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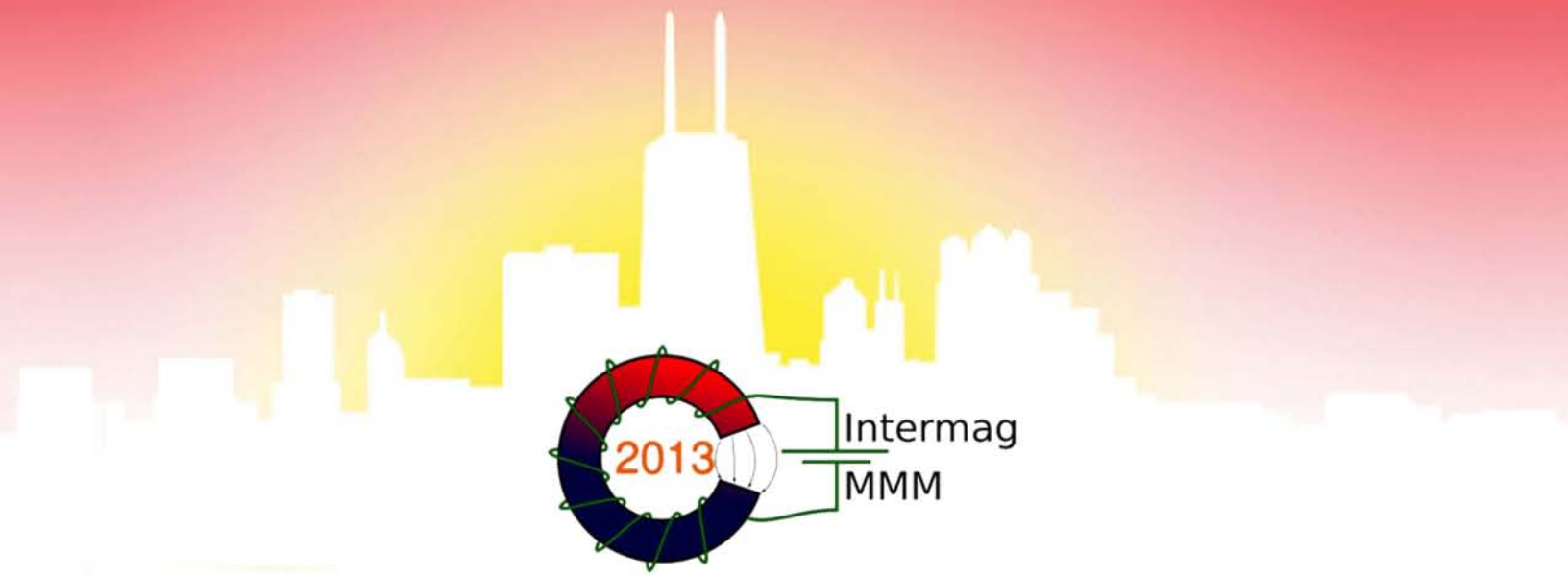


ABSTRACTS

IEEE MAGNETICS

AIP American Institute of Physics

Session ES
MULTIFERROIC MATERIALS I (POSTER SESSION)

Yan Zhuang, Chair

CONTRIBUTED PAPERS

ES-01. Magnetic and ferroelectric domain dynamics in multiferroic $YMnO_3$ single crystal. *Y. Du*[1], D. Chen[1], X. Wang[1] and S. Dou[1] *1. Institute for Superconducting and Electronic Materials (ISEM), University of Wollongong, Fairy Meadow, NSW, Australia*

We have investigated the magnetic and ferroelectric domain dynamics in magnetically frustrated multiferroic $YMnO_3$ single crystals. The single crystal samples were grown in various oxygen concentrations by a floating zone method. By using an ultra-high vacuum (UHV) magnetic force microscopy (MFM) and piezoresponse force microscopy (PFM), a trimerized antiferromagnetic and ferroelectric domain wall structure were observed at 60 K. It is found that six ferroelectric domains (±α, ±β, ±γ) joint at one point which are also the magnetic vortex core. The interlocked ferroelectric and antiferromagnetic domain walls form a wedge-shape multiferroic domain wall structure. When an electric field is applied, ferroelectric domains evolve into curved configuration which induces an corresponding motion of antiferromagnetic domain walls. By using dark-field TEM, we found multiferroic domain dynamics is dominated by structural antiphase domain wall, which firmly couples with both ferroelectric and antiferroelectric domain walls. By using high-resolution PFM, it is verified that defects, such as oxygen vacancies, could pin domain wall motion which in turn depress the electric polarization in the sample. Due to strong coupling among structural, ferroelectric, and magnetic DWs in $YMnO_3$, it is possible to manipulate ferroelectricity, magnetism and multiferroicity through controlling domain wall dynamics by tailoring oxygen vacancies.

