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Anomalous Hall Effect and Magnetoresistance in Sputter-Deposited Magnetic Weyl Semimetal Co_2TiGe Thin Films

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Herein, sputter-deposited ferromagnetic Weyl semimetal (WSM) and full-Heusler compound Co_2TiGe is investigated. Crystal quality is analyzed using X-ray diffraction and reflectivity. In addition, temperature-dependent transport and magnetization measurements are carried out. The sample shows indications on the formation of $L2_1$ crystal structure. Magnetization measurements show a saturation magnetization of 1.98 μ_B (f.u.)$^{-1}$ and 1.45 μ_B (f.u.)$^{-1}$ at 50 and 300 K, respectively. This is in close agreement to the calculated value of 2 μ_B (f.u.)$^{-1}$ at 0 K using the Slater–Pauling rule. The obtained Curie temperature is 378.5 K, which is close to prior results for bulk samples. The residual resistivity of 142.7 $\mu\Omega$ cm is mainly dominated by disorder scattering. At temperatures above 60 K, the Coulomb interaction dominates the resistance. The residual resistance ratio is around 1.49. Hall measurements show positive ordinary Hall and anomalous Hall constants and a positive dependence on temperature. Skew scattering and side jumps or intrinsic mechanisms contribute in similar amounts to the anomalous Hall resistivity, which indicates a higher than usual intrinsic contribution, which is expected for WSMs. The expected relation between the longitudinal and the anomalous Hall conductivity of $\sigma_{xy}^{A} \propto \sigma_{xx}^{0}$ is not met.

1. Introduction

Weyl semimetals (WSMs) have attracted large interest in recent years, as their band structure gives rise to nontrivial topological states. Their excitations (Weyl fermions) are expected to have a large mobility, and thus there are also potential applications of such materials in electronics. Their band structure shows a linear dispersion around Weyl nodes which results in exotic transport properties as well as a topological protection.[1–5] The WSM state is realized either by breaking time-reversal symmetry due to magnetism or crystal inversion symmetry. The latter was discovered in TaAs, whereas the magnetic counterparts remain elusive.[4,6,7]

Heusler alloys are a class of highly versatile materials, which provide a wide variety of properties such as ferrimagnetism, metallic or semiconducting character, and tailorable band structure.[8–10] Some of the cobalt-based Heusler alloys show a semimetallic behavior and have been thoroughly studied in recent years.[11–15] The Co_2TiGe (CTG) compound is one of those candidates and is promising, as it has a Curie temperature (T_C) above room temperature which is crucial for application. Several structural, magnetic, and transport studies on bulk CTG have been conducted and confirm the expected properties.[16–25] A recent study on CTG grown by molecular beam epitaxy (MBE) showed differing results.[26] In this work, we analyze thin films of CTG grown by sputter deposition, which is crucial for later real-life application and mass production.

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2. Results and Discussion

From X-ray fluorescence, the stoichiometry of the investigated sample system is found to deviate less than 1% from the target value of 50:25:25 of Co:Ti:Ge for each of the constituents. The X-ray reflectometry (XRR) and diffraction (XRD) measurements are carried out to find the best parameters for the film growth. The lattice constant of CTG is around 5.831 Å, thus, growth is expected to take place 45° rotated, i.e., parallel to the [110] direction on the substrate (MgO, lattice mismatch ≈2%).[27] This is confirmed by texture measurements (not shown here).

The crystallographic analysis is shown in **Figure 1**. Figure 1a shows the XRR result with a simulation of the experimental data using the Parratt recursion formula to simulate specular reflectivity. A very low roughness is obtained (standard deviation σ of the nominal thickness of 0.4 nm) and the fitted thickness $d = 20.4$ nm corresponds very well to the 20 nm value calculated via the deposition rates. The resulting density ρ is slightly higher than the expected value. Figure 1b shows the XRD results of the same sample on an MgO substrate with an adjacent MgO seed layer. The spectrum shows the MgO (002) substrate double peak (Cu $K_{\alpha1}$ and $K_{\alpha2}$) at $2\Theta \approx 42.9°$, as well as the small Cu K_β feature at $2\theta \approx 38.6°$. The CTG thin films is presented by the (004) fundamental peak at $2\theta = 63.76°$ and the order dependent (002) peak

