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Transport measurements toward gate-controlled transition between persistent and inverse persistent spin helix states

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Introduction: In semiconductor spintronics, electrical control of spin and suppression of spin relaxation are prerequisite techniques. In III-V compound semiconductors, there are two types of spin-orbit interactions (SOIs), *i.e.*, the Rashba SOI α and the Dresselhaus SOI β. When α is equal to β, spin rotational symmetry is preserved and results in long spin relaxation time due to the complete suppression of the D'yakonov-Perel' spin relaxation mechanism [1]. This is the so-called persistent spin helix state (PSH $\alpha = \beta$) [2]. In addition to the PSH, an inverse persistent spin helix state (*i*-PSH) with long spin relaxation time can be realized by making $-\alpha = \beta$. If we control these states by gate voltage, the spin complimentary FET will be possible [3]. Here, we tried to realize a gate controlled transition between the PSH and *i*-PSH states from magneto-transport measurements.

Method: A gate-fitted Hall bar was fabricated by using an InGaAs HEMT structure grown on InP (001) substrate (See Fig: 1(a)). The InGaAs based symmetric quantum well structure was carefully designed to make α close to β. We measured magneto-conductance (MC) by varying gate voltage (by controlling α) at 1.7K since short and long spin relaxation times result in weak anti-localization (WAL) and weak localization (WL), respectively.

Result: A transition from WAL to WL is observed at N_s= 1.54 x 10^{12} cm^{-2} by decreasing N_s (See Fig: 1(b)). We calculate the strengths of Rashba SOI α and Dresselhaus SOI β by using the ***k*・*p*** perturbation method (See Fig: 1(c)). By comparing with the calculation, the observed transition suggests the PSH and *i*-PSH states will be realized around N_s= 1.5 x 10^{12} cm^{-2} and 0.4 x 10^{12} cm^{-2}, respectively. However, WAL (β dominant region) and WL ($-\alpha = \beta$: *i*-PSH) are not observed by further decrease in N_s. This is probably because the measured temperature is still high so that the phase coherence length is shorter than the spin relaxation length, which yields the WL under the β dominant region. We will conduct magneto-conductance measurements at lower temperature such as 0.3K in order to enhance the phase coherence length.

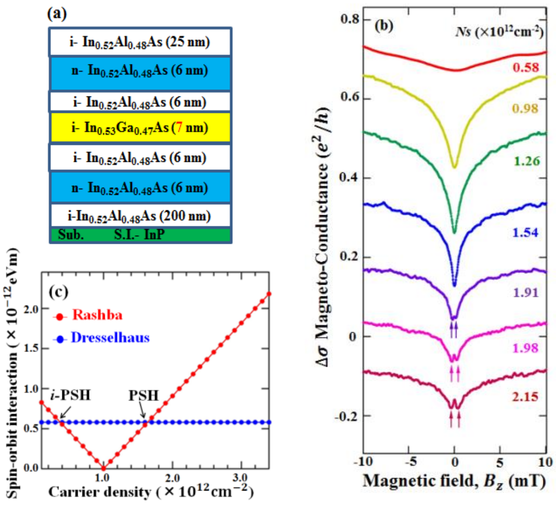

Figure 1: (a) Schematic layer structure used in the present study. (b) Magneto-conductance profiles (in units of e^2/h) measured at different gate voltages. (c) Expected SOI strengths calculated by the ***k*・*p*** perturbation method.

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