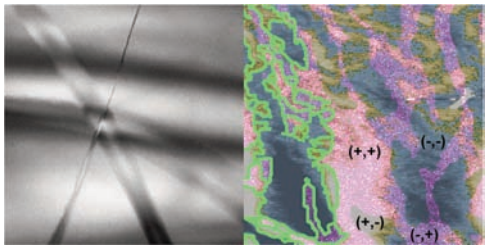
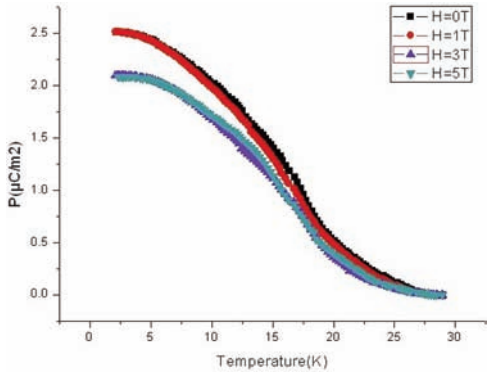


FIG.1 Dark-field TEM and combined MFM and PFM images of domain wall structure in $YMnO_3$ single crystal. (+,+), (+,-), (-,+), and (-,-) represent the different states of coupled magnetization and electric polarization.

ES-02. Multiferroicity in spin ice Ho2Ti2O7. D. Liu[1], L. Lin[1], Y. Xie[1], Z. Yan[1], *S. Dong*[2] and J. Liu[1] *1. Department of Physics, Nanjing University, Nanjing, Jiangsu, China; 2. Department of Physics, Southeast University, Nanjing, China*

Multiferroic materials in which ferroelectricity and magnetism can be controlled by a magnetic field or magnetic field have recently become the focus of much researches due to the potential applications. Pyrochlore compounds with the general formula A2B2O7 are an important class of dielectric materials and the ferroelectricity in a number of pyrochlore oxides, such as Cd2Nb2O7 and Cd2Re2O7 etc., were reported. In recent years, magnetic rare-earth titianate cubic pyrochlore materials with geometrically frustrated magnetic structures have been addressed and they are usually named spin ice materials. There are lots of attentions on the magnetic properties of these spin ice compounds including Ho2Ti2O7, Dy2Ti2O7, and Tb2Ti2O7. However, there is little work focusing on the multiferroic properties. Our work intends to deal with this issue. We perform careful experiments on the ferroelectric and magnetic behaviors of single crystal Ho2Ti2O7 in two different direction <111> and <110>. The polarization emerges below ~28K, coinciding with the dielectric bump, and increases smoothly with decreasing temperature, with polarization P ~2.40 uC/m^2 along the direction of <111> and ~2.0 uC/m^2 along the in the direction of <110> at 2K. The smooth increase of polarization may attribute to the mechanism proposed by Khomskii (D. I. Khomski, Nature Comm. 10, 1038 (2012)). We also found an abrupt suppressed polarization with the increase of magnetic field between 1T and 3T. This phenomenon is believed to be induced by the strong magnetic anisotropy. Our data indicate that Ho2Ti2O7 may be a multiferroic, as an example of spin ice oxides.



Mearsured polarization P along the <111> direction for Ho2Ti2O7.

ES-03. Effect of Ni substitution on Y-type Barium Ferrite. *M. Won*[1], J. Lim[1] and C. Kim[1] *1. Department of Physics, Kookmin University, Seoul, Republic of Korea*

