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14. ABSTRACT

This research project led to fabrication of tunable multilayer oxide structures based on Barium Strontium Titanate (BST) and Barium Hexaferrite (BaM) materials, demonstrate tunability of impedance when subject to external electrical and magnetic fields and also explore the fabrication, properties and electromagnetic properties of magnetic oxide nanoparticles. We showed for the first time low-leakage BST/BaM structures grown by PLD that had excellent dual tunability using electric and magnetic fields. The goals of the project were met with success and

15. SUBJECT TERMS

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Report Title

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This research project led to fabrication of tunable multilayer oxide structures based on Barium Strontium Titanate (BST) and Barium Hexaferrite (BaM) materials, demonstrate tunability of impedance when subject to external electrical and magnetic fields and also explore the fabrication, properties and electromagnetic properties of magnetic oxide nanoparticles. We showed for the first time low-leakage BST/BaM structures grown by PLD that had excellent dual tunability using electric and magnetic fields. The goals of the project were met with success and the research results were published in a number of papers and presented at major professional conferences.

List of papers submitted or published that acknowledge ARO support during this reporting period. List the papers, including journal references, in the following categories:

(a) Papers published in peer-reviewed journals (N/A for none)

1. “Measurement of spin polarization of doped strontium ruthenates using point contact Andreev reflection (PCAR)” –G. T. Woods, J. Sanders, S. Kolesnik, T. Maxwell, H. Srikanth, B. Dabrowski, M. S. Osofsky and R. J. Soulen., Jr., Journal of Applied Physics 104, 083701 (2008)
2. “Transverse susceptibility study of the effect of varying dipolar interactions on anisotropy peaks in a 3D assembly of soft ferrite nanoparticles” –P. Poddar, M. B. Morales, N. A. Frey, S. A. Morrison, E. E. Carpenter and H. Srikanth, Journal of Applied Physics 104, 063901 (2008)
3. “Static and dynamic magnetic properties of Co nanoparticles” –S. Srinath, P. Poddar, D. S. Sidhaye, B. L. V. Prasad, J. Gass and H. Srikanth, Journal of Nanoscience and Nanotechnology 8, 4086 (2008)
4. “Magnetization and magnetocaloric effect in ball milled zinc ferrite powder” –J. Gass, H. Srikanth, N. Kislov, S. Srinivasan and Y. Emirov, Journal of Applied Physics 103, 07B309 (2008)
5. “Multifunctional ferromagnetic-ferroelectric thin films for microwave applications” –R. Heindl, H. Srikanth, S. Witanachchi, P. Mukherjee, A. Heim, G. Matthews, S. Balachandran, S. Natarajan and T. Weller, Applied Physics Letters 90, 252507 (2007)
6. “Transverse susceptibility as a probe of interface magnetism in functional multilayers and nanostructures” –N. A. Frey, M. B. Morales, H. Srikanth and S. Srinath, Encyclopedia of Advanced Materials: Science and Engineering (Pan Stanford Publishers, in press 2007)
7. “Growth of barium hexaferrite nanoparticle coatings by laser-assisted spray pyrolysis” –G. Dedigamuwa, P. Mukherjee, H. Srikanth and S. Witanachchi, J. Amer. Ceram. Soc. (accepted 2007)
8. “Static and dynamic magnetic properties of composite $Au-Fe_3O_4$ nanoparticles” –N. A. Frey, S. Srinath, H. Srikanth, T. Chao and S. Sun, IEEE Transactions on Magnetics 43, 3094 (2007)
9. “Structure, magnetism and tunable microwave properties of PLD-grown Barium ferrite/Barium strontium titanate bi-layer films” –R. Heindl, H. Srikanth, S. Witanachchi, P. Mukherjee, T. Weller, A. S. Tatarenko and G. Srinivasan, Journal of Applied Physics 101, 09M503 (2007)
10. “Exchange bias in CrO_2/Cr_2O_3 bilayer thin films” –S. Srinath, N. A. Frey, H. Srikanth, G. Miao and A. Gupta, Advances in Science and Technology 45, 2528 (2006) Trans Tech Publications
11. “Magnetic anisotropy in CrO_2 and epitaxial CrO_2/Cr_2O_3 bilayers” –N. A. Frey, S. Srinath, H. Srikanth, M. Varela, S. Pennycook, G. Miao and A. Gupta, Physical Review B 74, 024420 (2006)
12. “Magnetization in insulating phases of Ti^{4+} doped $SrFeO_3$-□” –S. Srinath, M. Mahesh Kumar, K. Sahner, M. L. Post, M. Wickles, R. Moos and H. Srikanth, Journal of Applied Physics 99, 08S904 (2006)
13. “Magnetization and magnetoresistance in insulating phases of $SrFeO_3$-d” –S. Srinath, M. Mahesh, M. L. Post and H. Srikanth, Phys. Rev. B 72, 054425 (2005)
14. “Microstructure and magnetism in Barium Strontium Titanate (BSTO) – Barium Hexaferrite (BaM) multilayers –N. A. Frey, R. Heindl, S. Srinath, H. Srikanth and N. J. Dudney, Materials Research Bulletin 40, 1286 (2005)
15. “Superparamagnetism and magnetocaloric effect in functional magnetic nanostructures” –H. Srikanth and J. Gass, Reviews of Advances in Materials Science 10, 398 (2005)
16. “Magnetic properties of polydisperse and monodisperse NiZn ferrite nanoparticles interpreted in a surface structure model” –R. Swaminathan, M. McHenry, P. Poddar and H. Srikanth, Journal of Applied Physics 97, 10G104 (2005)
17. “Growth and characterization of sputtered BSTO/BaM multilayers” –S. Srinath, N. A. Frey, R. Hajndl, H. Srikanth, K. R. Coffey and N. J. Dudney, Journal of Applied Physics 97, 10J115 (2005)
18. “Spin polarization measurements on polycrystalline strontium ruthenates using point contact Andreev reflection” –J. T. Sanders, G. T. Woods, P. Poddar, H. Srikanth and B. Dabrowski, Journal of Applied Physics 97, 10C912 (2005)
19. “Observation of charge ordering and the ferromagnetic transition in single crystal LSMO using RF transverse susceptibility” –G. T. Woods, P. Poddar, H. Srikanth and Y. M. Mukovskii, Journal of Applied Physics 97, 10C104 (2005)
20. “Probing magnetic anisotropy and spin polarization in spintronic materials” –P. Poddar, G. T. Woods, S. Srinath and H. Srikanth, IEEE Transactions on Nanotechnology 4, 59 (2005)
21. “Inter-particle interactions and magnetism in manganese-zinc ferrite nanoparticles” –P. Poddar, H. Srikanth, S. A. Morrison and E. E. Carpenter, Journal of Magnetism and Magnetic Materials 288C, 443 (2005)
22. “Surface modification and magnetism in Co-implanted BSTO/Barium Hexaferrite composite films” –R. Hajndl, S. Srinath and H. Srikanth, Journal of the American Ceramics Society (ICF-9 Proceedings, p. 155, 2005)
23. “Magnetism and RF dynamics in nanocomposite materials” –H. Srikanth and P. Poddar, Journal of Metastable and Noncrystalline Solids 23, 355 (2005) Trans Tech Publications
24. Conference report on Seeheim Conference on Magnetism (SCM2004) –Srikanth Hariharan, Physica Status Solidi (a) 201, 2611 (2004) [Report at the invitation of the publisher, Wiley-VCH]
25. “Magnetic properties of conducting polymer doped with Mn-Zn ferrite nanoparticles” – P. Poddar, J. L. Wilson, H. Srikanth, S. A. Morrison and E. E. Carpenter, Nanotechnology 15, S570 (2004)
26. “Analyzing point contact Andreev reflection” –G. T. Woods, R. J. Soulen, Jr., I. I. Mazin, M. S. Osofsky, B. Nadgorny, J. Sanders, H. Srikanth, R. Datla and C. B. Eom, Physical Review B 70, 054416 (2004)

