Study on the contribution of Rashba interface to magneto-transport properties

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Keywords : Spintronics, Interface, Magneto-transport

1. Introduction

In these days, the spintronics draws great attention since the spintronic devices have an enormous advantage to achieve next-generation devices with low power consumption and infinite endurance. This advantage comes from a fact that the spintronic devices use a spin as a recording bit. And the operation of the Spintronic devices is realized by the spin current which is 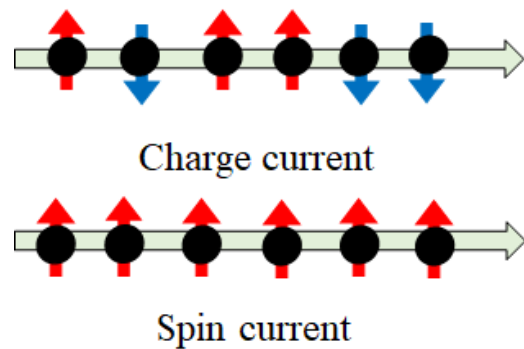a flow of uniformly spin-polarized electrons (Fig. 1). Therefore, we should understand how we can control the spin current. Due to the spin-orbit

Figure 1 Schematic diagram of charge current and spin current

interaction, we can interconvert between the spin current and the charge current via the spin Hall effect (SHE) and/or the Edelstein effect (EE). Here this spin current only accompanies with the transfer of the spin angular momentum without a flowing of the charge current. The former and the latter are shown in a bulk and surface/interface, respectively. Interestingly, there are number of reports that the spin/charge interconversion modulates transport properties in the bulk spin Hall materials [1,2]. Similarly, we expect the modulation of the transport due to the spin/charge interconversion at a surface or interface. Here we studied the magneto-transport properties in Rashba interface in ferromagnetic metal (FM)/normal metal (NM)/Bi_2O_3 thin films, where the NM/Bi_2O_3 interface shows the Rashba splitting [3]. In this study, I studied both of the transverse and longitudinal magneto-transport properties. The study was carried out by measuring the transverse and longitudinal resistance, and observed the modulation of the anomalous Hall effect (AHE) and the Edelstein magnetoresistance (EdMR).

2. Experiment

Studies on the anomalous Hall effect (AHE) was carried out to observe transverse magneto-transport. In this study, we prepared two trilayers, Py/Cu/Bi_2O_3 and Py/Ag/Bi_2O_3 thin films. We also prepared Py/Cu and Py/Ag bilayers as a reference. All the samples were patterned to the Hall bar structure with 4.0 μm width, 120 μm lengths through the photolithography and the

lift-off process. And each layer is deposited by using the electron beam evaporation. Here the Cu and Ag layers in all of the prepared samples are wedged layer with various thicknesses from 0 to 20 nm. The measurement was performed by applying 100 µA charge current and measuring the transverse and longitudinal voltage. The transverse resistance (R_{xy}) was measured with sweeping the out of plane magnetic field from -6 T to 6T. And the longitudinal resistance (R_{xx}) was measured by four-point probe method. The anomalous Hall resistance (ΔR_{xy}) is defined to a difference between the maximum and minimum value of R_{xy} (Fig 3). In order to analyze our result, firstly we derived the anomalous Hall resistivity (ρ_{AH}) considering with the shunting effect and the short-circuit effect. Then we obtained anomalous Hall angel (θ_{AH}) from a relation $\theta_{AH} = \rho_{xy}/\rho_{xx}$, where ρ_{xx} is the Py
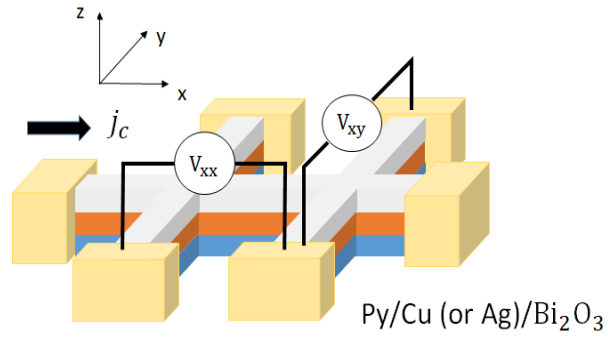

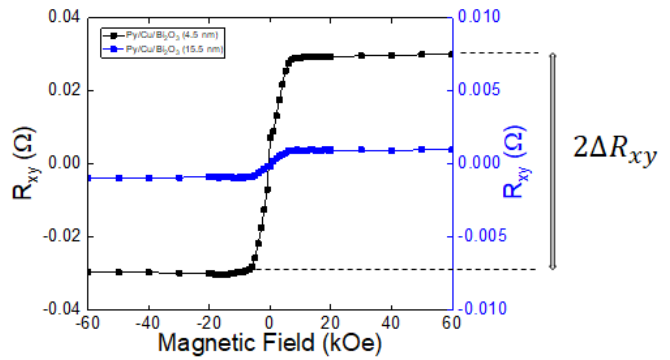Figure 2 Sample structure of the Py/Cu (or Ag)/Bi$_2$O$_3$ trilayers