Recently, non-collinear magnetic-ordered Y-type hexaferrites have been studied for magnetoelectric effect and helical spin structures which depend on the temperature and magnetic field. Especially, Ni substituted Y-type hexaferrites have higher magnetic ordering temperature than other types of hexaferrites have. Here, we studied the crystal structure and magnetic properties of Ni-substituted Y-type Barium Ferrite. The single-phased $Ba_2Co_{2-x}Ni_xFe_{12}O_{22}$ (x = 0, 0.5, 1) samples were synthesized by solid-state reaction method. The crystal structure of samples was determined to be hexagonal with *R-3m*. The Rietveld refinement showed that the unit cell volume of samples decreased with increasing Ni concentration because the ionic radius of the Ni^{2+} is smaller than that of Co^{2+}. Saturation magnetization (M_S) and coercivity (H_C) of $Ba_2Co_{2-x}Ni_xFe_{12}O_{22}$ with x of 0, 0.5, and 1 were M_S = 29.1, 27.3, 24.6 emu/g, and H_C = 207.10, 196.07, 127.41 Oe at 295 K, respectively. With increasing Ni content, M_S of samples decreased due to the fact that Ni^{2+}, which has smaller spin value S of 1 than Co^{2+} having S = 3/2, preferentially occupied the octahedral site with up spin sub-lattice. The temperature dependence of the magnetization under 100 Oe from 4.2 to 740 K showed the

magnetic structure transitions from hellimagnet to ferrimagnet around 210 K and from ferrimagnet to paramagnet around 625 K. While the spin transition temperature of samples decreased with increasing Ni content, the Né el temperature increased with Ni concentration. The Mö ssbauer spectra analysis showed the coexistence of Fe ions at six sub-lattices with different occupancy ratio and from temperature dependence of isomer shift value and magnetic hyperfine field (H_{hf}), we determined that Fe ions were at high spin Fe^{3+} state. Also, we have observed an abrupt change of H_{hf} around 210 K, corresponding to the hellimagnetic to ferrimagnetic phase transition temperature shown in ZFC curve.

[1] H. B. Lee, Y. Song, J. Chung, S. H. Chun, Y. S. Chai, K. H. Kim, M. Reehuis, K. Prokeš, and S. Mat'aš, Phys. Rev. B **83**, 144425 (2011). [2] Y. Hiraoka, H. Nakamura, M. Soda, Y. Wakabayashi, and T. Kimura, J. Appl. Pys **110**, 033920 (2011).

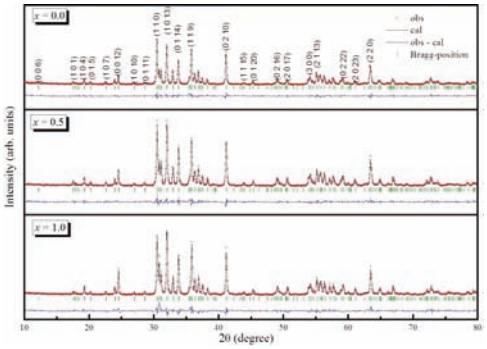


Fig. 1. Refined x-ray diffraction patterns of $Ba_2Co_{2-x}Ni_xFe_{12}O_{22}$ at 295 K.

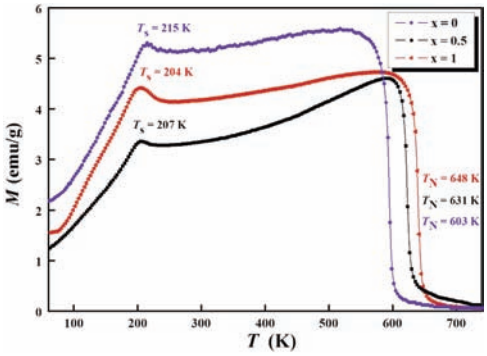
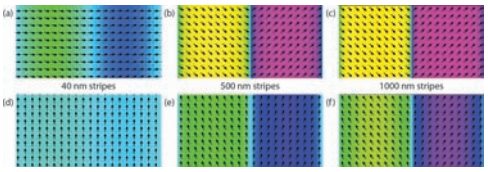


Fig. 2. Temperature dependence of the magnetization for $Ba_2Co_{2-x}Ni_xFe_{12}O_{22}$ with an external field 100 Oe.

