Spin relaxation time anisotropy of in-plane magnetic fields in InGaAs/InAlAs multiple quantum wells

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When the strength of Rashba and Dresselhaus spin-orbit interaction (SOI) are balanced in III-V (001) semiconductor quantum wells, the effective magnetic fields due to the SOI are aligned along a uniaxial $[1\bar{1}0]$ direction, which result in the spin relaxation anisotropy [1]. On the other hand, the spin relaxation is isotropic when the strength of Rashba SOI are much smaller than that of Dresselhaus SOI. Recently, we have investigated the influence of the above-barrier illumination on spin relaxation time of InGaAs/InAlAs multiple quantum wells (MQW), and found the spin relaxation time decreases with an increase of laser power at high temperatures (> 70 K). Spin relaxation time decrease could be attribute to the enhancement of the effective magnetic fields induced by momentum increase due to optical phonons created by above-barrier excited carriers. However, the further investigations are necessary to conclude the influence of optical phonons on the spin dynamics in the semiconductor QWs.

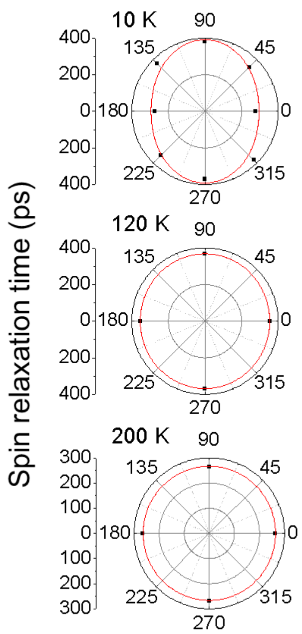

Fig. 1. Spin relaxation time measured as a function of the angle between B and the axis [110] at different temperatures.

In this work, we investigate the spin relaxation anisotropy of in-plane magnetic fields for 30 periods of 12 nm thick $In_{0.53}Ga_{0.47}As/In_{0.52}Al_{0.48}As$ MQW grown on the (001) InP substrate. Figure 1 shows the spin relaxation time measured by time-resolved Faraday rotation (TRFR) technique as a function of the angle between magnetic field (B = 1T) and the axis [110] at different temperatures. By fitting the curve of angular dependence of spin relation time (red curve), we derive the absolute strength of the Rashba SOI $|\alpha|$ as shown in Fig. 2. Here, we assume the strength of the Dresselhaus SOI $\beta = 4.5 \times 10^{-13}$ eVm [2]. At low temperatures (< 30 K), the optically excited electrons and holes trapped in the lower energies of the potential fluctuation retain the electric field band bending effect, which result in the spin relaxation anisotropy. On the other hand, at high temperatures above 30 K, optical phonons excite the electrons and holes and release the electric field band bending effect, which result in the spin relaxation isotropy.

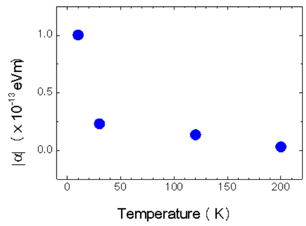

Fig. 2. Temperature dependence of absolute strength of Rasha SOI derived from the fitting in Fig. 1.

[1] A. V. Larionov *et al.*, Physical Review B **78**, 033302 (2008).
[2] R. Kurosawa *et al.*, Applied Physics Letters **107**, 182103 (2015).