Structural-order dependence of anomalous Hall effect in Co_2MnGa full-Heusler alloy thin films

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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, a large AHE has been reported in Co_2MnGa full Heusler alloy films with an anomalous Hall angle of ~10%.[3,4] The origin of the large AHE was attributed to the topological properties of their electronic structures. It has also been reported that the electronic structures of Heusler alloys can be tuned by changing their degree of structural order. [5] In this study, the dependence of the AHE on the degree of structural order was investigated in Co_2MnGa full Heusler alloy thin films by varying the deposition temperatures.

The Co_2MnGa films with the thickness of 30 nm were deposited by a sputter system at different deposition temperatures of RT, 200 ºC, 400 ºC, 500 ºC and 600 ºC. The structures of the thin films were characterized by X-ray diffraction (XRD) with out-of-plane and in-plane scans. The (002) and (004) peaks were observed for all the samples regardless of the deposition temperature, which indicates the films were grown along the (001) orientation on MgO(001) substrates. By tilting the samples to χ = 54.7°, the (111) peaks were also detected. With increasing the deposition temperature, the (111) peak appeared and was clearly observed at the temperatures of 500 ºC and 600 ºC. The degree of structural order of the samples was evaluated as a function of deposition temperature. The Co_2MnGa films possess two kinds of ordered structures: $L2_1$ and $B2$ structures. The degree of order for $B2$ structure increases with increasing the deposition temperature from RT to 400 ºC, then is nearly saturated with a degree of $B2$-ordering of ~80% from 400 ºC to 600 ºC. The degree of order for $L2_1$ structure starts to increase at 400 ºC. The maximum degree of $L2_1$-order of 40% was achieved in the sample deposited at 600 ºC.

In order to evaluate the AHE, the films were microfabricated to Hall bar structure. The dependence of anomalous Hall resistivity on the deposition temperature and measurement temperature were investigated. Large anomalous Hall angles were observed for the samples deposited at 400 ºC, 500 ºC, and 600 ºC. Anomalous Hall angles of ~14% at 10 K and ~12% at 300 K were achieved at maximum. Considering the structural order of Co_2MnGa films, it is found that the samples containing $L2_1$ order show enhanced AHE. The mechanism on the structural order dependence of AHE could be the variation of electronic band structures due to the different order in the Co_2MnGa films. By further investigating the dependence of Hall conductivity on longitudinal conductivity, we have found that the dominant contribution to the AHE in the system is intrinsic contribution. This research could contribute to the design of new materials exhibiting large AHE by the control of structural order.

Reference

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