Carbon-induced enhancement of anomalous Hall and negative anisotropic magnetoresistance effects in ferromagnetic thin films

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Current-induced magnetization switching (CIMS) has attracted attention because of its potential for spin-orbit-torque based magnetic random access memories (SOT-MRAMs).[1] However, external magnetic fields must be applied to the devices to break inversion symmetry for the CIMS by SOT, which is one of the issues to be solved for higher recording density. Several technologies have been proposed, on the other hand, we focus on the use of SOT originating from the anomalous Hall effects (AHE) in ferromagnetic (FM) layers. This is referred to as a spin-AHE, and the CIMS without external magnetic fields has been successfully demonstrated in the trilayer structure of FM1/non-magnetic layer/FM2.[2] Large AHE could promise high efficiency for spin-AHE, therefore, we aim to develop a technology to boost AHE in this study. As a result, it was revealed that one of the 2*p* light elements of carbon (C) was responsible for the enhanced AHE in an ordinary FM. Furthermore, increase in saturation magnetization and negative anisotropic magnetoresistance (AMR) were observed.[3]

C was embedded in the host 16-nm-thick CoMn films, which is known as an antiferromagnetic alloy,[4] via vacuum carburization process with Ar and C_2H_2 gas mixture under the annealing temperature of 500 °C.[3] Possible crystal structure revealed by x-ray diffraction is depicted in Fig. 1(a), suggesting the $L1_0$-like structure with the C at body-centered site. Figure 1(b) shows the AHE loops for the films with various content of C. It was revealed that the magnetic easy-axis lies on the film plane, and the magnitude of AHE enhanced drastically by C. Conversely, the film without C shows remarkably small value; therefore, C would be a booster of AHE. In order to discuss the origin of AHE, the relationship between σ_{xy} and σ_{xx} was examined as shown in Fig. 1(c). The σ_{xy} showed nearly constant at $\sigma_{xx} \approx 10^4$ S/cm, indicating the intrinsic contribution might dominate the AHE in the Co_2Mn_2C films. The enhanced saturation magnetization and negative AMR effects including fine crystal structures will be shown at the conference.

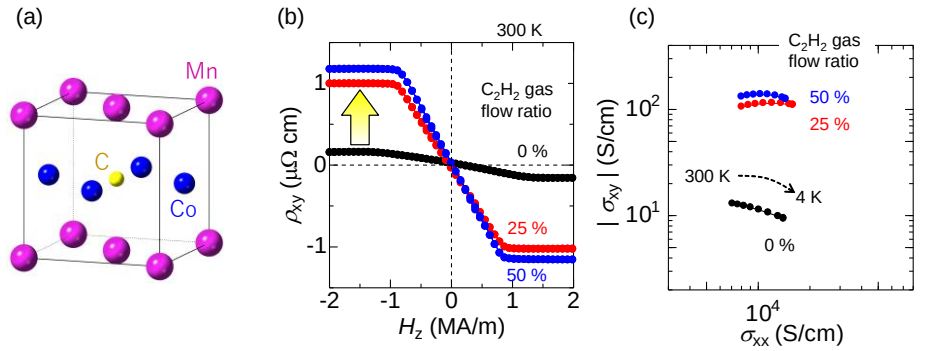

Fig. 1 (a) Unit cell of Co_2Mn_2C. (2) Transverse electric resistivity (ρ_{xy}) as a function of perpendicular magnetic fields (H_z) for the 16-nm-thick Co_2Mn_2C and CoMn films, where the content of C is varied by C_2H_2 gas flow ratio in the vacuum carburization process. (3) Longitudinal conductivity (σ_{xx}) dependence of transverse conductivity (σ_{xy}) for the same films.

Reference

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