Can $BaFe_{12}O_{19}$ Be Transmuted into a Room-Temperature Ferrimagnetic Ferroelectric?

Jayda Shine[1], Yilin Evan Li[2], Darrell G. Schlom[2]

[1]*Department of Physics, Spelman College, Atlanta*

[2]*Materials Science and Engineering, Cornell University*

ABSTRACT

Using Molecular Beam Epitaxy, Barium hexaferrite ($BaFe_{12}O_{19}$, BaM) is thinly grown on Al_2O_3 substrates to compute optimal growth conditions such as stoichiometric flux ratios along with crystal quality and smoothness. Following this calibration, an in-plane biaxial compressive strain is applied to $BaFe_{12}O_{19}$ grown on (Mg, Zr): $SrGa_{12}O_{19}$ (SGMZ) substrates to transmute $BaFe_{12}O_{19}$ from a ferromagnetic material into one that is multiferroic.

INTRODUCTION

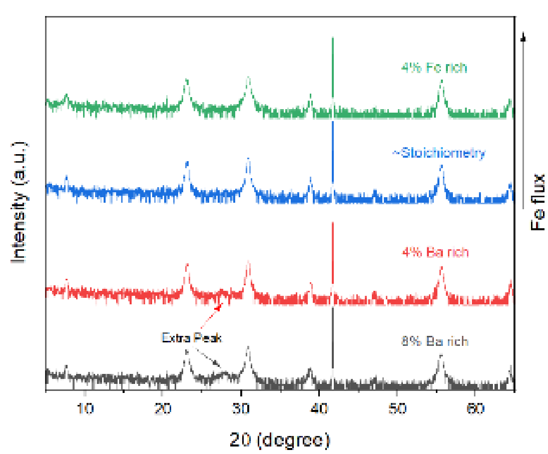
Multiferroic materials utilize electric-field control of magnetism which promises to be helpful in ultralow power, logic, or memory devices. $BaFe_{12}O_{19}$ is a ferrimagnetic, incipient ferroelectric material typically used in microwaves and refrigerator magnets. It possesses an unequal number of opposing magnetic moments, allowing spontaneous magnetization to occur still. BaM has a high magnetic transitions temperature at which it loses its net-magnetic moments and becomes demagnetized [1]. BaM is not ferroelectric since the Iron atom can jump up and down to have local polarizations; however, these polarizations are not stabilized to form ordered polar structures. Transmuting BaM into a real ferroelectric would allow for BaM to become a ferrimagnetic ferroelectric material.

METHODS

Theoretically, applying a 4% or larger in-plane biaxial compressive strain transmutes Barium hexaferrite into a ferroelectric material without losing its ferrimagnetic properties [2]. The in-plane lattice parameter of BaM is slightly larger than the SGMZ substrate. Commensurately growing BaM on SGMZ substrates, using the process of MBE, will also cause BaM to adopt the same in-plane lattice constant as its substrate, which will possibly stabilize the Iron atoms' local polarizations.

RESULTS

Experimentation began with BaM being thinly grown on sapphire (Al_2O_3) substrates. Sapphire substrates are an excellent template for BaM while being cheaper and more readily available than SGMZ substrates. Therefore, SGMZ was explicitly used for transmuting an epitaxial strain. Doing scans such as the XRD , scans and AFM Imaging shown in Figures 1, 2, and 3 respectively allow adjustments of Iron flux according to each sample's growth calibrations, allowing optimal crystal quality and



smoothness.

