Systematic investigation of anomalous Hall effect in Co_2(Fe, Mn)Si Heusler alloy films with various compositions

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Anomalous Hall effect (AHE) is attracting great attention as a new scheme for generating spin current for novel spintronic devices. [1, 2] Recently, large AHEs have been oberserved in antiferromagnets [3, 4] and ferromagnetic semimetals [5, 6] due to the topological nature of their electronic structures. Cobalt-based full Heusler alloys with half-metallic band structures are promising materials for achieving very large magnetoresistance ratios. It is also reported that the half-metallic Heusler alloys exhibit topological behaviors in their electronic structures. [7] It is interesting to investigate the AHE in the Heusler alloys from the viewpoint of their tunable electronic structures.

In this work, we studied AHE in a series of Co_2(Fe, Mn)Si Heusler alloy films having the various concentrations of Fe and Mn, leading to the variation in their electric structures. All the films were deposited on MgO(001) substrates in an ultrahigh vacuum sputter system by a co-sputtering method with Co_2MnSi and Co_2FeSi targets. The structure of film stack is MgO(001) substrate//Co_2(Fe, Mn)Si (30 nm)/Ti(1 nm). The structural characterization indicates all the films were epitaxially grown on the MgO(001) substrates. The composition dependence of saturation magnetization followed the Slater-Pauling behavior of ferromagnetic Heusler alloys. For all the films, Hall bars were microfabricated in order to carry out the anisotropic magnetoresistance (AMR) and AHE measurements. The results of AMR measurement indicated the decline of half-metallicity with increasing Fe concentration. The dependence of anomalous Hall conductivity on longitudinal conductivity was nearly constant, indicating that the AHE is dominated by intrinsic electronic structures of the films. [8] We found that the anomalous Hall angle (θ_{AHE}) decreases with increasing the Fe concentration at each temperature, which is attributable to the variation of electronic structures of the Co_2(Fe, Mn)Si films with changing the concentration of Fe and Mn.

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