Number of Papers published in peer-reviewed journals: 26.00

(b) Papers published in non-peer-reviewed journals or in conference proceedings (N/A for none)

Number of Papers published in non peer-reviewed journals: 0.00

(c) Presentations

Conference presentations - 32

1. Magnetism and magnetocaloric effect in multiferroic $LuFe_2O_4$ – Hari Srikanth, M. H. Phan, N. A. Frey, M. Angst, B. C. Sales and D. Mandrus, INTERMAG 2008, Madrid, Spain (May 4 – 8, 2008)
2. RF transverse susceptibility studies of effective magnetic anisotropy in nanoparticle assemblies – Hari Srikanth, P. Poddar, M. B. Morales, N. A. Frey, INTERMAG 2008, Madrid, Spain (May 4 – 8, 2008)
3. "Magnetocaloric effect in ferrite nanoparticles" J. Gass and H. Srikanth, APS March meeting, New Orleans, LA (March 10 – 14, 2008)
4. "Magnetic anisotropy and switching in Pr-Sr-Co-O using RF transverse susceptibility" –N. A. Frey, H. Srikanth, D. Stauffer and C. Leighton, APS March meeting, New Orleans, LA (March 10 – 14, 2008)
5. "Synthesis of surface functionalized nanoparticles and polymer nanocomposites" –M. Miner, M. B. Morales, S. Skidmore, T. Weller and H. Srikanth, APS march meeting, New Orleans LA (March 10 – 14, 2008)
6. "Normal to inverse spinel cation distribution and magnetocaloric effect (MCE) in ball-milled zinc ferrite particles" –J. Gass, H. Srikanth, M. J. Miner, N. Kislov, S. Srinivasan, Y. Emirov, 52nd annual Magnetism and Magnetic Materials (MMM) conference, Tampa, FL (Nov. 5-9, 2007)
7. "Unusual magnetic anisotropy and switching in Pr-Sr-Co-O probed by transverse susceptibility" –N. A. Frey, H. Srikanth, D. D. Stauffer, C. Leighton, 52nd annual Magnetism and Magnetic Materials (MMM) conference, Tampa, FL (Nov. 5-9, 2007)
8. "Magnetocaloric effect in nickel ferrite nanoparticles" –J. Gass, M. B. Morales, N. A. Frey, M. J. Miner, S. Srinath and H. Srikanth, APS March Meeting, Denver, CO (March 5-9, 2007)
9. "Magnetic properties of Fe_3O_4 and $CoFe_2O_4$ based ferrofluids" –M. B. Morales, J. Gass, S. L. Morrow and H. Srikanth, APS March Meeting, Denver, CO (March 5-9, 2007)
10. "Magnetic anisotropy and vortex dynamics in LCMO/YBCO heterostructures" –H. Srikanth, N. A. Frey, C. Visani and J. Santamaria, APS March Meeting, Denver, CO (March 5-9, 2007)
11. "Structure, magnetism and microwave properties of PLD-grown Barium Ferrite/Barium Strontium Titanate bilayer thin films" –R. Heindl, H. Srikanth, S. Witanachchi, P. Mukherjee, T. Weller, A. S. Tatarenko and G. Srinivasan, 10th annual joint INTERMAG/MMM conference, Baltimore, Jan 07
12. "Static and dynamic properties of 'dumbbell' and 'flower' shaped Au-Fe_3O_4 nanoparticles" –N. A. Frey, S. Srinath, H. Srikanth, T. Chao and S. Sun, 10th annual joint INTERMAG/MMM conference, Baltimore, Jan 07
13. "Magnetic anisotropy and exchange bias in epitaxial CrO_2/Cr_2O_3 bilayer thin films" –S. Srinath, N. A. Frey, H. Srikanth, G. X. Miao and A. Gupta, 10th annual joint INTERMAG/MMM conference, Baltimore, Jan 07
14. "Exchange coupling, surface and configurational anisotropy in magnetic nanoparticles" –H. Srikanth, MRS Fall 2006, Boston, Nov. 2006
15. "Sensor applications and spin transport measurements in carbon nanotube composites" –J. Sanders, J. Gass, H. Srikanth, F. K. Perkins and E. S. Snow, APS March Meeting, Baltimore, March 2006
16. "Magnetocaloric effect in nanoparticle systems and clathrates" –D. J. Rebar, J. Gass, S. Srinath, H. Srikanth and G. S. Nolas, APS March Meeting, Baltimore, March 2006
