(110)GaAs/AlGaAs 量子井戸における電子スピン緩和機構の定量的考察

Quantitative consideration of electron spin relaxation mechanisms in (110) GaAs/AlGaAs quantum wells

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Electron spin-relaxation time (τ_s) is a key parameter in semiconductor spintronics. In particular, for devices operating at room temperature, a longer τ_s is expected to enable spin-dependent transport and light emission while preserving the spin state, thus paving the way for semiconductor spin lasers [1,2]. However, the Dresselhaus-type effective magnetic field arising from spin–orbit interactions, due to bulk inversion asymmetry in III–V semiconductor quantum wells (QWs), significantly enhances spin relaxation via the D'yakonov–Perel (DP) mechanism. As a result, τ_s can be shortened to around 100 ps at room temperature, hindering device realization. To address this issue, we have focused on (110)-oriented QWs, in which the effective magnetic field is perpendicular to the QW plane, thereby suppressing out-of-plane spin relaxation via the DP mechanism. Although various spin-relaxation mechanisms operating under suppressed DP conditions have been proposed and τ_s has been discussed qualitatively, it is crucial to quantitatively elucidate the contribution of each mechanism.

In this study, we investigated the impact of different spin-relaxation mechanisms on τ_s in (110) GaAs/AlGaAs QWs. We calculated τ_s as a function of quantized energy, temperature, and electron density, taking into account the Elliott–Yafet (EY), intersubband spin relaxation (ISR), and exciton spin relaxation (ExSR) mechanisms. As shown in Fig. 1, our calculations agree well with the experimental data for (110) QWs. Our analysis revealed that the contribution of each mechanism to τ_s can be quantitatively identified and that the dominant mechanism varies under different conditions. These findings provide guidance for optimizing (110) QW-based spintronic devices and enable precise estimation of τ_s under relevant operating conditions.

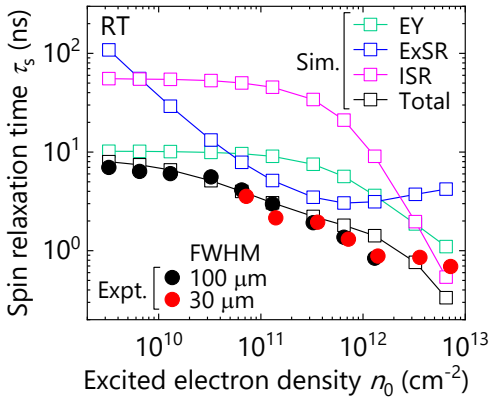

Fig. 1 Excited electron density dependence of spin relaxation time τ_s in undoped (110) GaAs/AlGaAs quantum wells at room temperature. Closed circles and open squares represent the experimental and calculated data, respectively.

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