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Picoseconds Carrier Spin Relaxation in $In_{0.8}Ga_{0.2}As/AlAs/AlAs_{0.56}Sb_{0.44}$ Coupled Double Quantum Wells

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1. Introduction

Spin relaxation is of interest from the viewpoints of fundamental physics and possible applications of spin-dependent optical nonlinearity. InGaAs/AlAs/AlAsSb coupled double quantum wells (CDQWs) have recently been attracting considerable attention for their use in all-optical switches because of their very large conduction band offset of 1.7 eV [1-3]. We have reported that spin relaxation time of $In_{0.53}Ga_{0.47}As/AlAs_{0.56}Sb_{0.44}$ quantum wells is 26 ps at room temperature [4]. In this paper, we report the spin relaxation of $In_{0.8}Ga_{0.2}As/AlAs/AlAs_{0.56}Sb_{0.44}$ CDQWs using time-resolved spin-dependent pump and probe reflectance measurements.

2. Experiment

The sample which includes $In_{0.8}Ga_{0.2}As/AlAs/AlAs_{0.56}Sb_{0.44}$ CDQWs as shown in Fig.1 was grown on a semi-insulating InP substrate by molecular beam epitaxy.

We performed time-resolved spin-dependent pump and probe reflectance measurements to observe the time evolution of the spin polarization [5]. An optical parametric oscillator pumped by a Ti-sapphire laser was used as the optical source. The wavelength was tuned between 1.15 and 1.23 μm at 10–300 K. Spin-aligned carriers were generated by circularly polarized pump pulse, and the reflected circularly polarized time-delayed probe pulse from the sample was then detected. The time resolution in this system was 200 fs determined only by the optical pulse width of 140 fs.

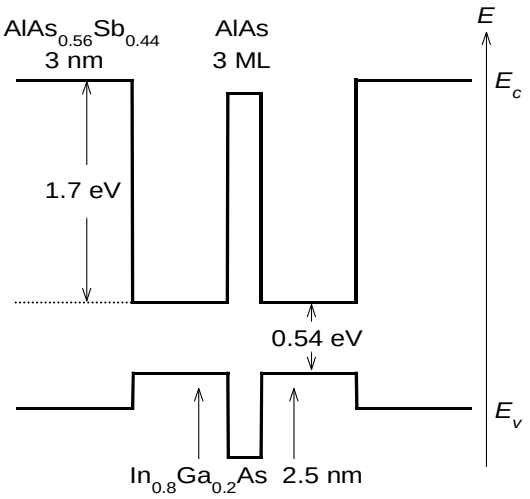

Fig. 1 Energy band diagram of $In_{0.8}Ga_{0.2}As/AlAs/AlAs_{0.56}Sb_{0.44}$ CDQWs.

3. Results and Discussion

The time evolutions of the reflectance at room temperature are shown in Fig. 2(a). I_+ and I_- indicate the cocircular polarization and anticircular polarization, respectively. The time evolution of the spin polarization, $(I_+ - I_-)/(I_+ + I_-)$, is plotted in Fig. 2(b).

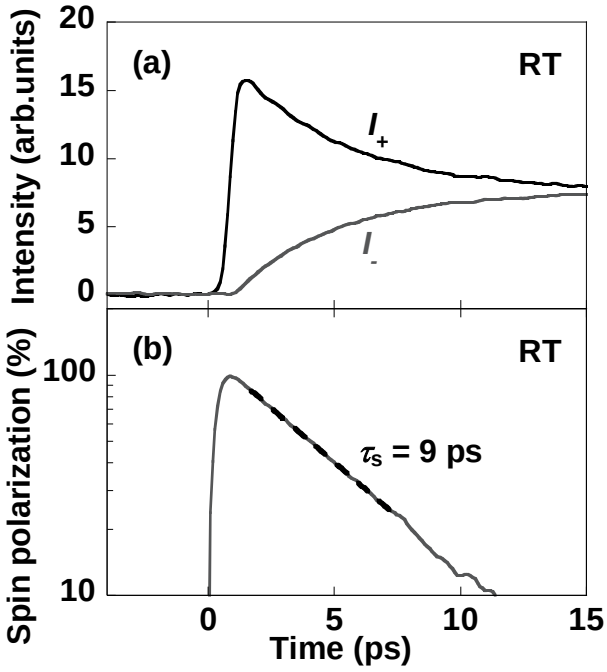

Fig. 2 Time evolution of (a) spin-dependent reflection intensity and (b) spin polarization in $In_{0.8}Ga_{0.2}As/AlAs/AlAs_{0.56}Sb_{0.44}$ CDQWs for excitation power of 20 mW at room temperature. I_+ and I_- indicate the cocircular polarization and anticircular polarization, respectively. The spin relaxation time, τ_s, is obtained to be 9 ps by a single exponential fitting.

Spin relaxation times, τ_s, were obtained to be 9 ps at room temperature, 13 ps at 200 K and 25 ps at 100 K using a single exponential fitting. The observed spin relaxation time of 9 ps at room temperature indicates high potential for applications to high-speed optical devices. The temperature dependence of spin relaxation time is plotted in Fig. 3. The spin relaxation time between 100 K and room temperature is found to depend on temperature, T, as $\tau_s \propto T^{-0.91}$. The carrier density dependence of the spin relaxation time was measured by varying the excitation power. The carrier density dependence is very weak at 200 K and room temperature. The presence of temperature dependence and the insensitivity to carrier density indicate that the spin relaxation mechanism is governed by the D'yakonov-Perel' process and Elliott-Yafet process between 100 K and room temperature.

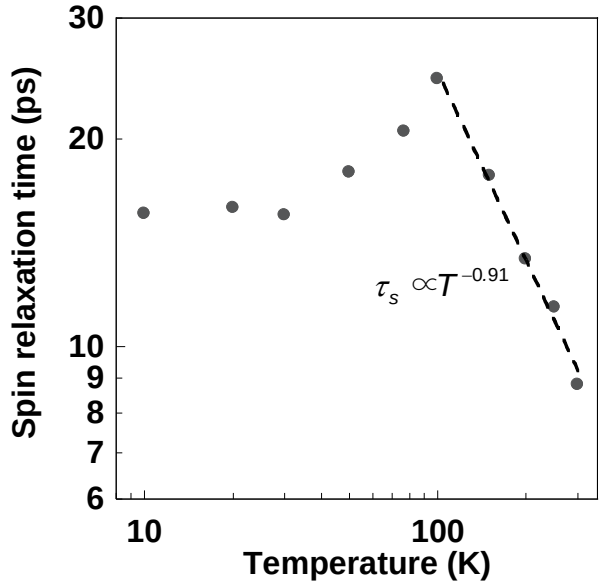

Fig. 3 Temperature dependence of spin relaxation time for the $In_{0.8}Ga_{0.2}As/AlAs/AlAs_{0.56}Sb_{0.44}$ CDQWs. The solid line showing $\tau_s \propto T^{-0.91}$ between 100 K and room temperature is fitted using the least-squares method.

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