17. "Synthesis and characterization of functional magnetic nanocomposites" –J. Gass, J. Sanders, S. Srinath and H. Srikanth, APS March Meeting, Baltimore, March 2006
18. "Magnetic anisotropy in CrO_2 and CrO_2/Cr_2O_3 bilayer thin films" –N. A. Frey, S. Srinath, H. Srikanth, G. Miao and A. Gupta, APS March Meeting, Baltimore, March 2006
19. "Microwave impedance and tunability of BSTO/BaM ferrite films" –R. Heindl, H. Srikanth, S. Balachandran, T. Weller, A. Kumar, P. Gadkari and K. R. Coffey, 50th Magnetism and Magnetic Materials (MMM) conference, San Jose, CA, Oct. 30-Nov. 3 (2005).
20. "Giant magnetocaloric effect (MCE) in clathrates" –H. Srikanth, S. Srinath, D. Rebar, J. Gass, G. Woods, M. Beekman, G. Nolas, 50th Magnetism and Magnetic Materials (MMM) conference, San Jose, CA, Oct. 30-Nov. 3 (2005).
21. "Static and dynamic magnetic response in Mn-doped InP diluted magnetic semiconductor (DMS) nanoparticles" –H. Srikanth, P. Poddar, S. Srinath, Y. Sahoo, P. N. Prasad, 50th Magnetism and Magnetic Materials (MMM) conference, San Jose, CA, Oct. 30-Nov. 3 (2005).
22. "Observation of a new magnetic anomaly below the ferromagnetic Curie temperature in $Yb_{14}MnSb_{11}$" –S. Srinath, P. Poddar, H. Srikanth, B. C. Sales and D. B. Mandrus, 50th Magnetism and Magnetic Materials (MMM) conference, San Jose, CA, Oct. 30-Nov. 3 (2005).
23. "Magnetization and electrical resistivity in insulating phases of $SrFeO_{3-d}$" –S. Srinath, M. Mahesh, M. L. Post and H. Srikanth, 50th Magnetism and Magnetic Materials (MMM) conference, San Jose, CA, Oct. 30-Nov. 3 (2005).
24. "Functional magnetic nanostructures" –Srikanth Hariharan, Nanomaterials and Nanotechnologies (NN 2005), Hersonissos, Crete (Greece), June 2005
25. "Magnetocaloric effect in ferrite nanoparticles" -D. Rebar, J. Gass, P. Poddar and H. Srikanth, American Physical Society March meeting, March 2005, Los Angeles, CA.
26. "Growth and characterization of tunable BSTO/BaM multilayers as substrates for magnetic nanoparticles" –N. A. Frey, S. Srinath, R.

Heindl, H. Srikanth, K. R. Coffey, N. J. Dudney, American Physical Society March meeting, March 2005, Los Angeles, CA.
27. "Dispersion of magnetic nanoparticles in polymer films" –J. Gass, J. Almand, P. Poddar and H. Srikanth, American Physical Society March meeting, March 2005, Los Angeles, CA.
28. "Transverse susceptibility as a probe of spin and charge dynamics in LSMO single crystals" –H. Srikanth, P. Poddar, G. T. Woods and Y. Mukovskii, American Physical Society March meeting, March 2005, Los Angeles, CA.
29. "Microstructure and magnetism in polymer nanocomposites with Fe and Fe3O4 nanoparticle dispersions" –J. Gass, J. Almand, P. Poddar and H. Srikanth, Magnetism and Magnetic Materials (MMM) conference, Jacksonville, FL, Nov. 7 – 11 (2004).
30. "Growth of electrically and magnetically tunable BSTO/BaF multilayers" –S. Srinath, N. A. Frey, R. Hajndl, H. Srikanth, K. R. Coffey, N. J. Dudney, Magnetism and Magnetic Materials (MMM) conference, Jacksonville, FL, Nov. 7 – 11 (2004).
31. "Observation of charge ordering and ferromagnetic transition in single crystal LSMO using RF transverse susceptibility" –G. T. Woods, P. Poddar, H. Srikanth and Y. M. Mukovskii, Magnetism and Magnetic Materials (MMM) conference, Jacksonville, FL, Nov. 7 – 11 (2004).
32. "Spin polarization measurements in polycrystalline ruthenates using point contact Andreev reflection" –J. T. Sanders, G. T. Woods, P. Poddar, H. Srikanth and B. Dabrowski, Magnetism and Magnetic Materials (MMM) conference, Jacksonville, FL, Nov. 7 – 11 (2004).

