izumi[1], Shin-Ichiro Gozu[2], Teruo Mozume[2],
Yu Saeki[1], Takao Nukui[1] and Atsushi Tackeuchi[1]

[1]Department of Applied Physics, Waseda University
3-4-1 Ohkubo, Shinjuku, Tokyo 169-8555, Japan
Phone: +81-3-5286-3853, E-mail: rearau@akane.waseda.jp
[2]National Institute of Advanced Industrial Science and Technology (AIST)
AIST Tsukuba Central 2-1, Umezono 1-1-1, Tsukuba, Ibaraki 305-8568, Japan

Introduction

Spin relaxation is of interest from the viewpoints of fundamental physics and possible applications of spin-dependent optical nonlinearity. From the viewpoint of optical communication applications, the spin relaxation process of InGaAs/AlAsSb quantum wells (QWs), which is recently attracting much attention for its use in all-optical switches because of the very large conduction band offsets of 1.6 eV [1, 2], is important. Here, we report the first observation of the spin relaxation of InGaAs/AlAsSb QWs. The spin relaxation time of 1.46 μm electron-heavy hole excitons was obtained to be 31 ps at room temperature by time-resolved spin-dependent pump and probe reflectance measurement.

Sample structure and reflectance spectrum

The sample we investigated consists of 36 periods of alternate 7.0-nm-thick $In_{0.53}Ga_{0.47}As$ QWs and 7.0-nm-thick $AlAs_{0.56}Sb_{0.44}$ barriers. To reduce atomic inter diffusion at the interfaces, 1-monolayer AlAs layers were inserted between the InGaAs wells and AlAsSb barriers [1]. The structure was grown on a semi-insulating InP substrate by molecular-beam epitaxy. Figure 1 shows a schematic energy band diagram of the InGaAs/AlAsSb QWs. The very large conduction band offset of 1.6 eV is suitable for device applications using intersubband transitions.

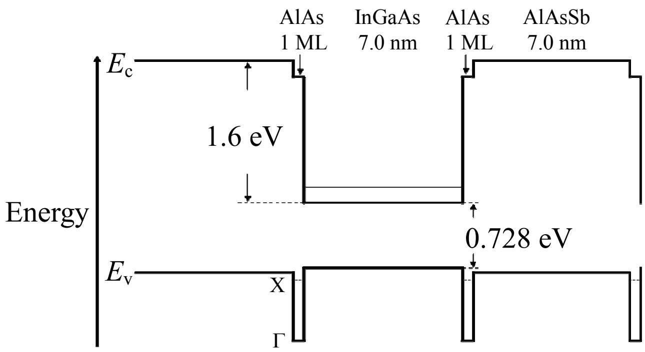

Fig. 1. Schematic energy band diagram of InGaAs/AlAsSb QWs.

We measured the normal-incident reflectance spectrum using a spectrophotometer (JASCO UbestV-570). A tungsten lamp was used as the light source. Figure 2 shows the reflectance spectrum of InGaAs/AlAsSb QWs at room temperature. The electron-heavy hole exciton (HH) absorption peak and electron-light hole exciton (LH) absorption peak were clearly observed at 1.46 μm and 1.41 μm, respectively.

Observation of spin relaxation

We performed a time-resolved spin-dependent pump and probe reflectance measurement to observe the time evolution of the spin polarization [3]. A Ti-sapphire laser with an optical parametric oscillator was used as the optical source in the pump-probe experiment. Spin-aligned carriers are created when electrons are excited by a circularly polarized optical pulse. After right circularly polarized photoexcitation the populations of carriers with a down (up) spin along the direction of light propagation are probed by a right (left) circularly polarized probe pulse. Since there is no magnetic field, the fully spin-polarized electrons relax to equilibrium with 50% up spins and 50% down spins. The advantage of this measurement system is its very high time resolution of 200 fs, which is determined only by the convolution of optical pulse width.

