Electrical detection of the ratio of Rashba and Dresselhaus spin orbit interactions in InGaAs/InAlAs quantum wires

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Introduction: In III-V semiconductor quantum well grown on [001] direction, there are two types of spin-orbit interactions (SOIs), *i.e*. Rashba SOI (α) originating from a structure inversion asymmetry and Dresselhaus SOI (β) originating from a bulk inversion asymmetry. These SOIs cause a spin relaxation which is so called D'yakonov-Perel' (DP) spin relaxation mechanism [1]. For future spintronic devices and quantum computation based on semiconductor heterostructures, suppression of the spin relaxation is essential technology. To overcome the spin relaxation problem, persistent spin helix (PSH) state (α/β=1) and dimensional confinement of the electron momentum in a narrow wire were known to be effective [2, 3]. To realize the PSH state, the evaluation of SOIs (α/β) is strongly required. Here, we directly determine α/β ratio by using quasi-one dimensional narrow wires [4].

Method: The InGaAs/InAlAs semiconductor heterostructure used in this study was grown by metal organic chemical vapor deposition (MOCVD) on (001) InP substrate. We fabricated parallel wire structures along the [100] direction with Au/Cr top gate electrode to modulate the Rashba SOI. We measured magneto-conductance (MC) σ with in-plane (B_{in}) and out of plane magnetic fields at T = 1.7 K. In this sample, wires width is narrower than the spin relaxation length, thus we observed weak localization effect (WL) as shown in Fig. 1(a).

Result: We can determine α/β ratio by measuring the anisotropy of MC with rotating B_{in}. The WL amplitude is enhanced when B_{in} is parallel to B_{eff} as shown in Fig. 1(a) (θ_{in}=107°). On the other hand, when B_{in} is not parallel to B_{eff}, observed WL amplitude is suppressed as θ_{in}=43° (Fig. 1(a)). Due to the perpendicular orientation of the effective magnetic fields for Rashba and Dresselhaus SOIs in [100] direction, the relationship between two SOI strengths is described by the effective magnetic field angle θ_{eff} as $\alpha/\beta = -\tan\theta_{\mathrm{eff}}$. As shown Fig.1(b) and 1(c), peak angle of $\Delta\sigma$ (=θ_{eff}) is 180° (N_s=0.86×10^{12} cm^{-2}) and 135° (1.43×10^{12} cm^{-2}) respectively. These cases correspond to only the Dresselhaus SOI state (α/β=0) and the PSH state (α/β=1), respectively.

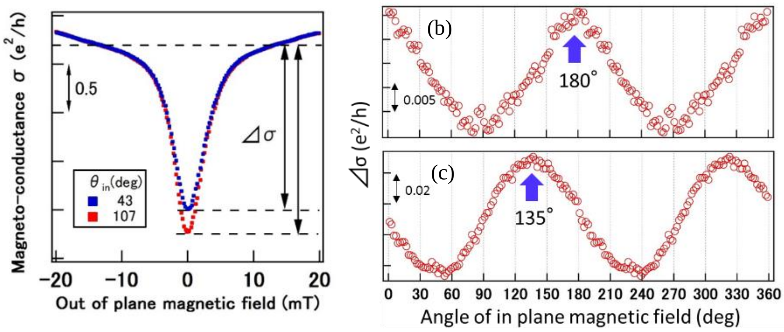

Figure 1: (a) Measured magneto-conductance for in-plane magnetic field angles θ_{in} = 43° and 107°, respectively.
(b) Weak localization amplitude $\Delta\sigma$ for different θ_{in} at N_s=0.86 × 10^{12} cm^{-2} (c) N_s=1.55×10^{12} cm^{-2}

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