Thermo-spin effects through antiferromagnetic insulator NiO detected by lock-in thermoreflectance

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In the research field of spin caloritronics, the control of a heat current using a magnetic material has gained much attention. Some of the thermo-spin effects generate a heat current from a spin current at the junction comprised of a magnetic material. There are two types of thermo-spin effects: the magnon-driven thermo-spin effect and the conduction-electron-driven thermo-spin effect, which are called the spin Peltier effect (SPE) [1,2] and the spin-dependent Peltier effect (SdPE) [3], respectively. In a nonmagnetic metal (NM)/ferromagnetic metal (FM) junction, the temperature changes due to the SPE and the SdPE are contaminated with the anomalous Ettingshausen effect (AEE) [4], which is the magneto-thermoelectric effect in FM. Therefore, those phenomena coming from the different physical origins may contribute to the temperature change in a multilayer involving an NM/FM junction, and the separation of those contributions is essential to understand the details of temperature change.

In this study, we investigate the thermo-spin effects in the Pt/NiO/$Co_{20}Fe_{60}B_{20}$ (CoFeB) trilayer by employing the lock-in thermoreflectance method [5], which is a combination of a lock-in detection and a thermometry using the temperature dependence of reflectivity. A spin current due to the spin Hall effect in Pt is injected into CoFeB through the antiferromagnetic insulator NiO. NiO transports the spin current while providing the electrical insulation between Pt and CoFeB, thus eliminating the AEE in CoFeB. Hence, the pure temperature change due to the thermo-spin effects is detected in Pt/NiO/CoFeB. We prepared Pt(10 nm)/NiO(t_{NiO})/CoFeB(20 nm) film grown on a MgO(111) substrate by magnetron sputtering. Subsequently, Al-O(20 nm)/Cr(5 nm)/Au(100 nm) was deposited by ion beam sputtering as a transducer for the temperature measurement. The magnetic field dependence of the temperature change for t_{NiO} = 10 nm corresponds to the *M-H* curve of CoFeB, indicating that the temperature change comes from the thermo-spin effects. From the NiO thickness dependence of the temperature amplitude in the range of $t_{\mathrm{NiO}} \geq$ 20 nm, the spin transmission length of NiO λ is estimated to be 19±6 nm, which is of the same order as the reported values [6,7]. In addition, we demonstrate that the thermoreflectance-based optical measurement allows us to clarify the spin transport in an antiferromagnetic insulator via the thermo-spin effects.

[1] J. Flipse *et al., Phys. Rev. Lett.* **113**, 027601 (2014). [2] S. Daimon *et al., Nat. Commun.* **7**, 13754 (2016). [3] J. Flipse *et al., Nat. Nanotechnol.* **7**, 166 (2012). [4] T. Seki *et al., Appl. Phys. Lett.* **112**, 152403 (2018). [5] T. Yamazaki *et al., J. Phys. D: Appl. Phys.* **54**, 354001 (2021). [6] Y. Wang *et al., Science* **366**, 1125 (2019). [7] T. Ikebuchi *et al., Appl. Phys. Express* **14**, 123001(2021).