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# Electric control of magnetization using magnetoelectric effect of $Cr_2O_3$ thin film for low energy consumption magnetic recording devices

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Recently for the demand of low energy consumption memories and storage devices, voltage control of magnetic properties are paid considerable attentions. Voltage control of magnetization by using magnetoelectric (ME) materials combined with exchange bias effect is one of the promising candidate. For the application, ME antiferromagnet $Cr_2O_3$ is the most powerful candidate, because $Cr_2O_3$ has relative high the Neel temperature $T_N$ ~ 307 K and strong exchange bias effect can be obtain for $Cr_2O_3$ (0001)/Co system. Since the antiferromagnetic domain of $Cr_2O_3$ can be reversed by the ME effect (by applying both magnetic field H and electric field E), it exhibits non-volatile properties. In addition, not uni-axial but uni-directional anisotropy is added by the exchange coupling effect. That is, the direction of the magnetization M thoroughly correspond to the direction of applied electric field E; if we apply positive (negative) E, positive (negative) M state is stabilized. Thus far, magnetization reversal of $Cr_2O_3$/ferromagnet system by ME effect was realized only using $Cr_2O_3$ bulk. Due to the difficulty to make $Cr_2O_3$ film which fulfill both good insulating and magnetic properties, ME effect had never observed for $Cr_2O_3$ thin film system. In this study, we fabricated a $Cr_2O_3$ thin film with good electrical and magnetic properties, and finally succeeded in observing electric switching of magnetization using samples with $Al_2O_3$ (0001) sub./Pt (25)/$Cr_2O_3$ (500)/spacer layer (t)/Co (1)/Pt (5 nm) structure. Both magnetic and electric fields are applied isothermally, and by changing the direction of the electric field during the isothermal process, the switching of magnetization was achieved. We provided the path to new energy saving magnetic recording devices.

**Keywords**: magnetoelectric effect, exchange bias, voltage control of magnetization, thin film