Observation of Neel temperature of Cr_2O_3 in Cr_2O_3/Co exchange coupled system

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Magnetoelectric chromia (Cr_2O_3) has a potential for application in development of low power consumption high density storage devices due to its electrically switchable magnetic states[1].However, the antiferromagnetic ordering temperature of bulk chromia is just above the room temperature (T_N=307 K), which restricts its practical application and hence it is required to enhance the T_N. Previous reports suggest that the T_N can be enhanced by inducing strain and doping in Cr_2O_3[2,3]. The detection of T_N and its distinction from blocking temperature T_B is sometimes difficult in an exchange coupled multilayer system. Since the exchange coupling adds unidirectional anisotropy (H_{EX}) or uniaxial anisotropy (H_C), in Cr_2O_3/Co exchange coupling system, T_N can be estimated by investigating temperature dependence of total anisotropy (H_{EX}+H_C). However to check H_{EX} and H_C, we have to measure a number of M-H curve, and it is time-consuming. In this work, we propose on the direct detection of T_N by M-T measurement. We also detect change in T_N due to lattice distortions from the M-T measurements.

Our specimen is a layered heterostructure of Al_2O_3<0001> substrate/Buffer layer/Cr_2O_3 (20)/Metal spacer/Co (1)/Pt (5) in nm. We have fabricated two samples having Fe_2O_3 (20), Pt (25) as buffer layer and one sample without buffer layer. Different buffer layers are used to control T_N by inducing lattice strain. Cr_2O_3 is deposited by using reactive RF magnetron sputtering from a metallic Cr target in Ar:O_2 atmosphere. Out of plane magnetization measurements are carried out by using a SQUID (MPMS XL7) magnetometer.

Figure 1 compares (a) the temperature dependent total anisotropy (H_{EX}+H_C) and (b) the temperature dependent FC magnetization of Fe_2O_3 buffered sample. FC magnetization measurement is carried out with an application of external magnetic field of 200 Oe. In Fig. 1 (a), the enhancement of H_{EX}+H_C is observed below 270K, which is assigned to the T_N of Cr_2O_3. In Fig. 1 (b), a sudden drop in FC magnetization is observed at temperature around 269 K, which is identical to the T_N. Above T_N of Cr_2O_3, the AFM order destroys, which results in the change of perpendicular magnetization in exchange coupled system. Same behaviors are noticed in the samples with Pt buffered and without buffered samples. In the former case, the observed T_N is 294 K, while the latter has 284 K. These results indicate that we succeed to observe T_N of Cr_2O_3 from M-T measurements. In all cases obtained T_N is lower than the bulk value which is mainly due to the reduction of Cr_2O_3 thickness. The difference in T_N for each sample may reflect the lattice mismatch induced strain. With increasing in-plane lattice parameter of buffer layer, observed T_N of Cr_2O_3 become smaller. This behavior is in agreement with the theoretical calculation results[2].

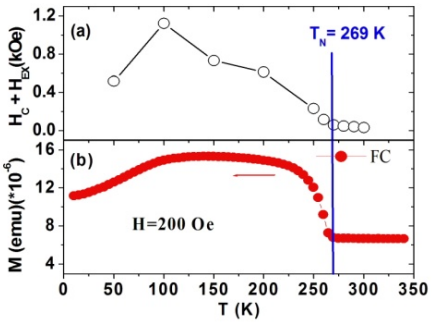

Fig 1. Temperature dependent H_C+H_{EX}(a) and FC magnetization(b) of Al_2O_3/Fe_2O_3(20)/Cr_2O_3(20)/metal spacer/Co(1)/Pt(5)

Reference
1) X. He *et al.* Nat. Mater., 9 (2010) 579.
2) Kota *et al.* Applied Physics Express 6 (2013) 113007.
3) Sai Mu *et al.* Phys. Rev. B, 87 (2013) 054435.