

Abstract

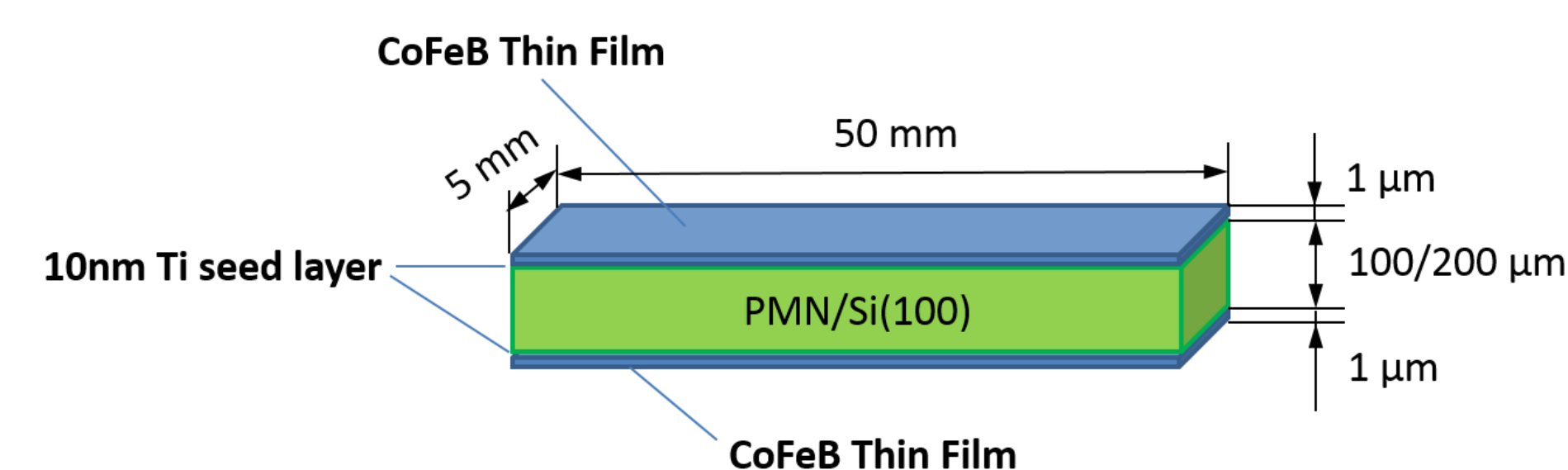
This work is an extension of previous experiments where multiferroic samples consisted of 22 μm thick $\text{Fe}_{78}\text{Si}_{10}\text{B}_{12}$ amorphous ribbons glued to a 500 μm thick poled PZT substrate. In this work we used much thinner thin films deposited on specially prepared Si substrates and Au-coated PMN substrates. The magnetomechanical resonance of these samples were then measured using the magnetic field produced by an AC coil and an applied electric field. The substrates of the correct size were placed into a high vacuum system. Then, an approximately 1 μm thin film of CoFeB was sputter-deposited on both faces of the substrates using an AJA Orion Sputtering System. The finished samples were then placed into the measurement system consisting of an AC excitation coil connected to a function generator, a DC bias coil connected to a DC power supply, and a sense coil connected to a compensation coil. The magnetomechanical resonance of each sample was then found. The resonance of CoFeB/Si(100) was found to be at 216.83 kHz. The magnetomechanical resonance of CoFeB on all PMN samples has yet to be determined from the data acquired.

Introduction

- Previous studies on large scale multiferroic composites made of amorphous ribbons and a PZT substrate found the magnetomechanical resonance of samples
- Smaller samples were used to see if magnetomechanical resonance was measurable
- Multiferroic composites may be used for tunable filters in electronic devices.