Number of Presentations: 32.00

Non Peer-Reviewed Conference Proceeding publications (other than abstracts):

Number of Non Peer-Reviewed Conference Proceeding publications (other than abstracts): 0

Peer-Reviewed Conference Proceeding publications (other than abstracts):

Number of Peer-Reviewed Conference Proceeding publications (other than abstracts): 0

(d) Manuscripts

Number of Manuscripts: 0.00

Patents Submitted

Patents Awarded

Awards

Graduate Students

NAME	PERCENT SUPPORTED
Ranko Heindl	0.50
Natalie Frey	0.50
FTE Equivalent:	**1.00**
Total Number:	**2**

Names of Post Doctorates

NAME	PERCENT SUPPORTED
Srinath Sanyadanam	1.00
Pankaj Poddar	0.10
FTE Equivalent:	**1.10**
Total Number:	**2**

Names of Faculty Supported

NAME	PERCENT SUPPORTED	National Academy Member
Hariharan Srikanth	0.20	No
FTE Equivalent:	**0.20**	
Total Number:	**1**	

Names of Under Graduate students supported

NAME	PERCENT SUPPORTED
Melody Miner	0.33
FTE Equivalent:	**0.33**
Total Number:	**1**

Student Metrics

This section only applies to graduating undergraduates supported by this agreement in this reporting period

The number of undergraduates funded by this agreement who graduated during this period: 1.00

The number of undergraduates funded by this agreement who graduated during this period with a degree in science, mathematics, engineering, or technology fields:...... 1.00

The number of undergraduates funded by your agreement who graduated during this period and will continue to pursue a graduate or Ph.D. degree in science, mathematics, engineering, or technology fields:...... 0.00

Number of graduating undergraduates who achieved a 3.5 GPA to 4.0 (4.0 max scale):...... 1.00

Number of graduating undergraduates funded by a DoD funded Center of Excellence grant for Education, Research and Engineering:...... 0.00

The number of undergraduates funded by your agreement who graduated during this period and intend to work for the Department of Defense 0.00

The number of undergraduates funded by your agreement who graduated during this period and will receive scholarships or fellowships for further studies in science, mathematics, engineering or technology fields:...... 1.00

Names of Personnel receiving masters degrees

NAME	
Ranko Heindl	
Natalie Frey	
Chamila Siyambalapitiya	
Total Number:	**3**

Names of personnel receiving PHDs

NAME	
Ranko Heindl	
Natalie Frey	
Total Number:	**2**

Names of other research staff

NAME	PERCENT SUPPORTED
FTE Equivalent:	
Total Number:	

Sub Contractors (DD882)

Inventions (DD882)

Scientific Progress

Technology Transfer

UNIVERSITY OF SOUTH FLORIDA

Final Report – Project DAAD 19-03-1-0277

Ordered magnetic nanoparticle arrays on tunable substrates for RF applications

PI: Hariharan Srikanth

FINAL REPORT (DAAD 19-03-1-0277)
Research period: 2004-2008

PI: Hariharan Srikanth, University of South Florida, Tampa, FL

The goal of this research project was to fabricate tunable multilayer oxide structures based on Barium Strontium Titanate (BST) and Barium Hexaferrite (BaM) materials, demonstrate tunability of impedance when subject to external electrical and magnetic fields and also explore the fabrication, properties and electromagnetic properties of magnetic oxide nanoparticles. The project started in January 2004 and initially was funded through May 2005. It was under no-cost extension until September 2006 and addition supplement funding was received in this grant for the period October 2006 thru July 2007. As a final stage, the project was granted a one-year no-cost extension from August 2007 thru July 2008. All the interim reports were submitted during the various stages. This is the final report which is a consolidated document outlining the various research efforts undertaken and successfully completed in this project that spanned multiple calendar years. Due to the phases (two no-cost extension periods and supplemental funding period), we present a chronological list of work done and achievements in the following sections. A list of publications and presentations acknowledging the grant is provided at the end.

2004-2007 (the first phase of the project):
Research highlights:

1. Magnetron sputtering, characterization and optimization of film growth parameters
2. Design and set up of a dedicated thin film impedance measurement system
3. Synthesis and RF dynamics in magnetic nanoparticles
4. Microstructure and growth parameters for BST/BaM heterostructures grown by sputtering and PLD
5. Magnetic properties, high frequency response and electrical tunability of the films
6. Measurements of ferromagnetic resonance tunability.

We briefly report on the scientific progress in these areas and present some representative results. **Information on research personnel supported on the grant, peer-reviewed publications and conference presentations that acknowledge support of this grant are collected and listed in a section at the end of the report.**

1. Growth and characterization of BSTO/BaF multilayers

We have grown bilayers and trilayers (total thickness around 1 to 1.5 microns) of alternating BSTO and BaF films using magnetron sputtering. The process was labor intensive as the key growth parameters such as deposition rate, substrate temperature, post-annealing conditions were modified systematically to achieve good quality samples.

