Epitaxial Growth of Single-Domain (110) $BiFeO_3$ Thin Films

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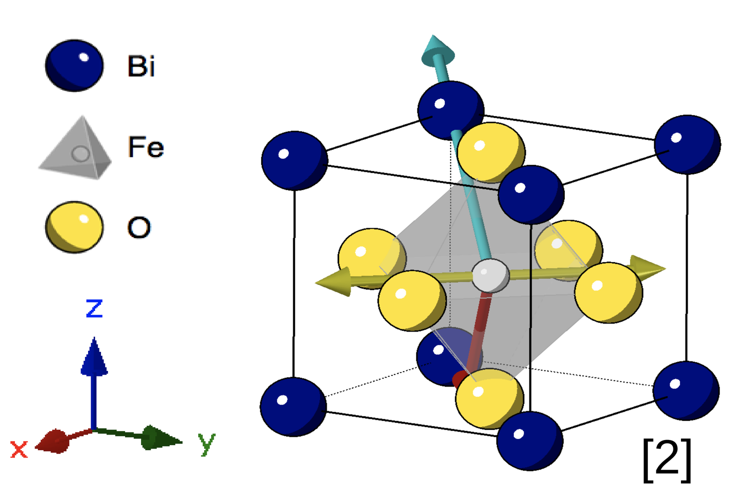
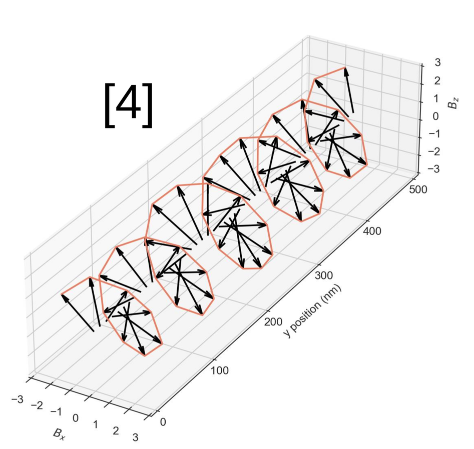
Introduction

Spintronics
- Are low-power, quantum-mechanical devices that utilize magnetism to store information. [1]



$BiFeO_3$ (BFO)
- Has a perovskite crystal structure.
- Is a room temperature ferroelectric and antiferromagnet.
- Has high polarization along the body-centered diagonal. [1]

Single-Domain Structure
- Has only one variation of the ferroelectric polarization direction.
- Has no ferroelectric domain walls. [3]

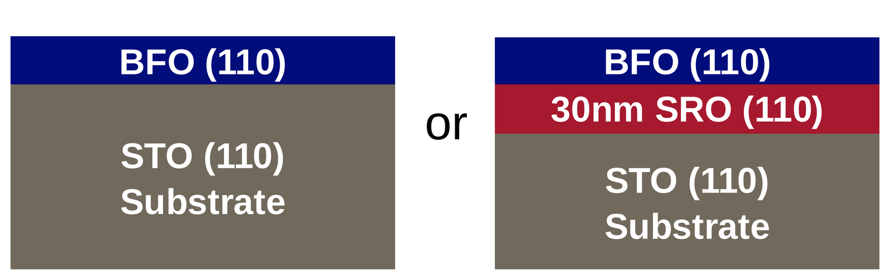


Spin Cycloids
- Are created in BFO ferroelectric domains by the Dzyaloshinskii-Moriya interaction of coupled polarization and spin [1].
- Act as highways for spin travel but are interrupted by ferroelectric domain walls [4].