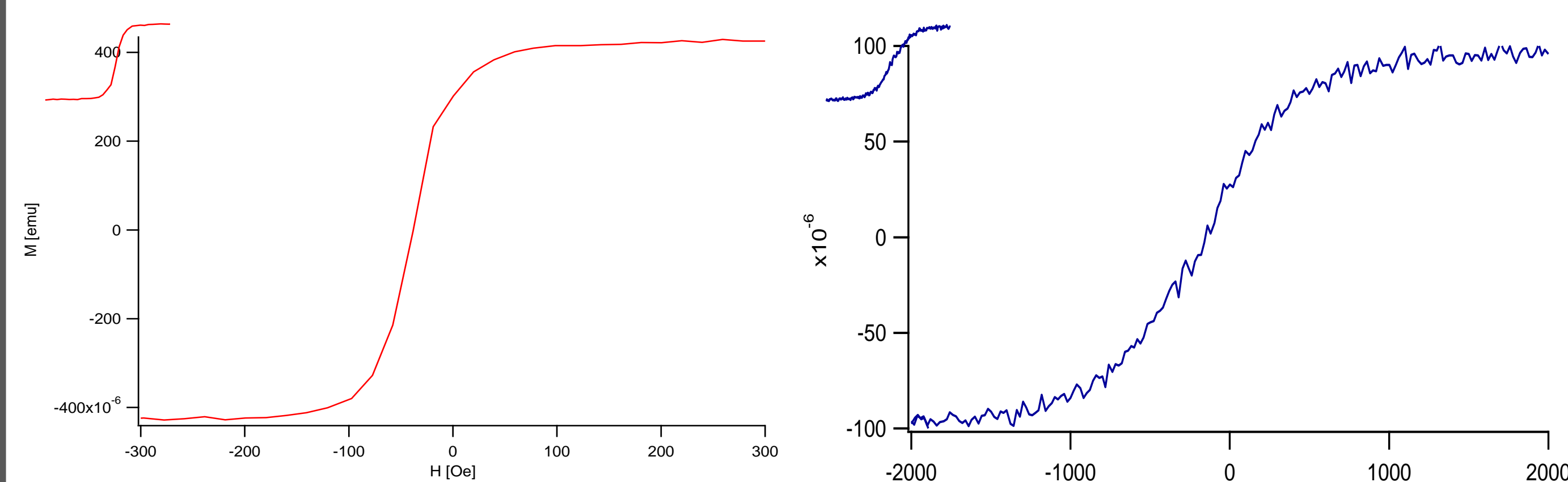
Sample Preparation

- Si(100) Sample Prep:
 - 500 μm thick Si(100) wafers cut into 2x1cm pieces using a diamond scribe
 - Samples then hand polished with 400 and 600 grit sandpaper until ~100 μm thick
 - Final polishing using automated polishing wheel with 800 and 1200 grit sandpaper, and 0.06 μm suspended nanoparticles
- PMN Sample Prep:
 - 50x9.30x0.10mm polycrystalline PMN cut in half along longest axis using wire cutter
 - 25x12x0.20mm single-crystal PMN cut into four even pieces along longest axis using diamond scribe
- Si and PMN crystals cleaned with Acetone & IPA then placed into a high vacuum system
- AJA Orion Sputtering System used to deposit 10 nm Ti seed layer, and 1 μm of CoFeB
- Crystals removed from vacuum, flipped, and placed back into vacuum for deposition on the opposite side
- After deposition, crystals removed from vacuum and an optical profiler determined the thickness of the thin film
- During handling the two polycrystalline PMN samples broke resulting in samples measuring 40x4.65x0.10mm, 27x4.65x0.10mm, and 21x4.65x0.10mm
- Diagram of finished samples:



Hysteresis Loops

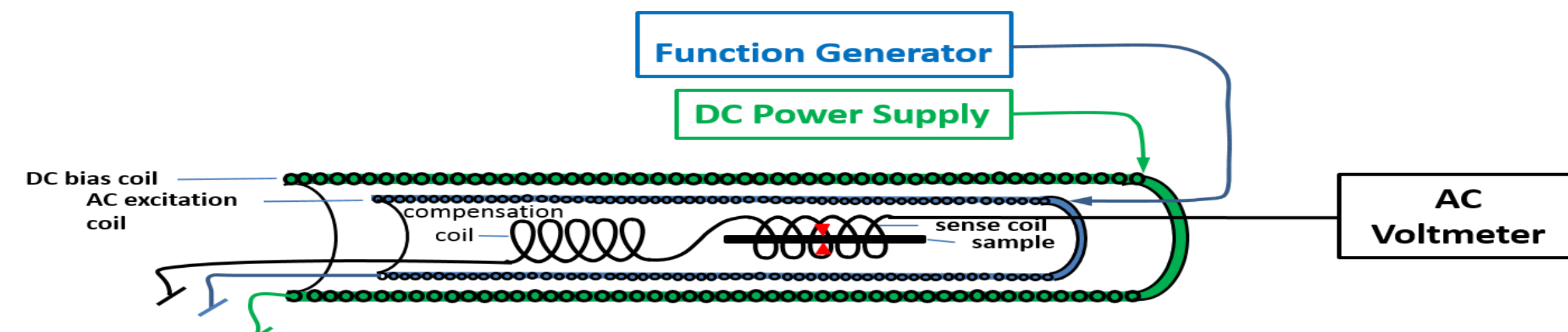
Hysteresis data of CoFeB/Si(100) taken with the help of Dr. Spinu's group