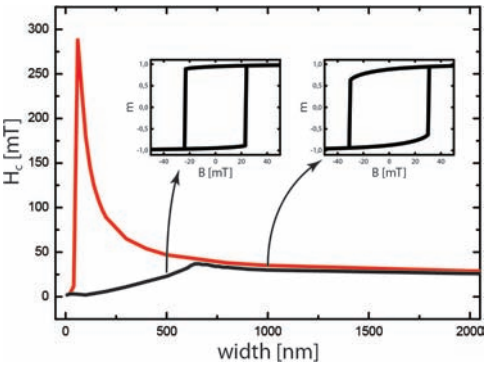
ES-04. Finite-Size Scaling of Domain Pattern Transfer in Thin-Film Ferromagnetic-Ferroelectric Heterostructures. *K. Franke*[1], T. Lahtinen[1] and S. Van Dijken[1] *1. Department of Applied Physics, Aalto University School of Science, Espoo, Finland*

Strain transfer in multiferroic heterostructures can produce large lateral modulations in magnetoelastic anisotropy via inverse magnetostriction and this can lead to full imprinting of ferroelectric domain patterns into continuous ferromagnetic films [1]. However, exchange and magnetostatic interactions within ferromagnetic films oppose the formation of such regular domains. As a consequence, imprinting of ferroelectric domains into ferromagnetic thin films depends critically on the competition between strain-driven magnetoelectric coupling at the interfaces of both ferroic materials and magnetic interactions within the ferromagnet. To elucidate the physics behind the relevant interaction mechanisms in continuous thin-film structures, finite-size scaling of domain pattern transfer is investigated using micromagnetic simulations [2,3]. Our model system consist of a thin ferromagnetic film that is coupled to a ferroelectric medium with a regular in-plane 90° ferroelastic domain pattern, which can be found in perovskite ferroelectrics such as $BaTiO_3$ and $BiFeO_3$. We demonstrate that the spin rotation between neighboring domains decreases when the width of the stripe domains is reduced (Fig. 1). Moreover, the domain size at which pattern transfer breaks down depends critically on the type and width of the magnetic domain walls [4]. The breakdown of domain pattern transfer coincides with a maximum in coercivity and a change in the shape of the magnetic hysteresis curves (Fig. 2).

[1] T.H.E. Lahtinen, J.O. Tuomi, and S. van Dijken, Adv. Mater. 23, 3187 (2011), ibid IEEE Trans. Magn. 47, 3768 (2011) [2] http://math.nist.gov/oommf. [3] W. Wang, C. Mu, B. Zhang, Q. Liu and D. Xue, Comput. Mater. Sci. 49, 84 (2010) [4] K.J.A. Franke, T.H.E. Lahtinen, and S. van Dijken, Phys. Rev. B 85, 094423 (2012)



Magnetic domain patterns as a function of stripe width for narrow uncharged (a-c) and broad charged (d-f) domain walls.



Coercivity as a function of domain stripe width for both domain wall types and hysteresis curves above and below the coercivity peak.

ES-05. Dielectric responses and origin in antiferromagnetic/ferroelectric (1-x)($BiFeO_3$)-(x)($BaTiO_3$) ceramics. *C. Tu*[1,2], Y. Peng[2], J. Anthoninappen[1], R.R. Chien[3], L. Chang[2] and I. Wu[2] *1. The Graduate Institute of Applied Science and Engineering, Fu Jen Catholic University, Taipei, Taiwan; 2. Physics, Fu Jen Catholic University, Taipei, Taiwan; 3. Physics, Montana State University, Bozeman, MT*

Dielectric responses and magnetization have been measured in antiferromagnetic/ferroelectric (1-x)($BiFeO_3$)–(x)($BaTiO_3$) (BFO-xBTO) ceramics for x=0.0, 0.05, and 0.10, which were prepared by the solid state reaction method. A frequency-dependent dispersion of dielectric maximum appeared in the low-temperature region, while a phase-shifted conductivity was evident in the high-temperature region. These frequency-dependent dielectric maxima are likely activated by the antiferromagnetic (AFM)-paramagnetic (PM) transition in the rhombohedral structure. The linear magnetization curves vs. magnetic field of BFO, BFO-5%BTO, and BFO-10%BTO indicate an antiferromagnetic feature as shown in Fig. 1. The magnetic susceptibilities of BFO, BFO-5%BTO, and BFO-10%BTO ceramics vary in the range of 5.0×10^{-6}-8.7×10^{-6} emu/gOe. The magnetization results suggest that $BaTiO_3$ substitution slightly reduces the magnetic susceptibilities. To understand the dielectric responses and large conductivity, a one-dimensional across-barrier model (as shown in Fig. 2) with intrinsic barriers B (in temperature units) every lattice constant a and extrinsic barriers B+Δ every distance d, is introduced to describe the dielectric responses and conductivity as functions of temperature and frequency. The across-barrier conductive hopping is responsible for the high-temperature conductivity and step-like dielectric relaxation in the high-temperature region (500-800 K). Good qual-