Crystalline structure, magnetic and magnetotransport properties of Mn_3Sn thin films with various thicknesses

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Non-collinear antiferromagnet $D0_{19}$-Mn_3Sn has attracted much attention owing to its unique physical properties [1,2] and functionalities [3,4]. For further exploration, comprehensive characterization of crystalline structure and magnetic/magnetotransport properties is of great importance. Here, we systematically investigate these fundamental properties of Mn_3Sn thin film as a function of thickness and discuss the correlation between each parameter.

For the sample preparation, we deposit stacks consisting of W (2 nm)/Ta (3 nm)/Mn_3Sn (t_{Mn_3Sn})/MgO (1.3 nm)/Ru (1 nm) on MgO (110) substrate by DC/RF magnetron sputtering with various Mn_3Sn thicknesses t_{Mn_3Sn} ranging in 10-100 nm, followed by annealing at 500 ºC for an hour.

X-ray diffraction reveals that the $(1\bar{1}00)$ oriented epitaxial structure is formed in 20-40 nm, where the lattice parameter a approaches the bulk value as t_{Mn_3Sn} increases; polycrystalline structure is formed above 50 nm; and the order parameter S for $D0_{19}$ structure, rapidly increases from 15 to 20 nm and keeps a constant value of ~0.6 as reported in [5] above 20 nm. Magnetization measurement reveals that the Mn_3Sn layer has a spontaneous magnetization of 4.5±1.0 mT with a magnetically inactive thickness of about 7 nm. Magnetic anisotropy evaluated from a transport measurement shows a dominant contribution of two-fold anisotropy λ_2 that decreases with t_{Mn_3Sn} in the range 20-40nm. The saturated Hall conductivity $\sigma_{\mathrm{H}}^{\mathrm{sat}}$ rapidly increases from 15 to 20 nm and, above 20 nm, it saturates at ~20 $\mathrm{Scm^{-1}}$, which is close to the one reported for a bulk sample [1]. From the obtained results, we infer that λ_2 is correlated with a through the strain as pointed out in a previous report [6] and $\sigma_{\mathrm{H}}^{\mathrm{sat}}$ is affected by a formation of $D0_{19}$ structure. This work is an important step towards developing functional devices based on non-collinear antiferromagnetic thin films.

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