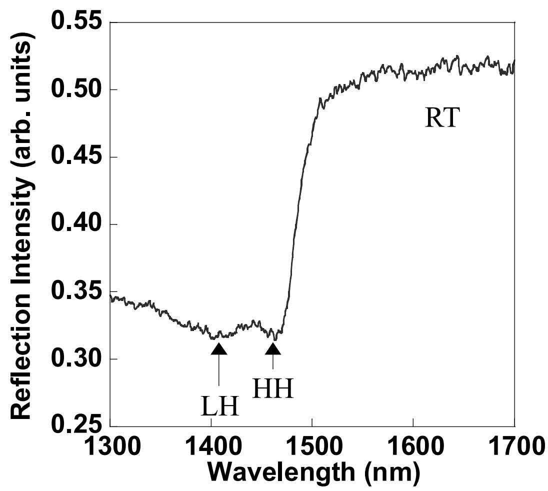

Fig. 2. Reflectance spectrum of InGaAs/AlAsSb QWs at room temperature.

The observed time dependence of reflectance at the HH absorption peak at room temperature is shown in Fig. 3(a).

I_+ and I_- indicate the cocircular polarization and anticircular polarization, respectively. The difference between I_+ and I_-, corresponding to the spin polarization, can be clearly observed.

The time evolution of the spin polarization, $(I_+ - I_-)/(I_+ + I_-)$, is plotted in Fig. 3(b). The curve shows single exponential decay. The spin relaxation time, which is twice the relaxation time of the spin polarization [5], is obtained to be 31 ps by a single exponential fitting.

The spin relaxation times of excitons in III-V QWs at room temperature have been reported to be between several and several hundreds of picoseconds. We previously reported that the spin relaxation time of $In_{0.53}Ga_{0.47}As$/InP QWs, whose bandgap wavelength is 1.55 μm, is 5 ps at room temperature [4, 5]. The observed spin relaxation time is approximately one order of magnitude slower than that of InGaAs/InP QWs. Since the spin relaxation time is affected by the sample quality in addition to the band structure, we cannot conclude that the difference originates from the different material system. Further studies are necessary to identify the spin relaxation mechanism.

From the viewpoint of applications, the observed spin relaxation time of 31 ps indicates high potential for applications to high-speed optical devices.

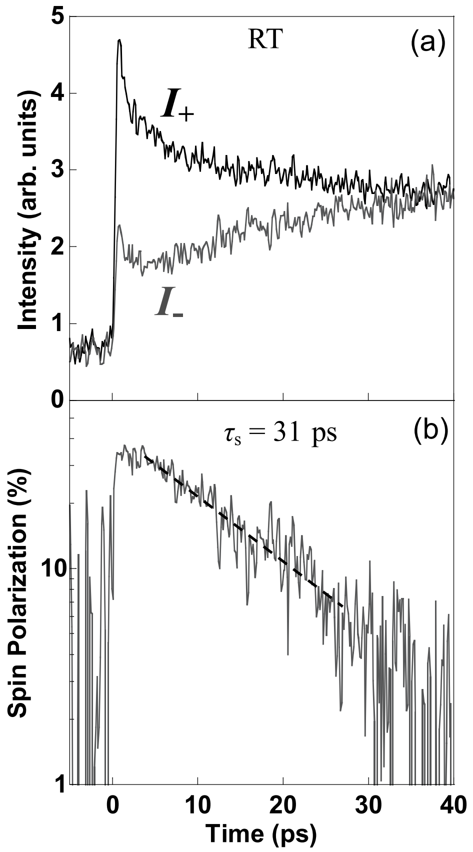

Fig. 3. Time evolutions of (a) spin-dependent reflectance and (b) spin polarization at HH absorption peak at room temperature. I_+ and I_- indicate the cocircular polarization and anticircular polarization, respectively.

Conclusions

We have observed exciton spin relaxation in InGaAs/AlAsSb QWs by time-resolved spin-dependent pump and probe reflectance measurement. The spin relaxation time of 1.46 μm electron-heavy hole excitons at room temperature was obtained to be 31 ps. This spin relaxation time indicates high potential for applications to high-speed optical devices.

References

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