Spin Hall effect in 2DEG in the presence of Rashba spin-orbit interaction

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1. Introduction

The generation of spin current in non-magnetic semiconductors is one of the most interesting issues in the field of spintronics. Since the spin Hall effect was predicted by several studies, theoretical and experimental approaches to spin Hall effect as a method to generate spin current has been intensively performed. Spin Hall effect originates from spin-orbit interactions by impurities or band structures, so-called extrinsic or intrinsic spin Hall effect, respectively. Also, in two-dimensional electron gas (2DEG), spin precession by Rashba spin-orbit coupling enables manipulation of spin current with gate voltage [1-3].

2. Experimental method

In this research, Rashba spin-orbit coupled InAs 2DEG is prepared and Rashba constant is 8.9 × 10-12 eVm. In order to measure the conversion from spin to charge current, inverse spin Hall effect, spin imbalance is needed and it can be achieved by spin injection from ferromagnetic source (FM). Permalloy as spin source is deposited on Hall bar as shown in Fig. 1. The easy axis of FM is y-axis due to aspect ratio, and external magnetic field is applied in x-axis to vary magnetization, because only x-directional spin can precess. The precessed spins have the z-component at the Hall probe and the Hall voltage is measured. All experiments are performed at 1.8 K to guarantee the precession of spin.

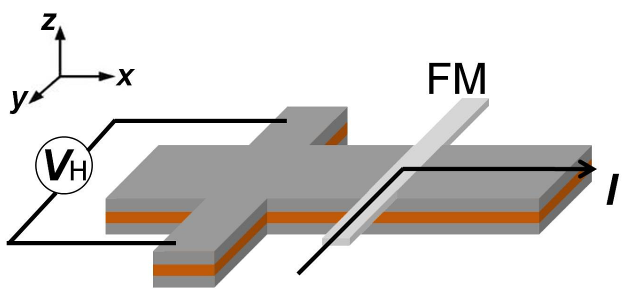

Fig. 1. Schematic diagram of spin Hall devise and measurement geometry.

3. Results

Injected spins ballistically propagate and precess, then induce electrochemical potential difference between Hall probes due to spin Hall effect. When magnetization of FM is reversed by external magnetic field, opposite spin Hall voltage appears, because injected spins have opposite direction. Also current can make the same situation, as shown in Fig. 2(a). We defined the difference between upper and lower base line as ΔR, and plotted these for their channel lengths in Fig. 2(b).

4. Discussion

The spin precession angle (z-component of spin) can be expressed as

$\Delta\Theta = 2\alpha m^{*}L/\hbar^{2}$,

and shown in Fig. 2(b) black dotted line. Also spin Hall signal (triangle) oscillates with its channel length. The experimental data agree with the theoretical prediction denoted by the dotted line.

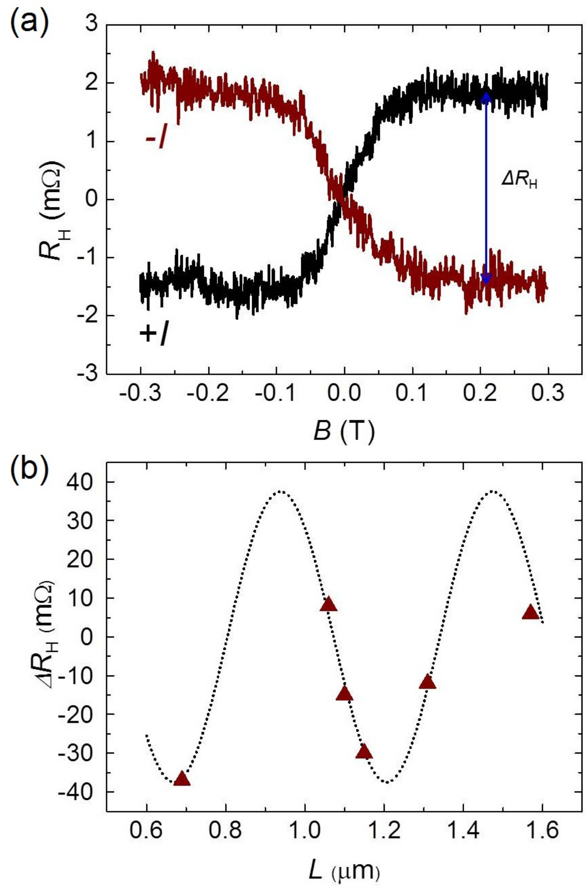

Fig. 2. (a) spin Hall signals as a function of external magnetic field, (b) ΔR's for each channel lengths (triangle) and spin *z*-component by the precession(black line).

5. Conclusion

In general, perpendicular magnetization is used for metal channel to confirm the spin Hall effect, because only perpendicularly polarized and injected spins can induce the spin Hall voltage in transverse direction without precession. In 2DEG, however, in-plane spin also can get z-component which contributes to spin Hall voltage. Therefore the oscillation of spin induce the oscillation of spin Hall voltage. We presented that the spin information can be utilized for the various device applications even without perpendicularly magnetized materials.

6. References

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