GaAs/GaAsP 歪補償超格子におけるスピン緩和の周期数依存性

Superlattice-periods dependence on spin relaxation time in GaAs/GaAsP strained-compensated superlattice

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The studies of GaAs-based photocathodes with negative electron affinity surface have attracted attentions for application in high-energy physics and particles physics. Strain compensation in superlattice (SL) suppresses the lattice mismatch and raises the quality of crystal.[1] SL layers with 24 periods of GaAs/GaAsP demonstrated a maximum spin-polarization of 92%, and with a high quantum efficiency (QE) of 1.6 %.[2-4] Increasing the periods of SLs can be effective to improve the quality of crystal. However, the spin polarization decreases with the increase of the periods, and the QE becomes saturated.[4,5] Therefore improving the spin polarization during the transportation of electron in the conduction miniband is essential to enhance the device. Previously, we reported the spin relaxation of 24 and 90 periods of GaAs/GaAsP strain-compensated SLs which have 4-nm-thick well and barrier layers.[6,7] In this study, we have comprehensively investigated the spin relaxation time of four GaAs/GaAsP strain-compensated SLs with different SL-periods by time-resolved pump and probe measurements.

The four samples were all grown on GaP substrate with a 600-nm-thick AlGaAsP buffer layer. The thickness of barrier layer and well layer are both 4 nm with Zn dopant concentration of 1.5×10^{18} cm^{-3}. Subsequently, the SL structures were coated with a highly doped 5-nm-thick GaAs layer with highly doping of 6×10^{19} cm^{-3}. The periods of SLs in the four samples are 12, 24, 60 and 90.

In the pump and probe measurements, spin-aligned carriers were generated with a circularly polarized optical pulse from a Ti-sapphire laser.[8] The energy of laser was tuned near the photoluminescence peak wavelength for the transition from the conduction band to the valence band. The time resolution of the measurement system is sub-picosecond, which was obtained from the time convolution of the optical pulses.

Figures 1 (a) and (b) show the time evolution of spin polarization in the 12 periods, and 60 periods sample at 14 K for excitation power of 110 mW.

Figure 2 shows the spin relaxation time in the 24 and 90 periods samples at 10 K, and 12 and 60 periods samples at 14 K for the excitation power of 110 mW. The spin relaxation time is prolonged by increasing the SL-periods. This result indicates the relevance of Bir-Aronov-Pikus (BAP) process, which originates from the exchange interaction between electrons and holes.[9,10] The increase of the periods decreases the overlap of the spatial wave function of electrons and holes, thereby resulting the suppression of the BAP process. Therefore, the spin relaxation time is prolonged by increasing the SL-periods.

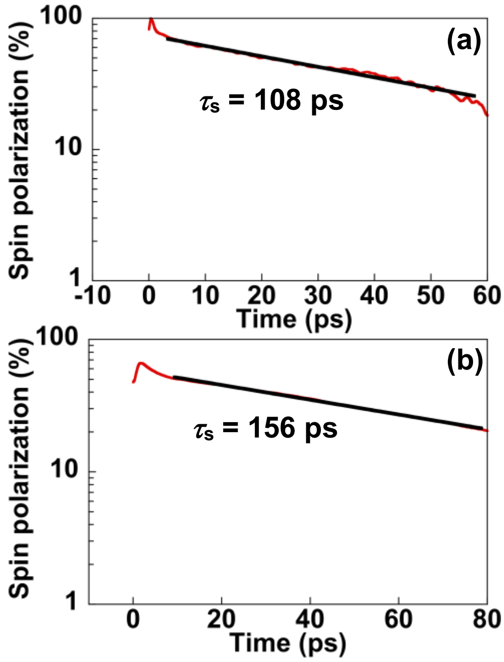

Fig.1 Time transition of spin polarization at 14 K for excitation power of 110 mW in (a) 12 periods SLs and (b) 60 periods SLs samples.

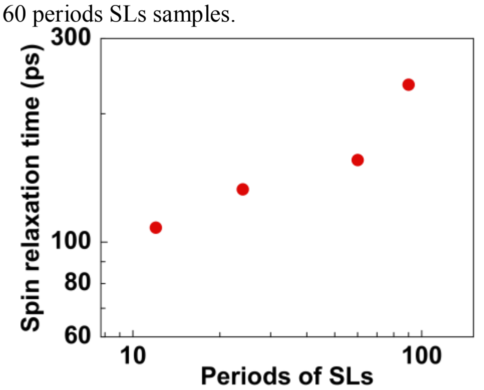

Fig.2 The relation between SL-periods and spin relaxation time at 10 K (24 and 90 periods) and 14 K (12 and 60 periods).

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