Temperature dependence of the electromotive force in the topological crystalline insulator SnTe induced by spin pumping

°Akiyori Yamamoto[1], Tomonari Yamaguchi[2], Ryo Ishikawa[2], Ryota Akiyama[1], Yuki K. Wakabayashi[1], Shinji Kuroda[2], Shinobu Ohya[1], and Masaaki Tanaka[1]
(1. *The Univ. of Tokyo*, 2. *Univ. of Tsukuba*)
E-mail: yamamoto@cryst.t.u-tokyo.ac.jp

The topological crystalline insulators (TCIs), which have gapless metallic surface states (SSs) protected by the mirror symmetry of the crystal, have attracted great attention for spintronics applications. SnTe is a typical and promising TCI, and the topological SSs have been experimentally confirmed by the studies of angle-resolved photoemission spectroscopy and electrical transport [1, 2]. In our previous presentation, we reported the observation of the electromotive force (EMF) *V* in the SnTe layer induced by spin pumping at room temperature [3]. However, in our previous study, it was difficult to estimate the spin-to-charge currents conversion efficiency of the SSs because the large conduction in the bulk states at room temperature. Here, we measure the temperature dependence of the EMF in the SnTe layer induced by spin pumping to investigate the spin-to-charge conversion efficiency of the SSs of SnTe.

In our spin-pumping experiments, we used a Fe (20 nm) / SnTe (70 nm) bilayer structure grown on CdTe / ZnTe / GaAs (100) substrate by molecular beam epitaxy. The root mean square (RMS) roughness of the SnTe layer was largely improved to 2.3 nm in comparison with that on a BaF_2 (111) substrate used in our previous study (7.6 nm) [2, 3]. At the ferromagnetic resonance (FMR) conditions, the dynamical exchange interaction drives the spin pumping, injecting a pure spin current into the SnTe layer. This gives rise to an EMF in the SnTe layer through the spin–momentum locking [4]. We used a sample with the size of 3 mm × 0.5 mm for our measurements (Fig. 1). The sample was placed near the center of a TE_{011} cavity of an electron spin resonance system (microwave frequency: 9.1 GHz). An external magnetic field *H* was applied at an angle of θ_H with respect to the in-plane <110> direction.

As shown in Fig. 1, the measured FMR spectra for θ_H = 0 and 180 deg showed two FMR peaks due to the magnetic anisotropy of the Fe film [5]. The *V-H* curves also exhibited two FMR peaks. The sign of the peaks were changed by reversing the magnetic field direction. This behavior is consistent with the expected behavior of the EMF induced by spin-momentum locking [4]. We measured the temperature dependence of *V-H* curves with θ_H = 0 deg and separated each FMR peak into symmetric Lorentzian and antisymmetric derivative Lorentzian (anomalous Hall) curves [6]. We defined the components of the Lorentzian curves centered at $\mu_0 H$ = 56 and 109 mT as $V_{sym,l}$ and $V_{sym,h}$, respectively. The obtained $|V_{sym,l}|$ and $|V_{sym,h}|$ increased with decreasing temperature below 80 K (Fig. 2). Meanwhile, the resistance *R* of the bilayer monotonically decreases with decreasing temperature. These results indicate that $|V_{sym}|/R$, which corresponds to the charge current induced in the bilayer by the spin-momentum locking, increases with decreasing temperature below 80 K. This increase in $|V_{sym}|$/R suggests an increase of the magnitude of the pure spin current injected into the SnTe layer, or an enhancement of the spin-to-charge current conversion efficiency or the spin diffusion length with decreasing temperature below 80K.

Acknowledgements: This work was supported by Grants-in-Aid for Scientific Research (No. 26103003, 23000010), and the Project for Developing Innovation Systems of MEXT. Part of this work was carried out under the Cooperative Research Project Program of RIEC, Tohoku University.

References

[1] Y. Tanaka *et al.*, Nat. Phys. **8**, 800 (2012). [2] R. Akiyama *et al.*,Nano Research DOI:10.1007/s12274-015-0930-8 (2015). [3] A. Yamamoto *et al.*, JSAP 2015 Autumn Meeting 14p-2J-18. [4] Y. Shiomi *et al.*, Phys. Rev. Lett. **113**, 196601 (2014). [5] G. A. Prinz *et al.*, J. Appl. Phys. **53**, 2087 (1982). [6] E. Saitoh *et al.*, Appl. Phys. Lett. **88**, 182509 (2006).

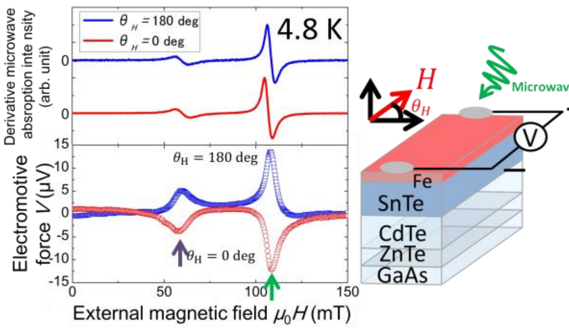

FIG. 1. The FMR spectra and the *V-H* curves measured for the Fe / SnTe bilayer with θ_H = 0 and 180 deg at 4.8 K.

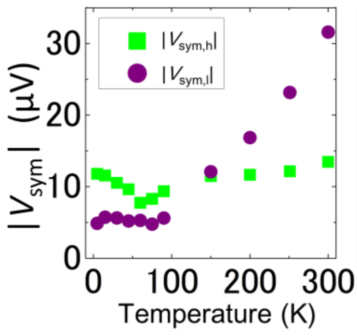

FIG. 2. *T* dependence of $|V_{sym,h}|$ and $|V_{sym,l}|$ with θ_H = 0 deg.

© 2016年 応用物理学会