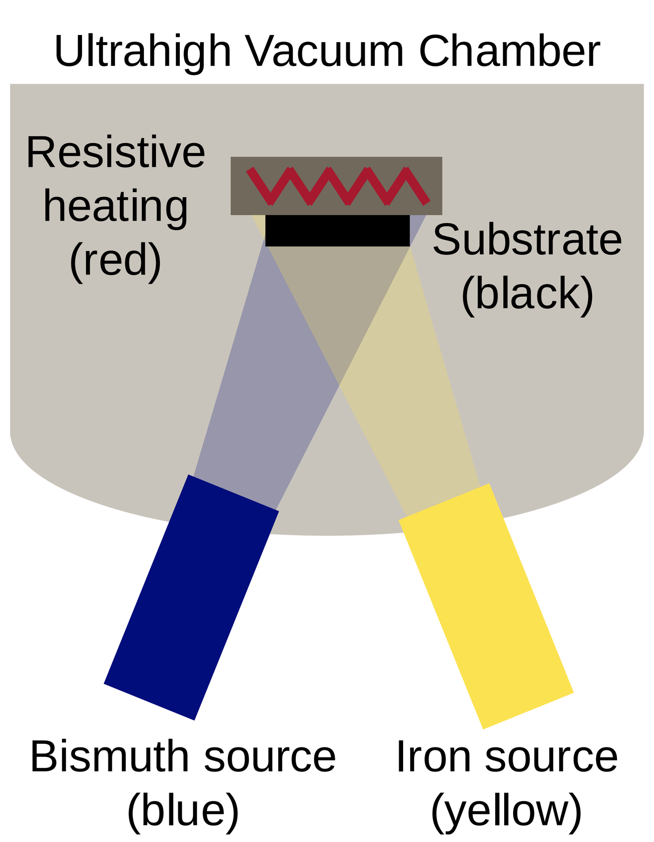
Objective: The epitaxial growth of (110) BFO that is single-domain to harness the spin cycloid for spintronics.

Growth Methods

Sample structure:
- $SrTiO_3$ (STO)
- $SrRuO_3$ (SRO)

