Quantitative imaging of antiferromagnetic spin cycloidal textures on strain engineered $BiFeO_3$ thin films with a scanning nitrogen-vacancy magnetometer

H. Zhong,[1] J. Fischer,[2] A. Haykal,[3] A. Finco,[3] A. Stark,[1] F. Favaro,[1] P. Maletinsky,[1] M. Munsch,[1] K. Bouzehouane,[2] S. Fusil,[2] V. Jacques,[3] and V. Garcia[2]

[1] *Qnami AG, Muttenz, Switzerland*
[2] *Unité Mixte de Physique, CNRS, Thales, Université Paris Saclay, Palaiseau, France*
[3] *Laboratoire Charles Coulomb, CNRS, Université de Montpellier, Montpellier, France*

Multiferroics, such as $BiFeO_3$, in which antiferromagnetism and ferroelectricity coexist at room temperature, appears as a unique platform for spintronic [1] and magnonic devices [2]. The nanoscale structure of its ferroelectric domains has been widely investigated with piezoresponse force microscopy (PFM), revealing unique domain structures and domain wall functionalities [3, 4], but nanoscale magnetic textures present in $BiFeO_3$ and their potential for spin-based technology remain concealed. Depending on the strain, growth conditions and crystal orientation, the magnetic state of $BiFeO_3$ thin films can either show different types of non-collinear cycloids, canted G-type antiferromagnetic orders, or even a mixture of these [5]. In this report, we present two different antiferromagnetic spin textures in multiferroic $BiFeO_3$ thin films with different epitaxial strains, using a scanning Nitrogen-Vacancy magnetometer (SNVM) based on a single NV defect in diamond with a dc field sensitivity of $\sim 1\ \mu\mathrm{T}/\sqrt{\mathrm{Hz}}$. The two $BiFeO_3$ samples were grown $DyScO_3$ (110) and $SmScO_3$ (110) substrates using pulsed laser deposition. The striped ferroelectric domains in both samples are first observed by the in-plane PFM. The corresponding SNVM images confirm the existence of the spin cycloid texture. For the $BiFeO_3$ grown on $DyScO_3$ (110) substrate, the 90-degree in-plane rotation of the ferroelectric polarization imprints the 90-degree in-plane rotation of the cycloidal propagation direction along k_1= [-1 1 0], corresponding to the type-I cycloid. On the contrary, in the $BiFeO_3$ film grown on $SmScO_3$ (110) substrate, the propagation vectors are found to be along $k_1^{'}$= [-2 1 1] and $k_2^{'}$= [1 -2 1] directions in the neighboring domains separated by the 71° domain wall. Our results here shed the light on future potential for reconfigurable nanoscale spin textures on multiferroic systems by strain engineering.

References:

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