Spin Hall effect in paramagnetic kagome-lattice topological semimetal $Co_3Sn_2S_2$

IMR, Tohoku University[1], CSRN, Tohoku University [2], CSIS, Tohoku University [3]

○Yong-Chang Lau[1,2], Kohei Fujiwara[1], Junya Ikeda[1], Takeshi Seki[1,2], Atsushi Tsukazaki[1,2], Koki Takanashi[1,2,3]

E-mail: yongchang.lau@imr.tohoku.ac.jp

Ferromagnetic shandite $Co_3Sn_2S_2$(CSS) has recently been identified as an exotic magnetic Weyl semimetal[1,2]. Giant intrinsic anomalous Hall effect[3] and anomalous Nernst effect[4] were found in ferromagnetic CSS, owing to its unique topologically non-trivial band structure protected by the time-reversal symmetry. The relatively low Curie temperature T_C ~ 180K of the ferromagnetic CSS, however, hinders the prospect of exploiting its topological properties for many practical applications. Meanwhile, only few studies[5] have been devoted for exploring the usefulness of CSS in the paramagnetic state, e.g. at room temperature.

Here, we examine the potential of the paramagnetic CSS as a spin current source at room temperature via the spin Hall effect(SHE). High-quality encapsulated CSS films of varying thicknesses were grown on Al_2O_3(0001) substrates by magnetron co-sputtering followed by high temperature annealing, as described in our previous work[6]. The SiO_2 encapsulating layer was then dry-etched *ex situ* using Ar ion milling, followed by ion beam sputtering deposition of either Cu(1.8)/$Co_{20}Fe_{60}B_{20}$(2)/AlO_x(3) or AlO_x(3) structures (thicknesses in nanometers). We carried out harmonic Hall measurement and spin-torque ferromagnetic resonance line-shape analysis on the former heterostructures with CoFeB for independent spin-orbit torque quantification. The latter structures without CoFeB served as references. The two experiments yield consistent estimation of the damping-like spin Hall efficiency, ξ_{DL}. Considering the current distribution within the heterostructure, we obtain ξ_{DL} ~ +0.11 for paramagnetic CSS at room temperature, corresponding to a spin Hall conductivity of ~340 ($\hbar$/2e) $\Omega^{-1}cm^{-1}$. Possible correlation between the observed SHC and the presence of avoided linear crossing in the band structure of paramagnetic CSS (corresponding to the Weyl nodes for the ferromagnetic CSS) will be discussed.

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