Ferroelectric and Magnetic Domain Structure Control in Co substituted $BiFeO_3$ Thin Films

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Professor Masaki Azuma obtained his Ph.D. from Kyoto University, Japan in 1995. From 2004 to 2010, he served as an associate professor at the Institute for Chemical Research, Kyoto University. Currently, he is a professor at Institute of Science Tokyo, Japan. He is the chairman of the World Research Hub Initiative at Institute of Science Tokyo, and a council member of the High Pressure Science and Technology Advanced Research Institute (HPSTAR) in Japan. He is a senior researcher in the field of solid-state physics and chemistry. He has discovered various functional new materials such as spin ladder compounds, ferromagnetic ferroelectrics, lead-free piezoelectric materials, and negative thermal expansion materials by high-pressure synthesis, and clarified their functional manifestation mechanisms by synchrotron radiation X-ray diffraction and spectroscopy.

Abstract

Electric field manipulation of magnetization is intensively investigated because of potential application in low-power-consumption non-volatile magnetic memory devises. Ferroelectric $BiFeO_3$ has a cycloidal space-modulated spin structure with a periodicity of 62 nm superimposed on the G-type antiferromagnetic structure which prohibits the appearance of net ferromagnetic magnetization due to spin canting. We have found a spin structure transition from low-temperature cycloidal one to high-temperature collinear one at ~200 K in rhombohedral $BiFe_{0.1}Co_{0.9}O_3$ [1]. Spontaneous magnetization of 0.03 mB/f.u. confined in a magnetic easy plane perpendicular to the electric polarization is generated by Dzyaloshinskii-Moriya interaction. Films fabricated by pulsed laser deposition on $GdScO_3$ (110) substrate has out-of-plane component of magnetization which can be observed by magnetic force microscopy (MFM). It is demonstrated that the out-of-plane magnetization can be reversed by electric polarization reversal using piezo response force microscopy (PFM) at room temperature [2]. Control of ferroelectric and magnetic domain structures of $BiFe_{0.1}Co_{0.9}O_3$ films with various orientations and nanodots will be discussed [3,4].

References

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Phase Transitions and Quantum Phenomena in Cross-Coupled Order Parameter Oxides

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Dr. Hena Das joined the WRHI and Laboratory for Materials and Structures at the Tokyo Institute of Technology (now Institute of Science Tokyo), Japan, in 2018 as a specially appointed Associate Professor. Currently, she holds a research position at the Kanagawa Institute of Industrial Science and Technology (KISTEC). She holds a Ph.D. from the University of Calcutta, India and has held research associate positions at the Cornell University, the Massachusetts Institute of Technology (MIT), and the University of California, Berkeley, USA. A theoretical condensed matter physicist by training, Dr. Das's research interests and activities focus on *ab* initio theoretical studies of various quantum phenomena in materials. Her research group aims to develop quantitative guidelines to tailor material properties for the design of novel materials for energy applications.

Abstract

Phase transitions and quantum phenomena in materials having multiple order parameters and cross-coupling between them are crucial. Our research focuses on understanding the microscopic mechanisms of these phenomena. In the first half of my talk, I will focus on multiferroic and magnetoelectric systems. I will explain how a sixfold primary order parameter coupled with electric and magnetic order parameters can realize ferrimagnetic orders with high magnetization and room temperature magnetic transition temperature, along with strong magnetoelectric coupling in a class of multiferroics forming topologically protected sixfold ferroelectric vortices [1-6]. I will also discuss multi-mode and magnetoelectric coupling phenomena in other systems, such as Co-substituted $BiFeO_3$ and 3d-5d high-temperature magnetic double perovskites. Finally, I will elaborate on the microscopic origin of spin-reorientation transitions rooted in cross-coupled mechanisms. In the second part of my talk, I will delve into the couplings between various order parameters and their influence on the thermal expansion properties of Ca_2RuO_4. I will emphasize the significance of higher-order anharmonic effects, which deviate from the quasiharmonic approximation, in understanding quasi-2D thermal expansion in Ca_2RuO_4.

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