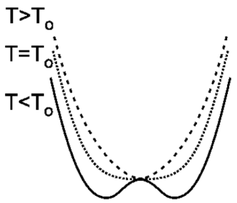
Motivation and Preparation for Growth of TSO/BFO Superlattices via MBE

Reid Markland[1,3], Maya Ramesh[2], Darrell Schlom[2,4]

[1]Department of Physics, Auburn University; [2]Department of Materials Science and Engineering, Cornell University; [3]PARADIM REU @ Cornell; [4]Kavli Institute at Cornell for Nanoscale Science, Cornell University

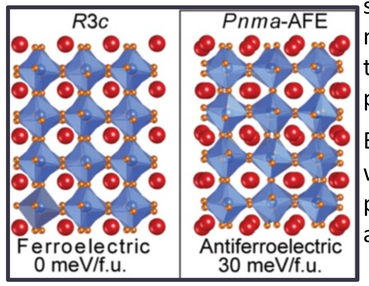
Multiferroics and BFO



Bismuth Ferrite (BFO) displays spontaneous reversible polarization, making it a ferroelectric. It also displays similar magnetic and elastic properties, classifying it as a multiferroic.

Having one of the largest room temperature spontaneous polarizations known, as well as maintaining magnetic properties at room temperature makes BFO among the most promising multiferroic materials.[1]

BFO has several low-energy phases, each with distinct features. Modulating the presence of these phases via straining BFO is an exciting topic of research



BFO/TSO Superlattice Phase Behavior

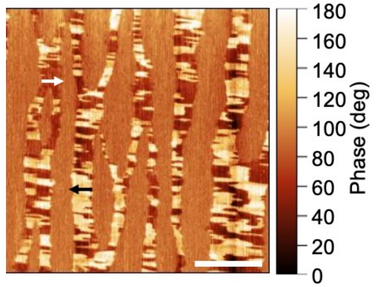
Confining BFO between layers of Terbium Scandate (TSO) in BFO/TSO superlattices creates an exciting new phase dynamic.

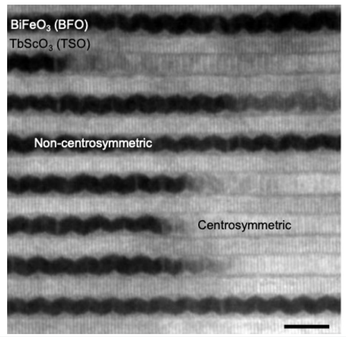
TSO stabilizes a nonpolar, centrosymmetric phase of BFO

The competition between this nonpolar, insulating phase with BFO's polar, semiconducting phase yields interesting physics and potential applications

Further, these phases can be switched between via application of an electric field.[2]

Our project is to create tri-layer superlattices to further explore the physics behind this phase dynamic.



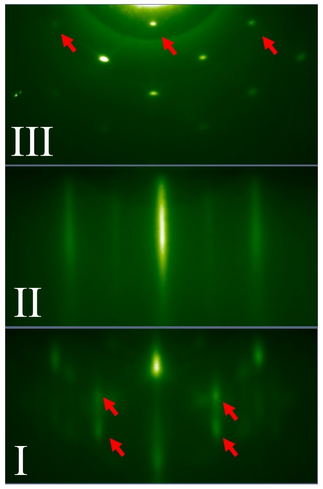


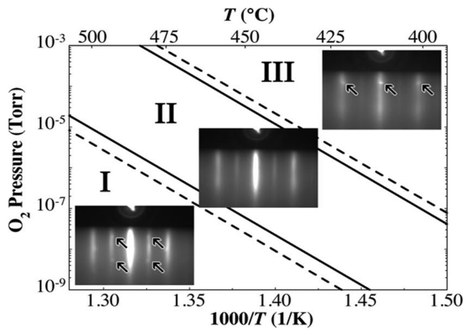
BFO Growth Methods

Basing our growth of BFO off methods described by J. F. Ihlefeld *et al*[3], we grew in an Fe-determined absorption controlled environment at an O_3 pressure of ~5e-6 torr. Our growth window fell between 650 and 700°C.

We monitored growth quality *in situ* via Reflection High Energy Electron Diffraction (RHEED).

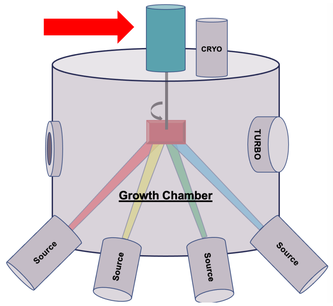
Via RHEED we were able to determine whether the sample was Fe-rich (I), stoichiometric (II), or Bi-rich (III).





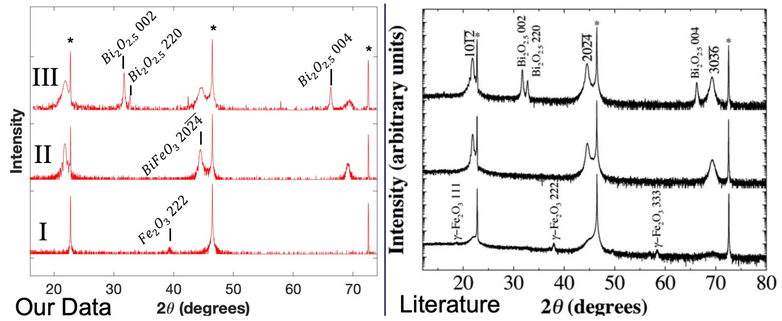
Growth Obstacles

Issues with the Atomic Force Microscope (AFM) resulted in a crushed sample and more tedious future measurements



A manipulator (blue cylinder) replacement was also necessary before growth could begin

BFO Growth Results

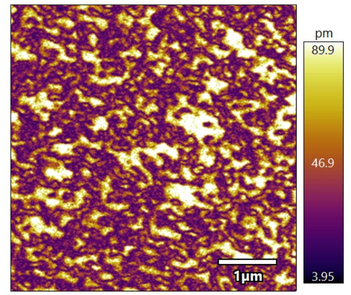


High quality, although inconsistent, growth of BFO was achieved.

Optimum growth window was determined to lie between 670-680°C

Ferroelectric domains of R3c phase BFO were measured via AFM

Further tuning required as BFO samples are rough on the surface



Wrapping Up

Conclusions

- BFO growth window lies between 650 ºC and 700 ºC
- We can grow BFO presenting ferroelectric domains
- More work needs to be done optimizing BFO growth

Next Steps

- Optimize growth of BFO
- Begin and optimize TSO growth
- Begin TSO/BFO tri-layer growth
- Characterize interfacial domains of tri-layer TSO/BFO

Acknowledgements

Thanks to my mentor Maya Ramesh, Jim Overhiser, and Darrell Schlom. This REU is supported by the National Science Foundation, Platform for the Accelerated Realization, Analysis and Discovery of Interface Materials (PARADIM) under Co-operative Agreement No. DMR-2150446.

References

[1]J. Seidel et al, Nature Materials 8, 229–234 (2009).
[2]L. Caretta et al, arXiv.2201.00289 (2022).
[3]J. F. Ihlefeld et al, IEEE Trans. Ultrason. Ferroelecr. Freq. Control 56, (2009).