Two choices of substrates were used –Al_2O_3 and Si/SiO_2. Our studies indicate that substrate adhesion is poor unless the sputtering and annealing conditions are precisely controlled. We define the benchmark of "good quality" samples as multilayers that reveal the expected surface microstructure, sharp interfaces and most important of all, display sharp X-ray peaks consistent with single phase materials. All these conditions have been met and two batches of multilayer samples with both BSTO and BaF as terminating layers have been grown. Fig. 1 shows the XRD data for one sample. All the peaks have been indexed either to BSTO, BaF or the substrate material. **To our knowledge, this is the first report of sputtered multilayers in this class of ferrite-ferroelectric materials and it is a significant accomplishment in this project.**

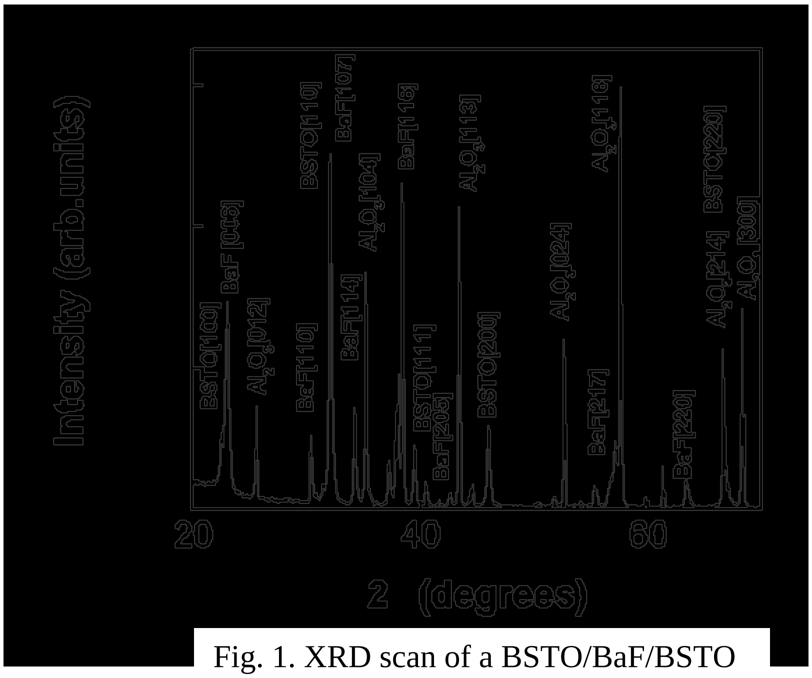


Fig. 1. XRD scan of a BSTO/BaF/BSTO trilayer sample.

In Fig. 2, the cross-sectional SEM images are shown for a multilayer sample before and after annealing at around 800 C. Some amount of interdiffusion appears to occur at the interfaces in postannealed samples. However, we determined that the post-annealing in flowing oxygen at such high temperatures is necessary to stabilize the hard magnetic hexaferrite phase (i.e. to achieve the expected coercivity and saturation magnetization of the BaF layers). Future work will address the effect of interdiffusion and surface roughness on the magnetic, dielectric and RF properties and attempts to further improve the quality of multilayers will continue.

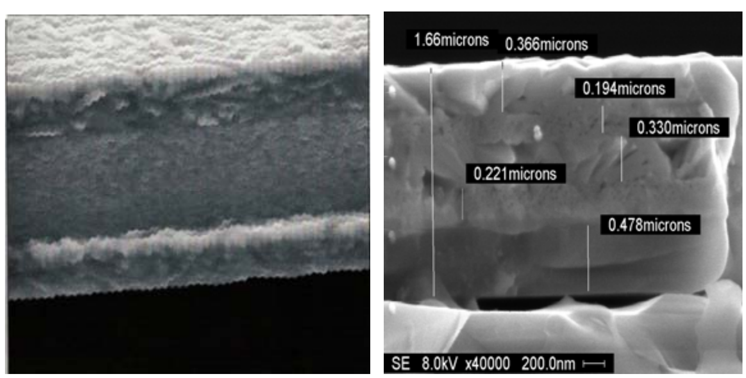


Fig. 2: Cross-sectional SEM images of BSTO/BaF multilayers. Left panel is before annealing and right panel is after annealing for 3 hours in flowing oxygen at 800 C.

The film growth and optimization of desirable parameters were being done by PI, his student and postdoctoral researcher supported in this project using off-campus magnetron sputtering systems through collaborations. We have realized the importance of having a dedicated deposition system in our Materials Physics Laboratory at USF. The PI has been actively seeking funds to purchase a state-of-the-art sputtering system. He was successful in getting a DURIP grant through the Army in 2007 and a commercial sputtering system from AJA, Inc. has been purchased and installed in his laboratory. This will have significant impact on future projects on oxides with substantial progress expected.

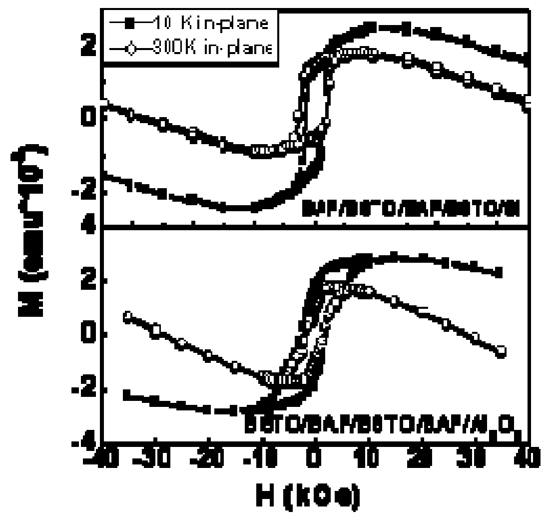


Fig. 3 M-H hysteresis loop data at 300K and 10 K

Fig. 3 shows the standard magnetic hysteresis loop measurements done on the multilayer samples using a Physical Property Measurement System. The large coercivities (1500 to 2200 Oe) obtained in the samples are consistent with values for BaF reported in the literature.