The above graph shows the hysteresis loop for ~10nm of CoFeB/Si(100) along the easy axis

The above graph shows the hysteresis loop for ~10nm of CoFeB/Si(100) along the hard axis

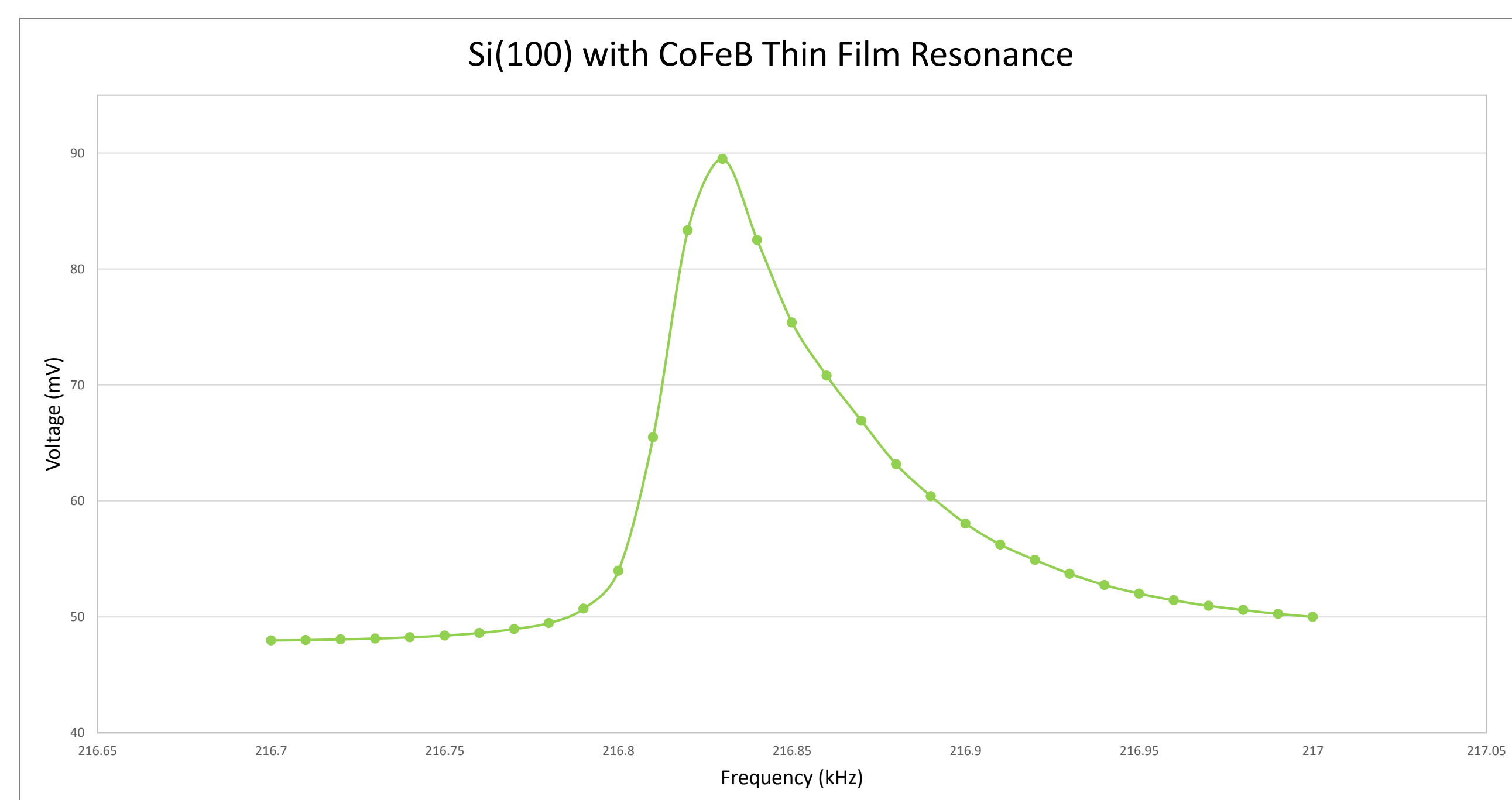
Measurement Setup



- The AC excitation coil was made to have ~270 turns
- The sense coil was made with a diameter of 4.5mm and ~175 turns
- The compensation coil was made with a diameter of 5mm and ~170 turns

