Conversion of spin current into charge current in $Bi_{0.85}Sb_{0.15}$

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In spintronics, materials with a large spin Hall angle are desired, since effective conversion between charge current and pure spin current is important for realization of novel spintronics devices [1]. Bi and Bi-based alloys are expected to have a large spin Hall angle because of the large spin-orbit couplings of Bi atoms and the Dirac electrons located at the L-point band. In theory, the spin Hall conductivity is proportional to the orbital susceptibility in the Dirac electron system, and it is estimated to be 100 times larger in Bi and BiSb than in Pt [2], which allows efficient spin conversion. Thus, we expected significant enhancement of a spin Hall angle in $Bi_{0.85}Sb_{0.15}$ because of its carriers located at the L-point and semiconducting properties.

A schematic illustration of the sample is shown in Fig. 1. $Bi_{0.85}Sb_{0.15}$ was deposited on top of a ferrimagnet, yttrium iron garnet ($Y_3Fe_5O_{12}$, YIG). Spin current was injected into the $Bi_{0.85}Sb_{0.15}$ from the YIG under the ferromagnetic resonance (FMR) conditions, by irradiating microwave with a frequency 9.12 GHz and sweeping external magnetic field. The injected spin current was expected to be converted into charge current due to the inverse spin Hall effect in the $Bi_{0.85}Sb_{0.15}$. Fig. 2 shows a detected electromotive force (EMF) from the $Bi_{0.85}Sb_{0.15}$ under FMR. The magnitude of EMF, V_{EMF}, was determined as ($V_{EMF}(\theta = 0°)$ - $V_{EMF}(\theta = 180°)$)/2 in order to eliminate spurious signals. Sign inversion of the EMF with the reversal of the magnetic field and a proportional relationship between EMF and P_{MW} (inset in Fig. 2) were observed. These results suggest that the EMF in the $Bi_{0.85}Sb_{0.15}$ was induced by the inverse spin Hall effect. The spin-charge conversion in the $Bi_{0.85}Sb_{0.15}$ due to its inverse spin Hall effect was achieved for the first time.

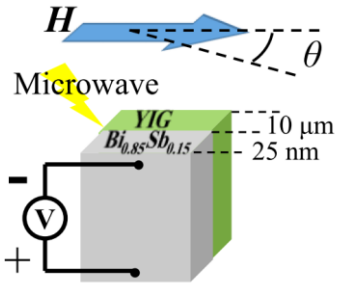

Fig.1 : Schematic illustration of the sample.

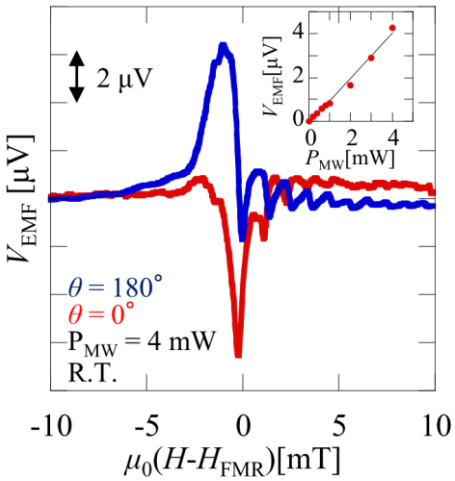

Fig.2 : Electromotive force from $Bi_{0.85}Sb_{0.15}$ under the FMR.

References :
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[2] Y. Fuseya *et al.*, J. Phys. Soc. Jpn. **83**, 074702 (2014).