Magneto-electric Coupling Measurements in $BiFeO_3$-$BiMnO_3$ Heterostructures and Thin Films

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Introduction

$BiFeO_3$ is a leading candidate for multiferroic behavior, in which magnetic and electric long-range order coexist [1]. Needed technologies in spintronics and memory require multiferroic materials with coupling between the magnetic and electric long-range order. $BiFeO_3$ has the highest ordering temperatures among multiferroics, exhibiting simultaneous canted antiferromagnetism and ferroelectricity above room temperature. However, the strength of the magneto-electric coupling is limited, and the magnetism has only a small net magnetism. Here we explore ways to improve $BiFeO_3$ with Mn doping. We have made highly-strained, ultra-slow grown films of $BiFe_{0.5}Mn_{0.5}O_3$ (BFMO) with a tetragonal structure. These have been shown to be both ferrimagnetic and ferroelectric at room temperature [2]. Magnetisation measurements, polarized neutron reflectivity, and x-ray magnetic circular dichroism, demonstrate the ferrimagnetism (T_c>600 K), with a room temperature saturation moment of up to 60 emu/cc (~0.39 μ_B/f.u.) for films grown on (001) single-crystal Nb doped $SrTiO_3$, and up to 90 emu/cc, ~ 0.6 μ_B/f.u on higher-quality pure (001) $SrTiO_3$. Piezo force microscopy measurements demonstrated strong ferroelectricity with retention of polarization at room temperature. The BFMO system is a very promising material for spintronic and memory applications at room temperature. However, it is uncertain as to the extent of the magnetoelectric coupling. In order to measure the magneto-electric coupling, several BFMO films of ~30 nm thickness grown on Nb doped $SrTiO_3$ were studied. Pt dots were deposited on the thin film surfaces for contacts.

Experimental

Platinum wires were attached to the top and bottom surfaces of the thin film with silver paint. The NHMFL-LANL facility can measure magnetic field-induced changes in the net electric polarization in DC and pulsed magnetic fields, with the faster pulses achieving higher signal to noise. These experiments were attempted on the thin films.

Results

We found that the conductivity of the films was too high, in the several kOhm to hundreds of kohm range, even at 4 K. The films may also have a tendency to short due to pinholes in the thin film when we apply contacts. We attempted to deposit Al_2O_3 on the surface of the film, however the conductivity problems continued.

Conclusions

In our next set of measurements we will deposit contacts with leads leading off the surface of the thin film, so that the silver paint and wire can be attached away from the film, to avoid silver paint entering pin holes in the thin film. Having contacts off the surface of the thin film also minimizes eddy current heating of the thin film.

Acknowledgements

The measurements at the NHMFL were conducted under the NHMFL core user program grant, funded by the NSF, the DOE, and the State of Florida.

References

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