Magnetomechanical Resonance

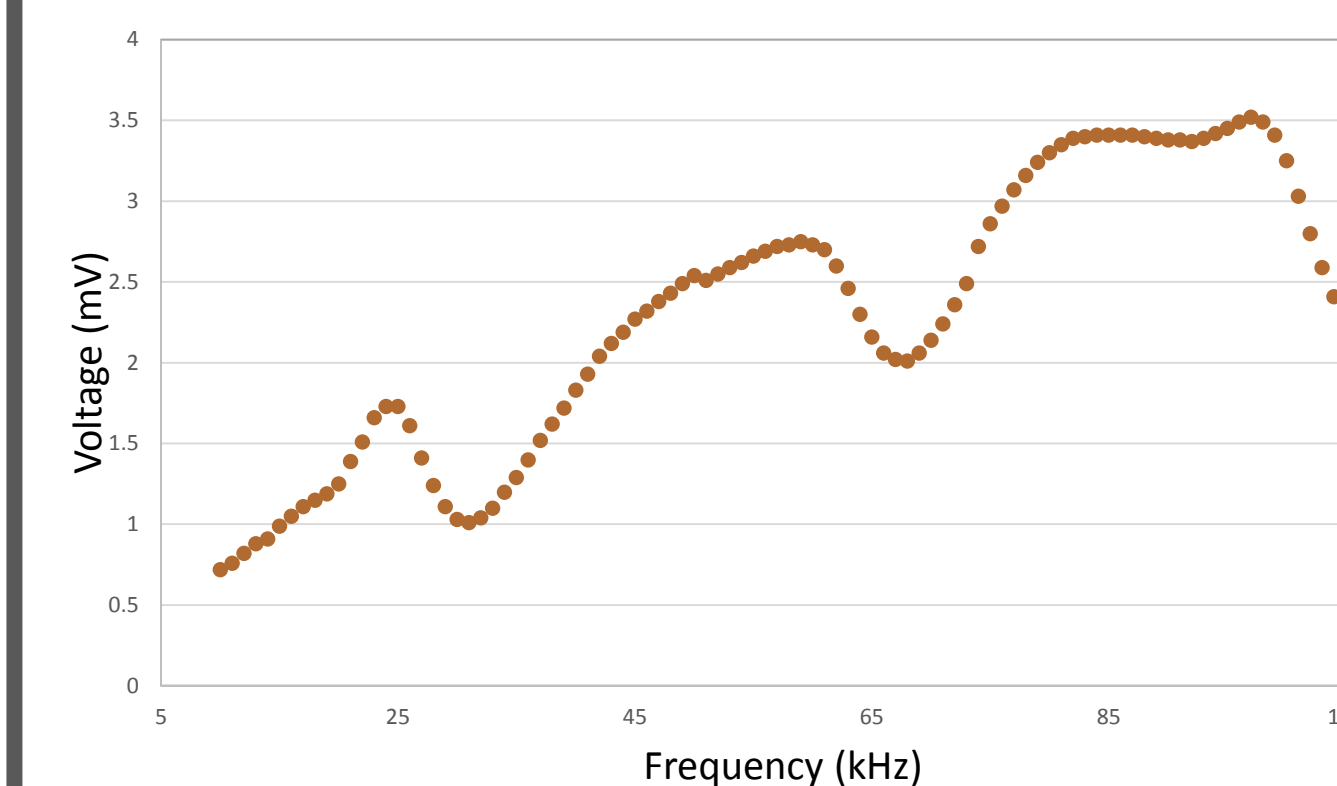
Using $f_{res} = \frac{\text{speed of sound in material}}{2 \times \text{Length of material}} = \frac{c_{\text{sound}}}{2L}$ it was determined that the resonance frequency of the CoFeB/Si(100) sample with a length of 2cm was ~210kHz



The above graph shows the resonance value for the CoFeB/Si(100) composite at 216.83 kHz