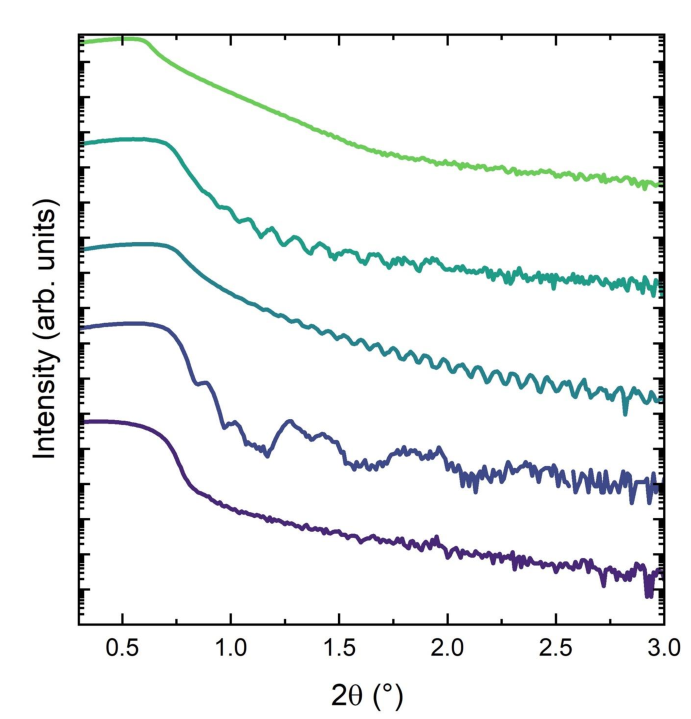


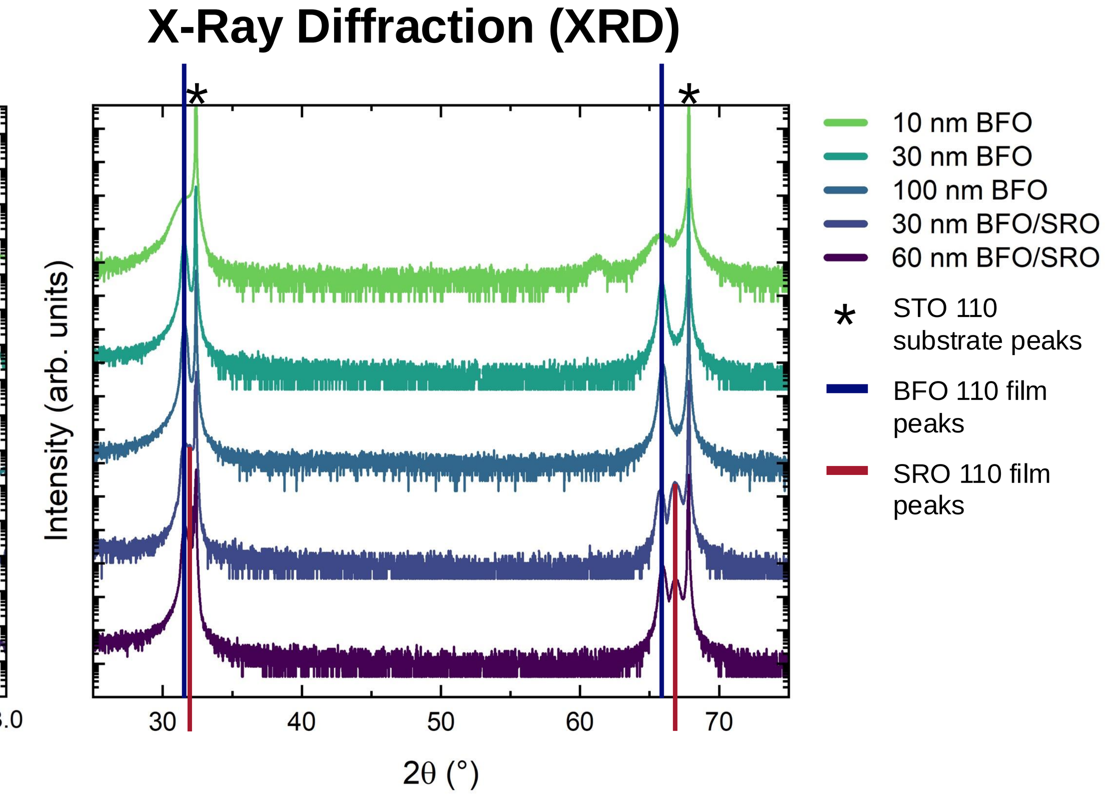
Molecular-Beam Epitaxy
- Elemental sources are heated to create cation beams that oxidize on the substrate in a distilled ozone environment.



$BiFeO_3$ Growth Parameters
- Distilled ozone
  - 80% O_3 and 20% O_2
  - 5 x 10^{-6} Torr
- 8:1 Bi:Fe flux ratio
- Substrate temperature
  - 675°C

