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All electrical determination of Rashba and Dresselhaus spin-orbit interactions in InGaAs narrow wires

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In the field of spintronics, electrical control of spin and enhancement of spin lifetime are prerequisite techniques. In III-V semiconductor heterostructures, when strengths of two spin-orbit interactions (SOI), the Rashba SOI α and the Dresselhaus SOI β are equal to each other, coherent spin propagation is realized and spin relaxation due to the D'yakonov-Perel' mechanism is completely suppressed [1]. This is the so-called persistent spin helix (PSH) state [2]. To realize and apply the PSH state, the electrical determination of α and β in a gated sample is essential. In this study, we have successfully evaluated the absolute value of α and β.

A sample used was an $In_{0.52}Al_{0.48}As$ / $In_{0.7}Ga_{0.3}As$ / $In_{0.52}Al_{0.48}As$ quantum well, which was epitaxially grown on InP substrate and processed into narrow wire structures (Length L = 200 μm, Width W = 750 nm, Number of wires N = 100) aligned in [100] direction. We measured out-plane magneto-conductance called weak localization (WL) (Fig. 1a) by varying an in-plane magnetic field $|\mathbf{B}_{in}|$ at T = 1.7 K.

The method to deduce the SOI parameters is based on the theoretical proposal that the WL exhibits minimum amplitude with maximum spin relaxation rate when the in-plane magnetic field $|\mathbf{B}_{in}|$ is very close to the effective magnetic field $|\mathbf{B}_{eff}|$ induced by two SOIs [3]. We experimentally observe the $|\mathbf{B}_{in}|$ dependence of the 'difference of the WL amplitudes $G' = \Delta\sigma(\theta \neq 0^o) - \Delta\sigma(\theta = 0^o)$' at V_g = -5V (Carrier density $N_s = 2.16\times10^{-12}$ cm^{-2}), where $\Delta\sigma$ is a WL amplitude and θ is the angle between $\mathbf{B}_{in}$ and $\mathbf{B}_{eff}$ (Fig. 1b). $|G'|$ corresponds to how much WL amplitude is suppressed by the additional spin relaxation, which becomes maximum at dip position with the ratio $|\mathbf{B}_{in}|/|\mathbf{B}_{eff}| \approx 1$. From the dip position in Fig. 1b, we estimate $|\mathbf{B}_{eff}| \approx 1.55$T. Moreover, using the estimated $|\mathbf{B}_{eff}|$ values together with the ratio α/β deduced by our proposed method [3], it is possible to evaluate the absolute values of α and β.

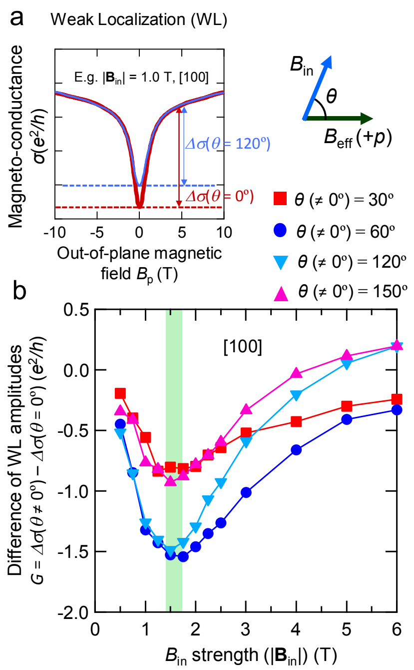

Figure 1: a. measured WL in [100] direction with $|\mathbf{B}_{in}|$ = 1T in different θ. b. The difference of WL amplitudes $G' = \Delta\sigma(\theta \neq 0^o) - \Delta\sigma(\theta = 0^o)$ as a function of $|\mathbf{B}_{in}|$. Each angle $\theta \neq 0^o$ was set as θ = 30°, 60°, 120° and 150°.

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