Controlling the Structural Domain in $BiFeO_3$ Thin Films

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Introduction

Non-trivial spin-lattice coupling effects have been studied in the popular multiferroic, bismuth ferrite $BiFeO_3$. Bulk $BiFeO_3$ has a rhombohedrally distorted perovskite structure that allows a commensurate ferroelectric and an incommensurate antiferromagnetic ordering at room temperature. The spins are not collinear, but instead take the form of a long-wavelength (62 nm) spiral symmetry. Consequently, the linear magnetoeletric effect averages to zero and indeed only the quadratic effect has been observed. In order to understand the origin of multiferroicity in $BiFeO_3$, a detailed study in the influence of strain in $BiFeO_3$ on the coupling between magnetic and ferroelectric properties under high magnetic field was performed.

Experimental

We succeeded in fabricating high quality thin films of $BiFeO_3$ achieving an unprecedented level of control on the structural domain [1]. With increasing strain above 4 %, a structural phase transition takes place from a rhombohedral (R) to a supertetragonal(T)-like structure. The relative fraction of the T and the R phases is controllable as function of both film thickness and an electric field. Magnetization measurements up to 33 T were performed by using a Vibrating Sample Magnetometer (VSM).

Results and Discussion

The surface morphologies were investigated by scanning probe microscopy. Clear step terrace structures, as shown in **Figure 1** (a) and (b), reveal that films were grown in a step flow mode, indicating good crystallinity. The thinner film mainly consists of the T-like $BiFeO_3$, while the thicker one contains mixed phase area (darker areas in the AFM) where the T-like phase and the R phase alternate on nano length scales. Fig.1 (c) shows the result of VSM measurement for highly strained $BiFeO_3$ thin film. The diamagnetic signal from the substrate is removed and then the saturation of magnetic moment can be observed above 25 T.

Conclusions

Although the magnetic signal is weak, we can improve the signal by reducing the thickness of substrate. For sensitive magnetic properties measurement, torque magnetometry will be performed in the future. For electrical characterization, we will measure the dielectric constant and pyroelectric or magnetoelectric current using a capacitor geometry of the films.

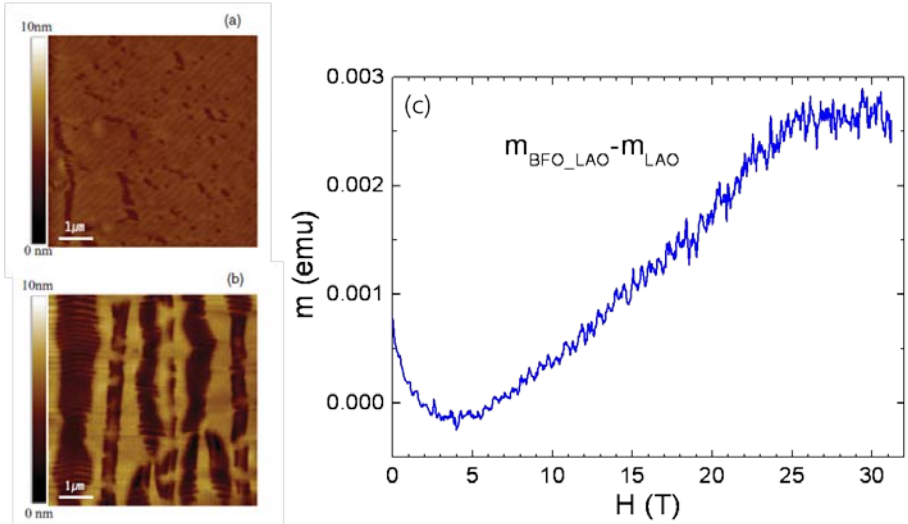

Figure 1. (a) Surface morphologies taken by scanning probe microscopy for the $BiFeO_3$ films with thickness of (a) 30 and (b) 80 nm, (c) Magnetization for highly strained $BiFeO_3$ thin film.

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References

[1] KyungTae Ko, *et al.,* Nature Communications **2**, 567 (2011).