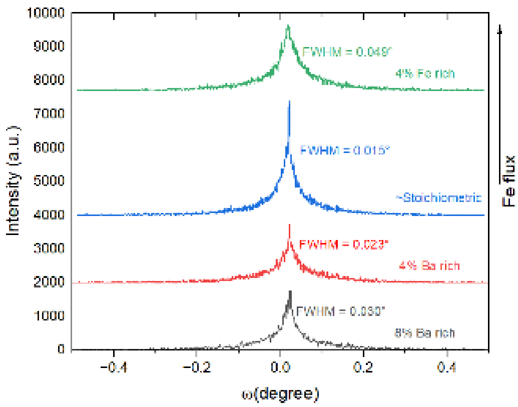


Figure 1: scans allow for adjustments to flux ratios to be made to achieve stoichiometry

Figure 2: scans allow for adjustments to flux ratios to be made to achieve optimal crystal quality

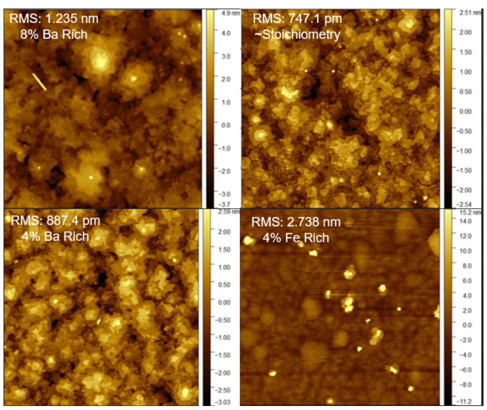


Figure 3: AFM Imaging allows for adjustments to flux ratios to be made to achieve optimal crystal smoothness

Following Figure 2, the sample with the best crystal quality had the lowest FWHM value at 0.015°. Figure 3 shows that the smoothest film has the lowest RMS roughness value of 747.1pm. Following calibration of optimal growth conditions, these conditions were applied to BaM on SGMZ to apply an epitaxial strain. An AFM reading was done to prove that optimal growth conditions were accurate, and then reciprocal space mapping and scans were done to prove that a strain was applied. Figure 5 proves the application of strain since the in-plane lattice constant for the substrates and the film are identical, while Figure 6 shows that the film sits almost right on top of the film.

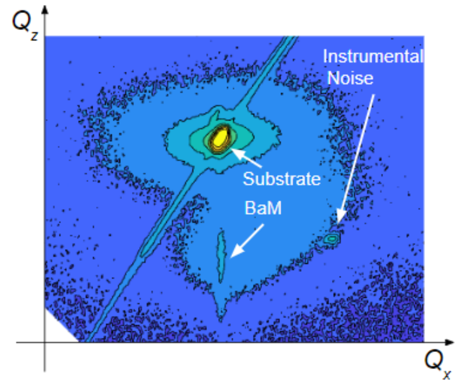


Figure 5: Reciprocal space mapping shows BaM and the substrate having the same Q_x.

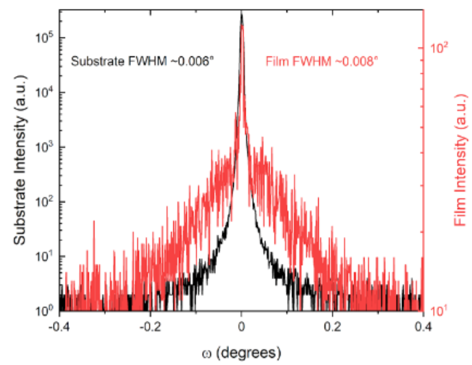


Figure 6: scans showing strain

CONCLUSION

An epitaxial strain has not been able to be reproduced. Future work includes research on possible barriers preventing an epitaxial strain from being applied to BaM on SGMZ substrates. The work completed this summer is funded by National Science Foundation (Platform for the Accelerated Realization, Analysis, and Discovery of Interface Materials (PARADIM)) under Cooperative Agreement No. **DMR-2039380**. This work is also being funded by NSF-PREM: Emergent Interface Materials" has been awarded by Clark Atlanta University. Sponsor Award Number: **DMR-2122147**

REFERENCES

[1] Shepherd, P., Mallick, K. K., Green, R. J. Magnetic and structural properties of M-type barium hexaferrite prepared by co-precipitation. *Magn. Magn. Mater* **311**, 2 (2007) 691.
[2] Wang, P. S., Xiang, H. J. Room-Temperature Ferrimagnet with Frustrated Antiferroelectricity: Promising Candidate toward Multiple-State Memory. *Phys. Rev. X* **4**, 001035 (2015) 9.