Characterization Methods

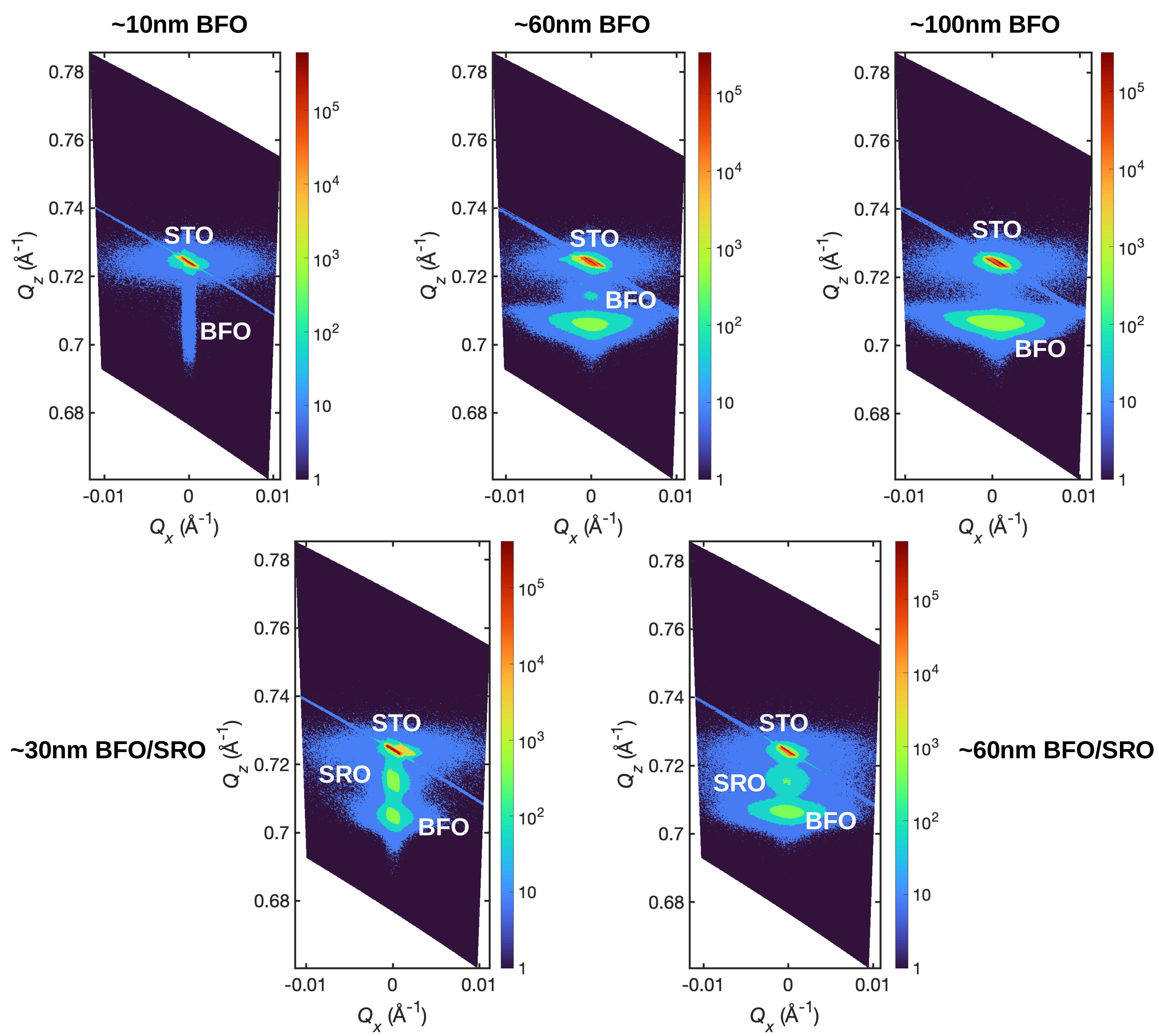




XRR
- Confirms film thickness.

XRD
- Confirms film phase purity.
- Confirms film and substrate orientation.

Reciprocal Space Map (RSM) at the 221 peak



Results

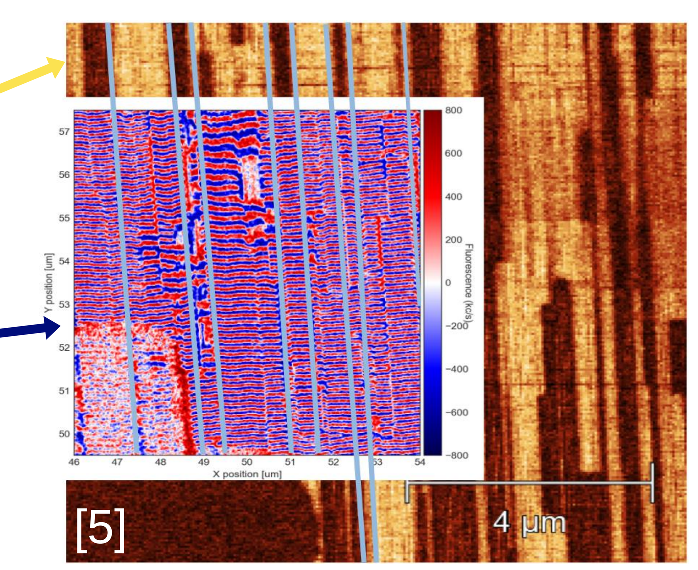
Sample Quality
- Consistently correct XRR and XRD peaks indicate quality, stoichiometric BFO (110) film growth.

RSM Results
- The BFO 221 peak is characteristic of structural variations, including ferroelectric domain structure variations in the film [3].
  - Splitting of the BFO 221 peak in the ~60nm BFO sample indicates **multiple ferroelectric domains**.
  - The single BFO 221 peak in the ~100nm BFO, ~30nm BFO/SRO, and ~60nm BFO/SRO samples indicates successful **single-domain** structure.
  - The indistinguishable ~10nm BFO 221 peak requires further testing.

Conclusion: Most epitaxial (110) BFO growths were likely single-domain.

Future Work

Confirm single-domain structure with
- Piezoforce Microscopy (PFM) to observe ferroelectric domains.
- Nitrogen Vacancy Magnetometry to observe magnetic domains and spin cycloids.



Acknowledgements

I would like to acknowledge my mentor Maya Ramesh and principal investigator Dr. Darrell G. Schlom for their support and guidance in this project. This research is funded by the National Science Foundation (NSF) Platform for the Accelerated Realization, Analysis, and Discovery of Interface Materials (PARADIM) and the NSF Research Experience for Undergraduates Site: Summer Research Program at PARADIM.

References

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