高スピン偏極電子源用 GaAs/GaAsP 歪補償超格子におけるスピン緩和時間の周期&井戸幅依存性

Period & well width dependences of spin relaxation time of GaAs/GaAsP strain-compensated superlattice as highly spin-polarized electron source

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Photocathodes of GaAs-related semiconductors with negative electron affinity (NEA) surface are drawing much attention for applications in accelerators and electron microscopy.[1-3] Among them, a structure with 24 periods of GaAs/GaAsP strain-compensated SL layers demonstrated the high performance, a maximum spin-polarization of 92% with a high quantum efficiency of 1.6 %.[4] Increasing the number of SL periods is effective way for improving the quantum efficiency. However, the spin polarization of the electrons emitted from the SL layer decreases with increasing layer thickness above 36 periods due to the spin relaxation during electron transport.[4] Therefore, realizing long spin relaxation time is essential for improving the quantum efficiency. Previously, we reported the spin relaxation of 24 periods of GaAs/GaAsP strain-compensated SL whose well width, L_w, are 4 nm, and barrier width, L_b, are 4 nm.[5] In this study, we have measured the spin relaxation time of two GaAs/GaAsP strain-compensated SL samples by time-resolved pump and probe measurements.

The measured samples compose of 8-period-SL layers of $L_w = L_b = 6.3$ nm or 90-period-SL layers of $L_w = L_b = 4.0$ nm with Zn dopant concentration of 1.5×10^{18} cm^{-3}. After the growth of a 600-nm-thick AlGaAsP buffer layer on GaP substrate, SL layers were fabricated on them and coated with a 5-nm-thick GaAs layer with highly Zn doping of 6×10^{19} cm^{-3}.

In the pump and probe measurements, spin-aligned carriers were generated when the samples were irradiated with a circularly polarized optical pulse.[6] We used a Ti-sapphire laser as the optical source and tuned its wavelength to near the photoluminescence peak. The time resolution of this measurement system is about 200 fs, which was evaluated from the time convolution of the optical pulses.

Figure 1 (a) shows the time evolution of spin polarization of 8-period-SL sample of $L_w = 6.3$ nm at room temperature. In regard to the D'yakonov-Perel' (DP) process[7], which is considered as the candidate spin relaxation mechanism at room temperature, the spin relaxation becomes slow as increasing the well width. However, the measured spin relaxation time of 109 ps is almost the same as that of 24-period-SL sample of $L_w = 4.0$ nm shown in Fig.1 (b). This result indicates that the spin relaxation cannot be explained only by DP process.

Figure 2 (a) shows the time evolution of spin polarization of 90-period-SL sample at 10 K. The measured spin relaxation time of 234 ps is twice the spin relaxation time of 24-period-SL sample, which has the same well width and barrier width as 90-period-SL sample, shown in Fig.2 (b). This result indicates that the Bir-Aronov-Pikus process[8], which is considered as the candidate spin relaxation mechanism at low temperature, becomes less effective for 90-period-SL sample.

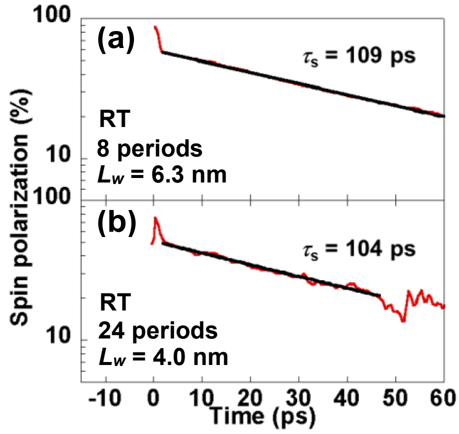

Fig.1 Time evolutions of spin polarization of (a) 8-period-SL sample and (b) 24-period-SL sample at RT for excitation power of 110 mW.

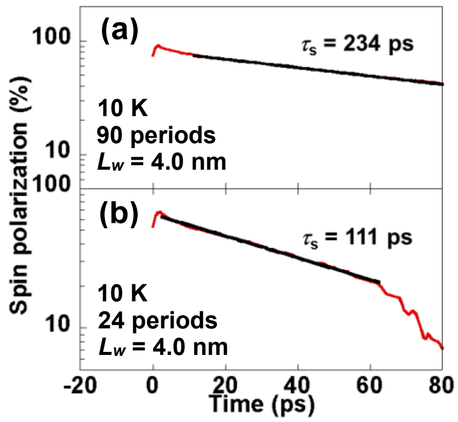

Fig.2 Time evolutions of spin polarization of (a) 90-period-SL sample and (b) 24-period-SL sample at 10 K for excitation power of 110 mW.

[1] C. K. Sinclair, Nucl. Instrum. Methods Phys. Res., Sect. A **318**, 410 (1992).
[2] T. Duden and E. Bauer, Rev. Sci. Instrum. **66**, 2861 (1995).
[3] C. Hernandez-Garcia et al., Proc. 2005 Particle Accelerator Conf., 2005, p. 3117
[4] X. G. Jin et al., Appl. Phys. Lett. **105**, 203509 (2014).
[5] 大木 他, 第 63 回応用物理学会春季学術講演会 19p-W241-11 (2016).
[6] A. Tackeuchi et al., Appl. Phys. Lett. **56**, 2213 (1990).
[7] M. I. D'yakonov et al., Zh. Eksp. Teor. Fiz. **60**, 1954 (1971) [Sov. Phys. JETP **33**, 1053 (1971)].
[8] G. L. Bir et al., Zh. Eksp. Teor. Fiz. **69**, 1382 (1975) [Sov. Phys. JETP **42**, 705 (1976)].