Characterization of magneto-electric switching energy in Cr_2O_3 antiferromagnetic thin films

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Introduction: Towards applications in voltage-controlled HDD and MRAM, usually the ferromagnetic layer is considered as the “active” media. A possibility of using antiferromagnetic (AFM) media is hindered by the difficulty of controlling and accessing the antiferromagnetic state. Recently, there is a revival in utilizing the magnetoelectric (ME) antiferromagnet Cr_2O_3, where the electric control of perpendicular exchange-bias in a Cr_2O_3/Co multilayer system has been realized under the simultaneous application of electric and magnetic fields[1–4] . However, The required energy of the product of electric and magnetic fields (EH) is 2 to 3 orders of magnitude higher in thin-film systems compared with bulk crystals[1,5]. In this presentation, we will present the investigation of the origin of this increase, and a novel way to control it.

Experimental procedure: Two samples were used, sample A was a commercial bulk Cr_2O_3 substrate, sample B was a sputter-deposited thin-film sample of the following structure: *c*-Al_2O_3 sub./Pt 25 nm/Cr_2O_3 500 nm/Pt 25 nm. The average domain state of Cr_2O_3 was measured by the linear magnetoelectric susceptibility (α) in a SQUID magnetometer. The application of a small electric field (E) results in an induced magnetization (M = αE), and the sign of α indicates the AFM domain state of Cr_2O_3.

Results and discussions: Figure 1 shows the comparison between the temperature-dependence of α in samples A and B. Except for a small decrease in Neel temperature, the magnitude of α is same and the ME property is intrinsically similar in thin films as to bulk crystals. The increase of EH switching product in thin films is mostly due to the increase of exchange-bias energy density as the thickness becomes reduced orders of magnitude.

Additionally, we surprisingly found a weak magnetization from Cr_2O_3 films, which was coupled to AFM order parameter. This weak magnetization required an additional EH switching energy for single-layer Cr_2O_3. However, the sign of switching EH energy required to overcome the weak magnetization is opposite to the EH energy required to overcome the exchange-coupling energy with the Co layer. We could design a balance between both, and we could decrease the switching energy 2 orders of magnitude compared to other reports on thin-film Cr_2O_3.

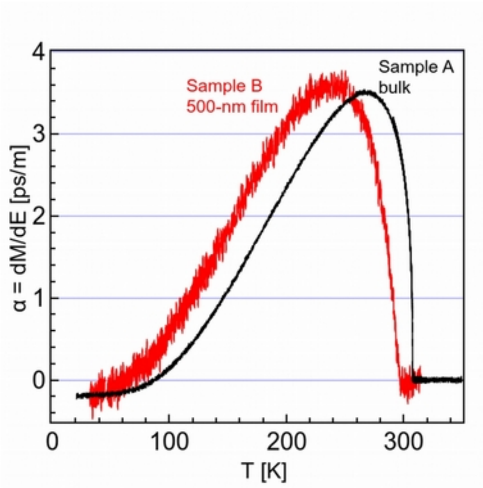

Fig. 1 Temperature-dependence of α in samples A and B

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