Inverse Spin Hall Effect in an InAs Two-dimensional Electron Gas Layer

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1. Introduction

The spin Hall effect (SHE) generates a transverse spin current by an electric current, with spin perpendicular to the plane of channel layer. This effect is closely related to the anomalous Hall effect (AHE) which generates a Hall current in a ferromagnetic material. The SHE emerges from the deflection of flowing spins in the non-magnetic channel and the flowing direction is determined by the spin orientation. Especially, the conversion of spin current into charge current is called the inverse spin Hall effect (ISHE). Here, we report electrical measurements of the ISHE in InAs two-dimensional electron gas (2-DEG) layer. Electrical observation of the spin polarized current in semiconductors is the most important factor for the future spin-electronics (spintronics) architectures.

2. Experiment details

The spin Hall device is composed of an $In_{0.53}Ga_{0.47}As$/InAs based 2-DEG Hall bar and Pd/CoFe mutilayers with perpendicular magnetization, in which the ISHE can be examined at various temperature range from 1.8 K to 300 K. The InAs 2-DEG is well known for large spin-orbit interaction and relatively long diffusion length. An inset in Fig. 1 shows the scanning electron microscope image of the spin Hall device. The width of Hall bar is 15 μm and spin injector is ranged from 0.4 μm to 2.0 μm. The center-to-center distance between injector and InAs Hall bar (channel length, L) varies in the range from 2.0 μm to 3.5 μm. The spin injector with perpendicular magnetization generates perpendicularly (z-direction) polarized spin current flowing in the x-direction. Thus, the spin current is deflected at the InAs Hall cross and charge imbalance occurs in the y-direction, which is electrically detected as the spin Hall voltage (V_{SH}). The current bias and the voltmeter are configured for the detection of the ISHE.

3. Results and Discussion

Fig. 1 shows the inverse spin Hall resistance (ΔR_{ISHE}) as a function of channel length (L). The dashed curve based on the spin diffusion model is well fitted to our experimental data. A large ΔR_{ISHE} of 3.0 mΩ is obtained at L = 2.0 μm. We verify that the measured data decays exponentially with increasing channel length, and this result is well matched to theoretical expectation. The temperature dependence of ΔR_{ISHE} is shown in Fig. 2. ΔR_{ISHE} decreases with increasing temperature (T). Also, we calculate the spin Hall conductivity to the electrical conductivity of channel (spin Hall angle, α_H). We assume that the spin polarization (P) of multilayers is about 0.02. An inset in Fig. 2 shows the spin Hall angle with various temperature range. The large spin Hall resistance of up to 3.0 mΩ at 1.8 K is attributed to the large spin Hall angle at low temperature.

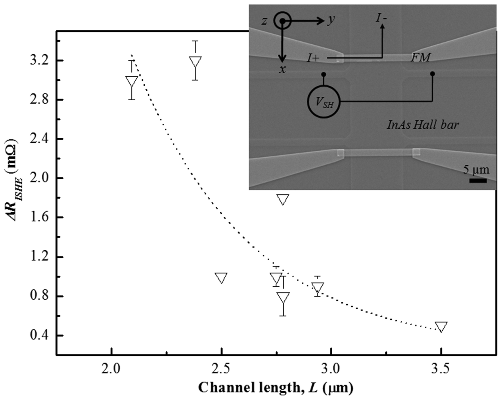

Fig. 1. The resistance of ΔR_{ISHE} as a function of channel length, L, measured at 1.8 K. The dashed curve is obtained by fitting experimental results to spin diffusion model. The inset shows the scanning electron microscope image of the spin Hall device. The current bias and the voltmeter are configured for the detection of ISHE.

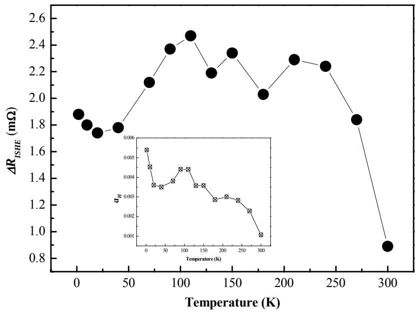

Fig. 2. Measured temperature dependence of ΔR_{ISHE} for the devices with L = 2.78 μm. The inset shows the spin Hall angle, α_H, as a function of the temperature.

4. References

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