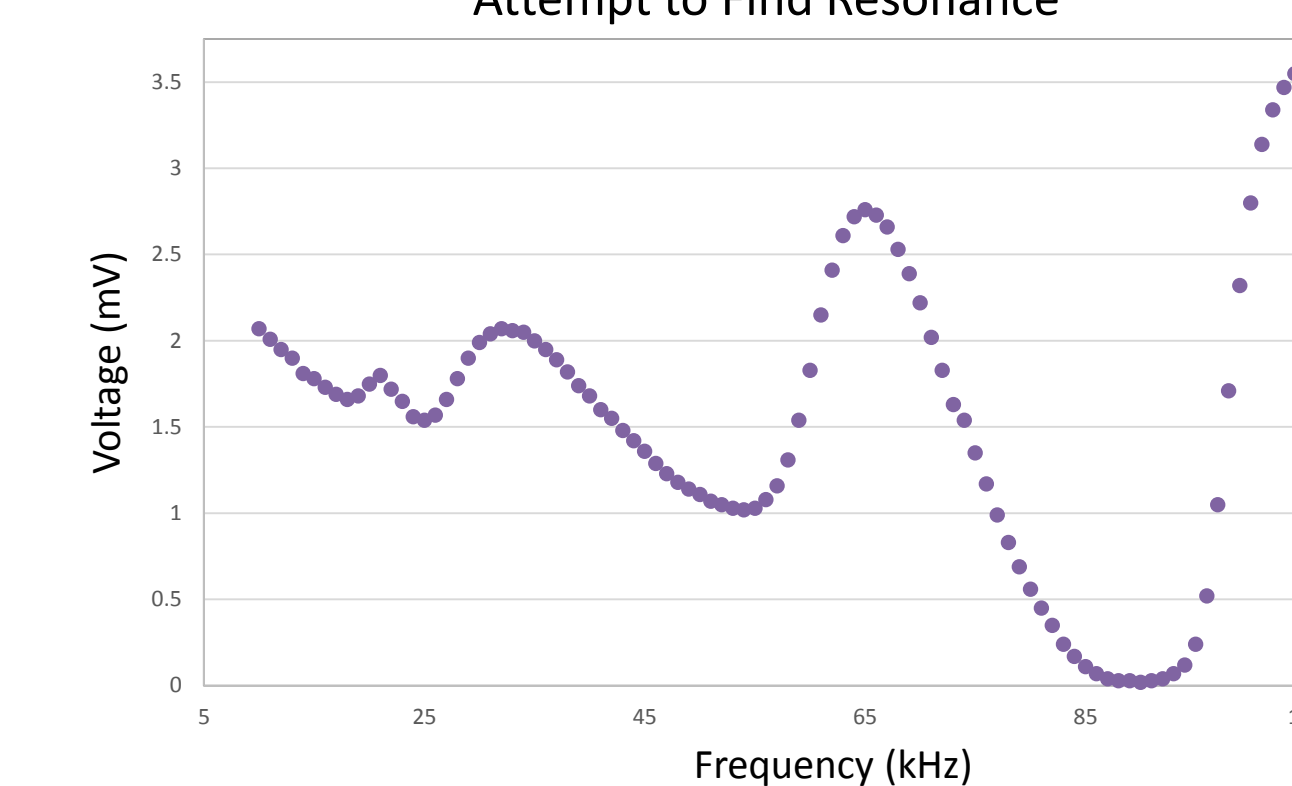
PMN Resonance Testing

CoFeB on 40x4.65x0.10mm polycrystalline PMN Attempt to Find Resonance



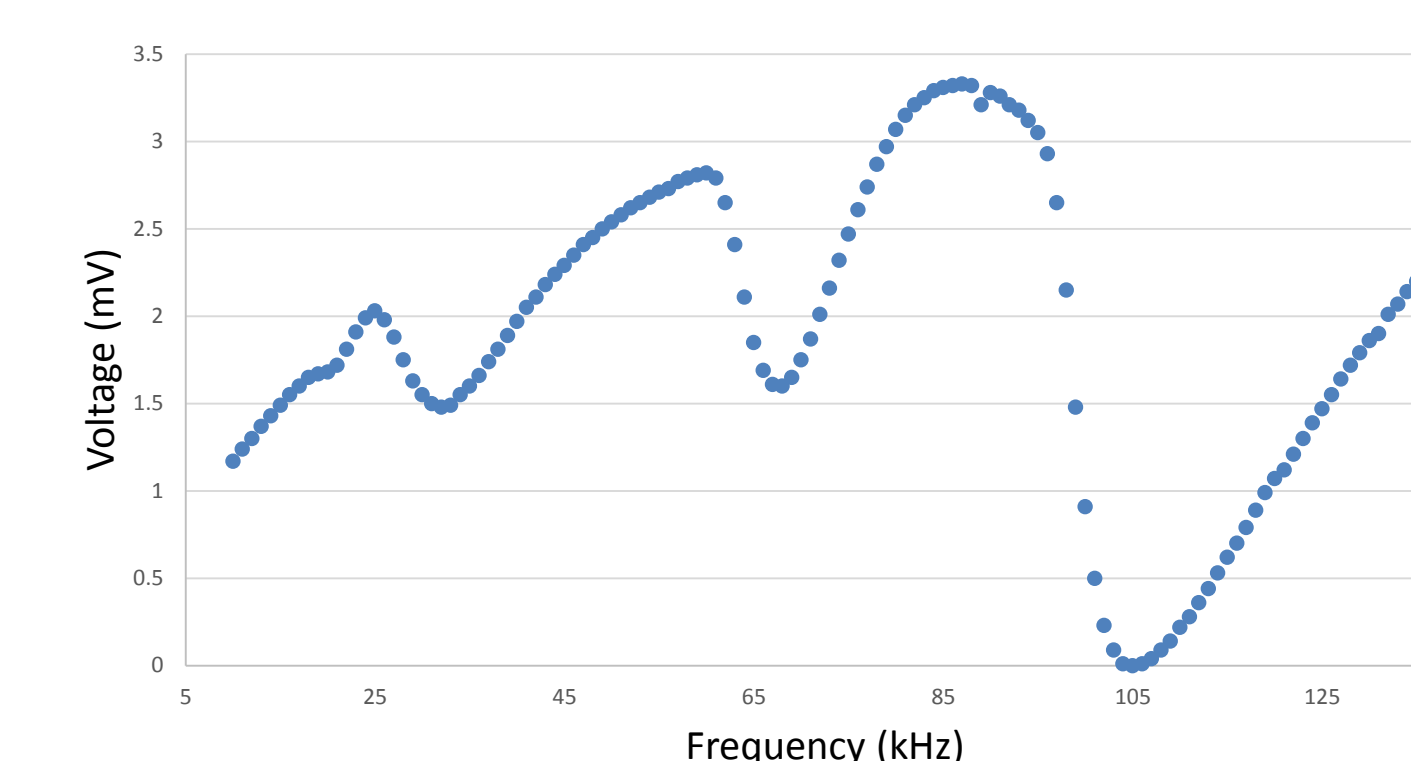
The above graph shows ongoing data to find the resonance value for CoFeB on the 40x4.65x0.10mm polycrystalline PMN

CoFeB on 27x4.65x0.10mm polycrystalline PMN Attempt to Find Resonance



The above graph shows ongoing data to find the resonance value for CoFeB on the 27x4.65x0.10mm polycrystalline PMN

CoFeB on 25x3x0.10mm polycrystalline PMN Attempt to Find Resonance



The above graph shows ongoing data to find the resonance value for CoFeB on the 25x3x0.20mm polycrystalline PMN

Conclusions

- 1 μm thin films of CoFeB do show magnetomechanical resonance of Si(100) substrates
- CoFeB/Si(100) is saturated at ± 200 Oe along its easy axis (± 1500 Oe hard axis)
- The magnetomechanical resonance was measured for the 2cm composite with Si
- Due to effects from the PMN substrate on the magnetomechanical resonance, a resonance has not yet been determined for any of the CoFeB/PMN samples

References

- [1] M. I. Bichurin and D. Viehland, Magnetolectricity in Composites, Pan Stanford Publishing, USA 2012
- [2] Ce-Wen Nan, M. I. Bichurin, D. Viehland, G. Srinivasan, Journal of Applied Physics, 103, 031101 (2008)m

Acknowledgements

We gratefully acknowledge the support of this work by the LA Board of Regents Contract No. NSF(2010-15)-RII-UNO and the NSF-EPSCoR Cooperative Agreement No. EPS-1003897. I would also like to thank Genia Rober for all of her help in helping me to complete this project. Also thank you to Daniel from Dr. Spinu's group for getting hysteresis data.