A Multiferroic on the Brink: Modulation of Ferroelectric, Magnetic, and Optical Response using Strain-induced Transitions in $BiFeO_3$ films

D. Sando[1,*] T. Young[1], Y. Zhou[1], C. Carrétéro[2], V. Garcia[2], S. Fusil[2], A. Barthélémy[2], M. Bibes[2], P. Munroe[1], and V. Nagarajan[1]
[1]Department of Materials Science and Engineering, UNSW Sydney, 2052 Australia
[2]Unité Mixte de Physique, CNRS, Thales, Univ. Paris-Sud, 91767 Palaiseau, France
*Daniel Sando: daniel.sando@unsw.edu.au

Bismuth ferrite ($BiFeO_3$ – BFO) is one of the few known multiferroic materials. The bulk compound is rhombohedral (R), and in thin films it has been shown to possess a wealth of strain-induced property modifications [1-3]. Under strong compressive strain, a structural transition into a "super tetragonal phase" (T-phase) in this material occurs [4], and the discovery of this phenomenon incited a flurry of research activity focused on gaining an understanding of the phase transition and its possible functionalities [5]. This metastable T phase of $BiFeO_3$ is also multiferroic, with large ferroelectric polarization and coexisting antiferromagnetic order [4], but above all it is the strain relaxation-induced phase mixtures and their outstanding piezoelectric and magnetoelectric responses [6,7] which continue to intrigue and motivate the physicist and materials scientist communities. A particularly important facet of this phase mixture system is the possibility to interconvert between the different phases by the application of an electric field [6]. Since the octahedral coordination of the R and T polymorphs is vastly different [8], the electronic, magnetic, and optical properties can be dynamically modulated using only an electric field. An additional rather crucial (and thus far underexplored) aspect of the mixed R/T phase BFO system is the role of chemistry in the formation of the metastable T-phase. Since these samples are typically fabricated by pulsed laser deposition, the growth parameters can be used as a strong handle to tailor the film properties and functionalities.

In this presentation we describe our results on the modulation of the optical and ferroelectric properties of $BiFeO_3$ films tuned near the strain-induced morphotropic phase boundary. Since the optical band gap and absorption edges of the R and T phases are rather distinct, using an applied electric field we demonstrate a strong modulation of the optical absorption in the visible spectral range [9], a property known as *electrochromism*. In addition, we will show that by precisely controlling the fabrication conditions, the formation of the mixed phase can be completely suppressed for film thicknesses up to 100 nm. This intriguing result could be useful for applications where thicker pure T phase films are needed, such as for measuring the polarization of the T phase, or for precisely controlling the proportions of the various phases. Combined with the other remarkable functionalities of this material, one can envisage multifunctional devices, for example, that harvest mechanical and solar energy, or to enhance magnetoelectric coupling at these phase boundaries.

References

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