Ferromagnetism in $Co_3Sn_2S_2$ ultrathin films

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In extensive research activities on the quest for magnetic Weyl semimetals (MWS) [1], recent experiments have verified that $Co_3Sn_2S_2$ is a real example of MWS. [2–5]. As a platform for studying theoretically proposed exotic transport phenomena [6] and device functionalities [7], we have developed the growth process of $Co_3Sn_2S_2$ films, demonstrating anomalous Hall effect (AHE) with a tangent of Hall angle σ_{xy}/σ_{xx} as large as 0.20 [8] (σ_{xx} : longitudinal resistivity, σ_{xy} : Hall resistivity). In this study, by investigating the thickness d dependence of the electrical and magnetic properties, we detected ferromagnetism in a few-unit-cells-thick $Co_3Sn_2S_2$ films.

The films were grown on Al_2O_3 (0001) substrates by sputtering using a mosaic target composed of $SnS_{1.35}$ and Co metal [8]. The film composition measured for d = 40 nm by energy dispersive X-ray spectroscopy was $Co_3Sn_{2.02}S_{1.97}$. The single-phase, c-axis oriented growth was confirmed by X-ray diffraction. Using the identical growth condition, d was varied from 40 nm to 2.7 nm (~2 unit cell).

The d dependence of ρ_{xx} and ρ_{yx} at T = 2 K, and Curie temperature T_C is summarized in Fig. 1. The insets of Figs. 1(a) and (b) show the temperature T dependence of electrical resistivity ρ_{xx} and anomalous Hall resistivity ρ_{yx} for d = 40 nm, respectively. The decrease in d makes the system resistive, particularly for d less than 4 nm; ρ_{yx} (AHE) increases simultaneously. In addition to the determination of T_C using the AHE, we also measured the T_C for the insulating 2.7-nm-thick film with a superconducting quantum interference device magnetometer (Fig. 1(c)). These results indicate that the ferromagnetism of $Co_3Sn_2S_2$ persists in only a few-unit-cells thickness. The d dependence of MWS features will also be discussed in the presentation.

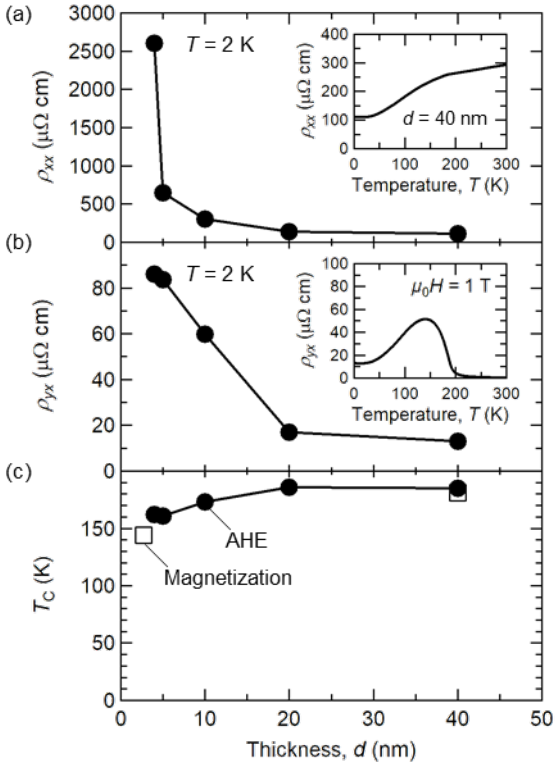

Fig. 1. d dependence of (a) ρ_{xx} and (b) ρ_{yx} at T = 2 K, and (c) T_C determined by the AHE and magnetization data. The insets in (a) and (b) display the T dependence of ρ_{xx} and ρ_{yx} measured for d = 40 nm, respectively.

References: [1] B. Yan and C. Felser, *Annu. Rev. Condens. Matter Phys.* **8**, 337 (2017), [2] E. Liu *et al*., *Nat. Phys.* **14**, 1125 (2018), [3] Q. Wang *et al*., *Nat. Commun.* **9**, 3681 (2018), [4] D. F. Liu *et al*., *Science* **365**, 1282 (2019), [5] N. Morali *et al*., *Science* **365**, 1286 (2019), [6] L. Muechler *et al*., arXiv:1712.08115 (2018), [7] K. Kobayashi *et al*., *J. Phys. Soc. Jpn.* **87**, 073707 (2018), [8] K. Fujiwara *et al*., *Jpn. J. Appl. Phys.* **58**, 050912 (2019).