The negative slope at high fields is due to the diamagnetic background of the non-magnetic BSTO and Al2O3 components of the multilayer structure.

2. Thin film impedance measurement system

During the course of the project, we designed and set up a dedicated thin film impedance measurement system operational over a frequency range of 1 MHz to 6 GHz. The system includes a fixture designed to fit between the pole pieces of a water-cooled electromagnet that can generate static magnetic fields up to 0.8 Tesla. The high frequency probing is done with a GGB two-probe contact on film surface and the signal is fed to an HP 8753 vector network analyzer.

A picture of the RF probe station set up in is shown. Three manuscripts based on results generated from this system have been published in leading journals such as Applied Physics Letters and Journal of Applied Physics. Dr. Ranko Heindl (a former Ph.D. student of the PI who received full-time RA support on this grant) worked with this system for his doctoral dissertation. He received his Ph.D. in December 2006 and later accepted a National Research Council Postdoctoral Associateship at NIST (Boulder).

3. Synthesis and RF susceptibility in magnetic nanoparticles

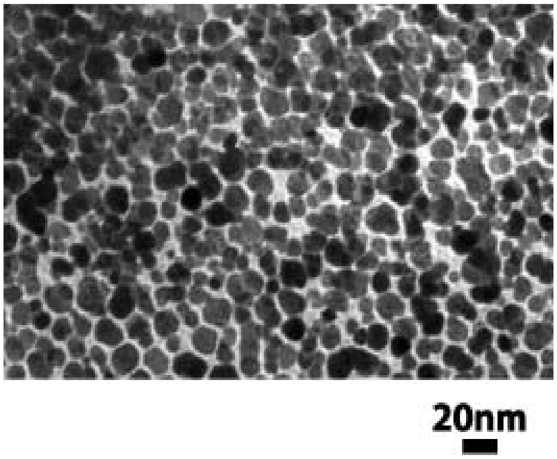


Fig. 4. TEM image of Fe_3O_4 nanoparticles with average size ~ 12 nm

As part of the efforts on this project, a wet-chemical synthesis section was set up in our laboratory and we have been able to routinely produce high quality magnetic oxide nanoparticles in-house.

Fig. 4 shows a Transmission Electron Microscopy (TEM) image of iron oxide (Fe_3O_4) nanoparticles with oleic acid as the surfactant, synthesized in our laboratory using chemical co-precipitation. The excellent size dispersion is clearly evident and the quality of these nanoparticles is comparable with that produced by leading groups in this field. This is just a representative example for this final report. Please refer to the list of publications on magnetic nanoparticles at the end the report for additional information on various systems that were synthesized and studied during the course of the project.

In addition to in-house synthesis, we collaborated with several researchers, including Dr. Everett Carpenter (formerly from Naval Research Lab, currently at Virginia Commonwealth University –Chemistry Dept.), Prof. Sara Majetich and Prof. Michael McHenry from Carnegie Mellon University, Prof. Vincent Harris from Northeastern University. We have continued investigations of dynamic magnetic response using RF transverse susceptibility experiments on Fe, Mn-Zn and Ni-Zn ferrite nanoparticles. Our studies have led to understanding of inter-particle interactions, surface spin disorder and their influence on the magnetic susceptibility in the superparamagnetic and blocked states in these systems. Several papers were published on these studies.

4. Near-epitaxial growth of BaM/BST bilayers using pulsed laser deposition (PLD)

After initial work on sputtered films, we moved to PLD for deposition of oxide heterostructures. This led to optimizing the growth parameters of the hexaferrite and BST films. We have been successful to produce the first such bilayers with highly oriented grains (in-plane as well as out-of-plane). This was a significant breakthrough as control of the interface properties and microstructure resulted in manipulation of the magnetic anisotropy. The influence of the substrates (MgO, single crystalline Al_2O_3) was systematically studied and was shown to play an important role in the orientation of the BaM films. During the period 2005-2007, a lot of effort from research personnel supported on this project went to fine-tuning the fabrication process to achieve the goals of high quality, epitaxial interfaces and showing excellent magnetic and dielectric properties. A few representative results are given below. All the main results from this work have been published journals and presented at major conferences. The PI gave a highly visible invited talk at the 2008 American Physical Society March meeting about the role of interfaces in layered ferromagnetic-ferroelectric oxides fabricated in the lab.

