Strain and Magnetic Field Induced Spin-Structure Transitions in Multiferroic $BiFeO_3$

A. Agbelele[1], D. Sando[2,3,*], C. Toulouse[4], C. Paillard[5], R.D. Johnson[6], R. Rüffer[7], A.F. Popkov[8], C. Carrétéro[2], P. Rovillain[4], J.-M. Le Breton[1], B. Dkhil[5], M. Cazayous[4], Y. Gallais[4], M.-A. Méasson[4], A. Sacuto[4], A.K. Zvezdin[8], A. Barthélémy[2], J. Juraszek[1], and M. Bibes[2]

[1]Normandie Univ, UNIROUEN, INSA Rouen, CNRS, GPM, 76800 Rouen, France

[2]Unité Mixte de Physique, CNRS, Thales, Univ. Paris-Sud, 91767 Palaiseau, France

[3]Department of Materials Science and Engineering, UNSW Sydney, 2052 Australia

[4]Laboratoire MPQ (UMR 7162 CNRS), Université Paris Diderot-Paris 7, 75205 Paris Cedex 13, France

[5]Laboratoire SPMS, CentraleSupelec, CNRS-UMR8580, 92290 Châtenay-Malabry, France

[6]Clarendon Laboratory, University of Oxford, Parks Road, Oxford OX1 3PU, UK

[7]European Synchrotron Radiation Facility, CS 40220, F-38043 Grenoble Cedex 9, France

[8]Moscow Institute of Physics and Technology (State University), 141700 Dolgoprudny, Russia

*Daniel Sando: daniel.sando@unsw.edu.au

In multiferroic materials [1], the coexistence of several exchange interactions often results in competition between non-collinear spin orders which are sensitive to temperature, hydrostatic pressure, or magnetic field. In bismuth ferrite ($BiFeO_3$), a room-temperature multiferroic [2], the intricacy of the magnetic phase diagram is only fully revealed in thin films [3]: epitaxial strain suppresses the cycloidal spin order present in the bulk [4], transforming it into various antiferromagnetic states, modifying the spin direction and ordering patterns [5]. Here, we explore the combined effect of strain and magnetic field on the spin order in $BiFeO_3$. Through nuclear resonant scattering [6] and Raman spectroscopy, we show that both strain and magnetic field destabilize the cycloid, resulting in a critical field sharply reduced from the bulk value [7]. Neutron diffraction data support this hypothesis, with a cycloid period larger than the bulk value and increasing with strain and/or magnetic field. Analysis of the data in light of Landau-Lifshitz calculations [8] indicates that very small strains are sufficient to induce large modifications in magnetoelastic coupling [9], suggesting interesting opportunities for strain- and/or field-mediated devices which take advantage of finite-size effects in multiferroic films. Our results have important implications for magnonic devices using multiferroic films.

References

[1] W. Eerenstein, N. D. Mathur, J. F. Scott, Nature **2006**, 442, 759.

[2] G. Catalan, J. F. Scott, Adv. Mater. **2009**, 21, 2463.

[3] D. Sando, A. Barthélémy, M. Bibes, J. Phys. Condens. Matter **2014**, 26, 473201.

[4] I. Sosnowska, T. Peterlin-Neumaier, E. Steichele, J. Phys. C Solid State Phys. **1982**, 15, 4835.

[5] D. Sando *et al*., Nat. Mater. **2013**, 12, 641.

[6] R. Röhlsberger *et al*., Phys. Rev. B **2003**, 67, 245412.

[7] A. Agbelele *et al*., Adv. Mater. **2017**, 1602327.

[8] Z. V. Gareeva, A. F. Popkov, S. V. Soloviov, A. K. Zvezdin, Phys. Rev. B **2013**, 87, 214413.

[9] D. Sander, Reports Prog. Phys. **1999**, 62, 809.