Figure 3 The typical Py/Cu/Bi$_2$O$_3$ data for obtaining transverse resistivity. The blue one means results at smaller thickness.

resistivity. Finally, we extracted the Edelstein effect influence on the AHE by using $\theta_{AH}^{add} = \theta_{AH}$ (Py/NM/Bi$_2$O$_3$) $- \theta_{AH}$ (Py/NM), where θ_{AH} (Py/NM/Bi$_2$O$_3$) and θ_{AH} (Py/NM) are θ_{AH} from the Py/NM/Bi$_2$O$_3$ and Py/NM thin films, respectively.

The EdMR shows the modulation of the longitudinal resistance by EE and Inverse Edelstein effect (IEE) [4]. To study the properties of longitudinal magneto-transport, we prepared four CoFe/Cu/Bi$_2$O$_3$ thin films with the different Cu deposition rate. And we fabricated the Hall bar devices on the CoFe/Cu/Bi$_2$O$_3$ thin films. The longitudinal resistance measurement was carried out by applying the 6 T magnetic field on the yz-plane.

3. Results and Discussions

We observed that there is a clear modulation on θ_{AH}. Interestingly, the sign of θ_{AH}^{add} is opposite between Py/Cu/Bi$_2$O$_3$ and Ag/Bi$_2$O$_3$. The opposite sign of θ_{AH}^{add} is shown even if we decrease temperature to 10 K. Considering that a previous report indicates the sign the Rashba parameters from these interfaces have opposite sign [5], we supposed that the EE critically influences to the AHE. Here the EE influence is mediated by the spin swapping inside the Cu layer, which converts the spin direction of the spin current from y-axis to z-axis (Fig. 5) [6].

The observed modulation of the EdMR is shown in Fig. 6. The sinusoidal resistance as a function of the field angle is a signature of the EdMR. In thin Cu thickness regime, we observed the magnitude of the EdMR is changed in each trial. However we think the sensitive formation of the Rashba interface independent of the depostion rate is responsible to the change in a device with thin Cu layer.
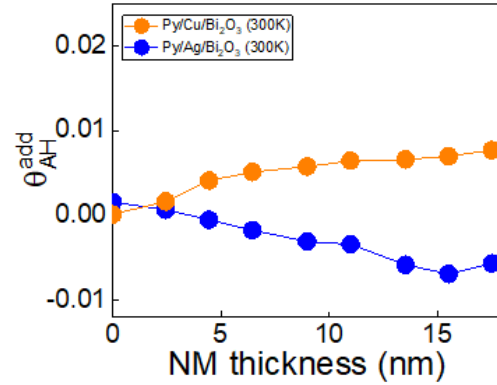

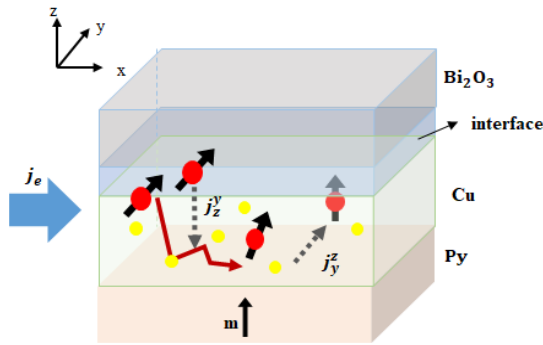Figure 4 The calculated results of additional AHA (θ_{AH}^{add})

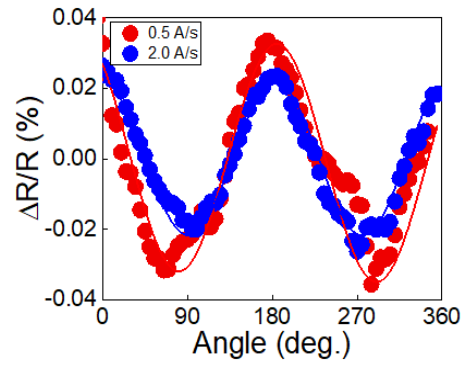Figure 5 Schematic diagram of spin swapping on Py/Cu/Bi$_2$O$_3$. Ag case have opposite z-direction.

Figure 6 The EdMR has different magnitude in similar thickness.

4. Reference

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5. Conference poster presentations

- The Joint Meeting of Scientific Research on Innovative Areas (2017. 09), "Rashba-Edelstein effect influence on the anomalous Hall effect"

- The Spin Conversion Workshop (2017. 11), "Modulation of anomalous Hall effect by Rashba-Edelstein effect"