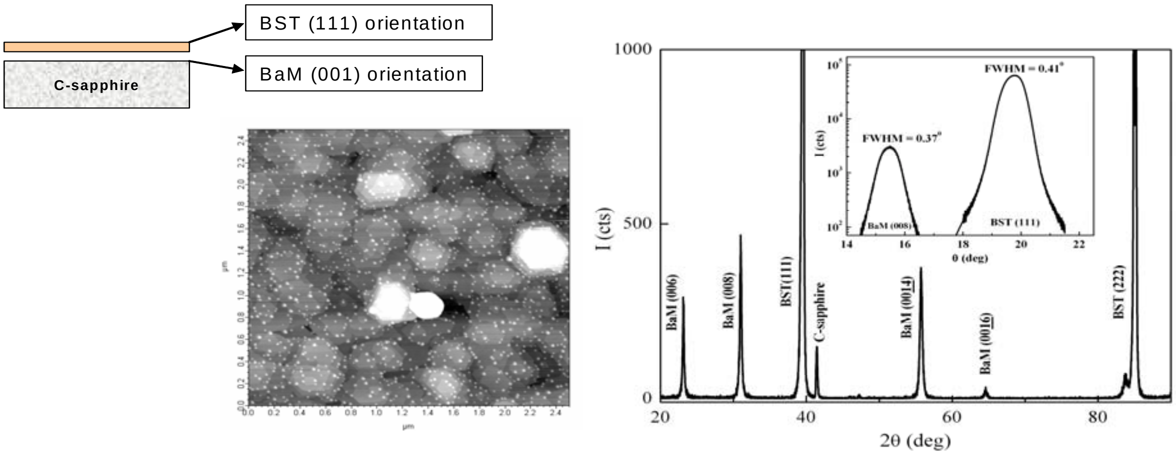


Fig. 5 (Right) X-ray diffraction and rocking curves are shown for BaM/BST bilayer grown by PLD on heated C-sapphire substrate. (Left) AFM image of c-axis oriented hexagonal platelet grains of BaM film grown on C-sapphire

Fig. 5 shows the high quality of the microstructure of the BaM/BST bilayers and oriented BaM films achieved by optimizing the growth parameters. The in-plane and out-of-plane magnetization of the bilayers at room temperature is shown in Fig. 6. Consistent with the strong preferential orientation of the BaM grains, the magnetic properties are highly directional. Essentially, our results indicated that the substrate and the BST underlayer combine to tune the grain growth and orientation of BaM. This can be used to tune the magnetic and microwave properties of these structures. These results were first of their kind in these systems and were published in a paper in Applied Physics Letters.

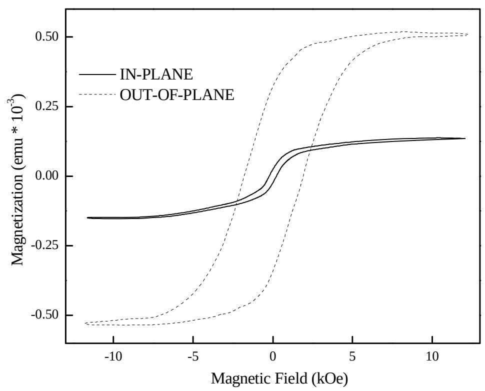
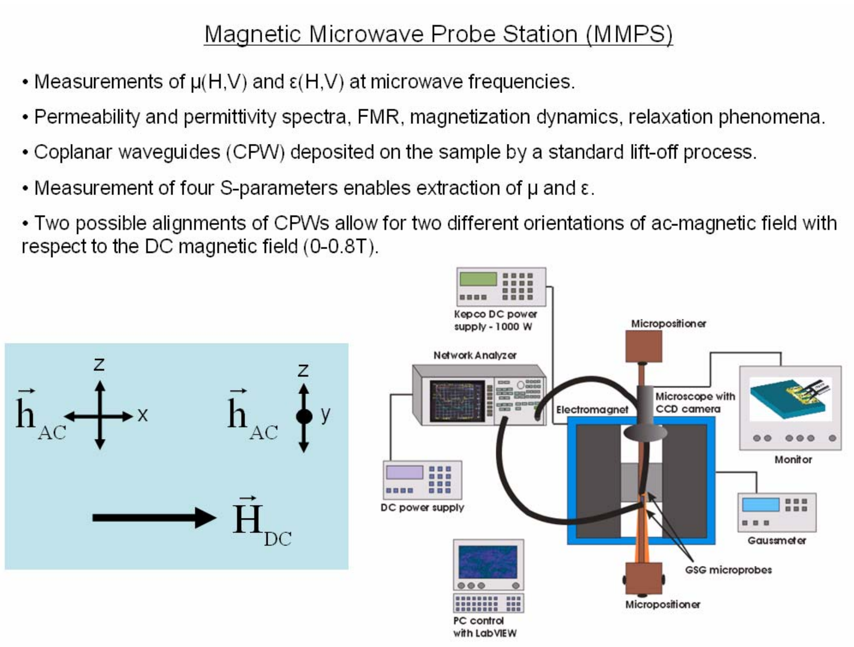


Fig. 6 M-H loops at 300K for the BaM/BST bilayer grown on C-sapphire. In-plane and out-of-plane correspond to external H field parallel and perpendicular to the film surface.

5. <u>Impedance measurements and electrical tunability</u>

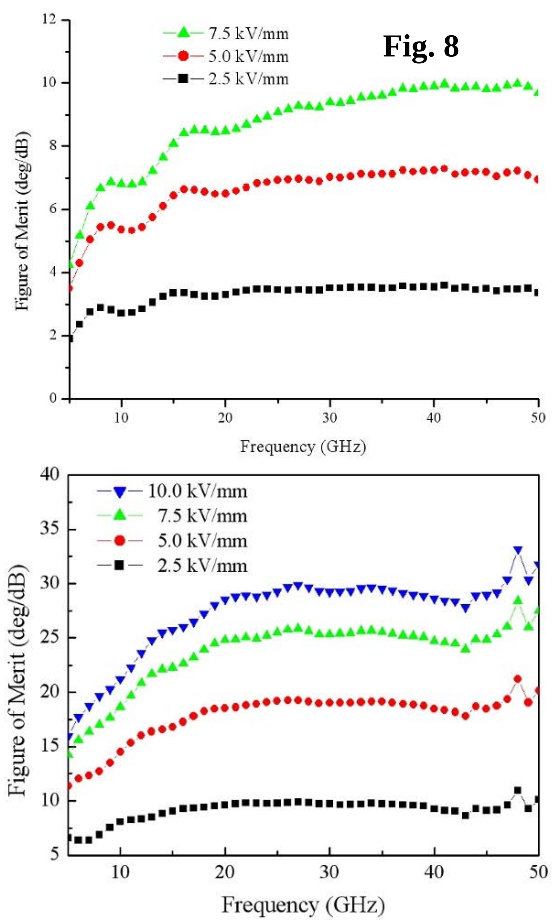
A picture and schematic of our thin film impedance measurement system is shown below in Fig. 7. The system includes a fixture designed to fit between the pole pieces of a water-cooled electromagnet that can generate static magnetic fields up to 0.8 Tesla. The high frequency probing is done with a GGB two-probe contact on film

