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Study on Magnetoelectric Effect in Thin Film Cr_2O_3 Sesquioxide and Electrical Switching of H_{EX} and Residual Magnetization

Magneto-Electric (ME) effect has been paid much attention from the perspective of voltage controlled magnetization switching. Cr_2O_3 oxide is a typical sesquioxide that shows ME effect and its antiferromagnetic Neel temperature is T_N =307 K, which is highest in ME materials. A robust isothermal electric control of exchange-bias field at RT is actually reported for bulk single crystal Cr_2O_3 (0001) substrate/Pd 0.5 nm/(Co 0.6 nm/ Pd 1.0 nm)$_3$ exchange-biased system after initial ME annealing (E=1 kV/cm and H=778 Oe), where isothermal-field exposure is under E=26 kV/cm and H= 1.54 kOe (|EH| product ~ 40 kV/cm・ kOe), respectively [1]. But it is of much note that ME effect has been not yet confirmed in thin film form, which is the key for the whole evolution to device application, because of its large leakage current while ME effect like behavior is reported to be observed up to 200K in an ultrathin Cr_2O_3/Fe_2O_3 nano-oxide layer by investigating the training effect (partial surface spin reversal by the ME effect) [2]. Considering the application of ME effect to storage/memory technology for voltage-controlling magnetization switching, there are many concerns including the above, which should be resolved. The first is to realize and design an effectually high exchange-bias filed between Cr_2O_3 and FM thin film layers in the higher temperature range than RT, which means high blocking temperature (T_B), where the properly low coercive force of FM is also required. The second is to invest FM layer with a perpendicular anisotropy, which is thought to be caused by both of the hybridization of FM 3d and O 2p orbitals (interface anisotropy; K_S) and the exchange anisotropy (K_{EX}) at the interface between FM and Cr_2O_3 besides the bulk anisotropy (K_V) of FM layer. The third is to confirm ME effect in the thin film Cr_2O_3 after getting Cr_2O_3 thin film which shows good electrical properties. In this study, magnetoelectric effect of the thin film Cr_2O_3 sesquioxide with good leakage-current property (~10^{-5}A/cm^2) and the exchange-bias property were investigated. We successfully confirmed ME effect of the Cr_2O_3 thin film, and observed clear electrical switching of H_{EX} and the residual magnetization in M-H curve for the perpendicular magnetized FM layer with low coercivity. The electrical properties in the perpendicular direction of our thin film were as follows ; The leakage current density at E = 20 [kV/cm] is as small as 3 × 10 $^{-6}$ [A/cm^2]. The parasitic resistance, the film resistance and the capacitance were 16.6 [Ω], 80.2 [kΩ] and 17.2 [nF], respectively. Dielectric constant ε_r calculated from these results was 13.8, which is almost same as that reported (ε_r = 11.9). In addition, we also successfully observed the effect of Fe_2O_3 buffer layer on H_{ex} and T_B. Exchange biased system with Cr_2O_3 thin film and thin Fe_2O_3 buffer (5 nm) shows high J_K up to 0.44 (erg/cm^2) and higher T_B more than 200K. In presentation, the control of both of Neel temperature for Cr_2O_3 and Morin temperature for Fe_2O_3 is also discussed from a perspective of future device application.

Monday, November 11, 4:00 pm (*refreshments at 3:45 pm*)
Room 136 Jorgensen Hall

Host:
Dr. Christian Binek
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Physics & Astronomy

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