Fig. 3



surface and the signal is fed to a vector network analyzer. The S-parameters are recorded and a Figure of Merit for tunability in degrees/dB are calculated from the measured S_{11} and S_{21}. **Microwave measurements and analyses done in this project formed the major portion of the Ph.D dissertation of PI's doctoral student (Ranko Heindl) and the dissertation defense was held in October 2006. Details of measurements and calculations were reported in this dissertation which is available in the public domain.**

The electrical tunability of the BST/BaM bilayer films grown on MgO and *c*-sapphire substrates is shown in Fig. 8. These data were obtained by depositing interdigitated Au coplanar waveguides in the capacitor configuration on the surface of the films deposited through pre-fabricated mechanical masks. Two different gaps were tested and the CPWs were calibrated over the entire range of frequency. For example, a flat response was obtained for the substrates alone in the same configuration as they should not show any tunability. Fig. 8 shows the freqeuncy scans for different electric fields across the CPW generated capacitors. The figure of merit was extracted from S-parameter data through standard microwave analyses procedures. Our VNA (HP 8753) went up to only 6 GHz so it was not of much use for the measurements. Data over frequencies up to 50 GHz were taken with a borrowed network analyzer from a

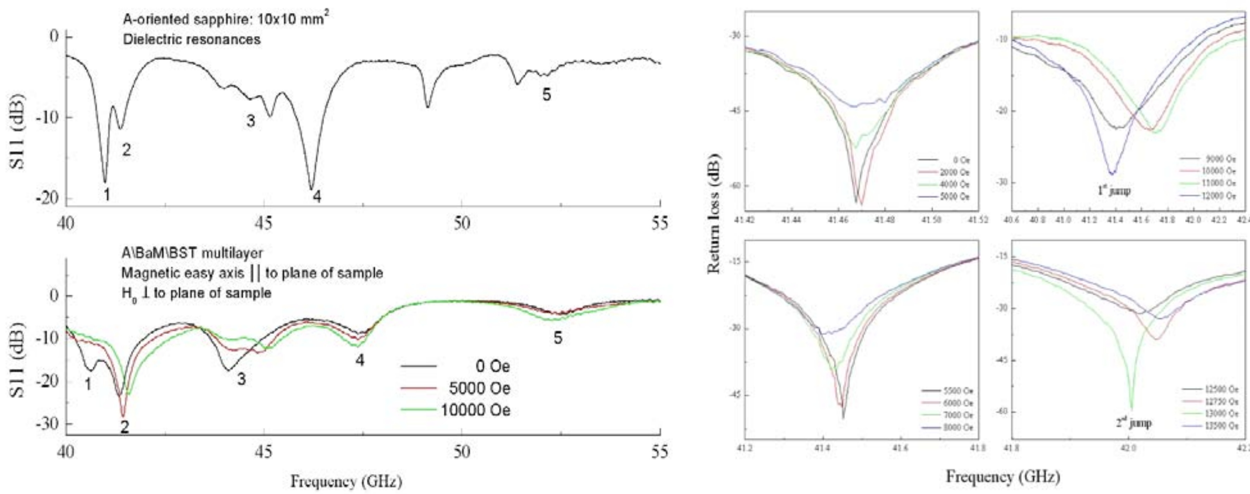


collaborator (Prof. Tom Weller from Electrical Engineering at USF). The observed electrical tunability was quite impressive and comparable to the best quality BST films reported in the literature. This demonstrated that our bilayer devices would be as effective in tunable filter/phase shifter applications.

6. **<u>Ferromagnetic resonance in BaM/BST and its tunability</u>**

An important goal of this project was to demonstrate dual tunability (i.e. with electric and magnetic fields). Through a collaboration with Prof. Gopalan Srinivasan at Oakland University in Michigan, we measured the ferromagnetic resonance and its sensitivity to the external magnetic fields using a resonant cavity method in his lab.

Fig. 9 shows the reflected power data for our BST/BaM measured with



Srinivasan's set-up which consists of a U-band waveguide-coaxial adapter. The panel on the left shows the full frequency scan with multiple resonances that include the dielectric resonances of the bilayers + the substrate along with the FMR due to the barium ferrite. One of the problems was that the FMR was nearly superimposed with a dielectric resonance (at around 42 GHz). Nevertheless, they can be separated out by applying an external H field and looking at the tunability or variation of the resonance. The right panel of Fig. 5 zooms in on the FMR frequency around 42 GHz and shows how this resonance feature varies as the external magnetic field is changed from 0 to 12.5 kOe. There is distinct change in the resonance thus demonstrating that indeed our BaM/BST bilayers are magnetically tunable. More work is needed to qualitatively and quantitatively extract the FMR and its tunability. But essentially, the results demonstrate our intended goal of dual tunability (electric and magnetic) in these heterostructures.

<u>2006-2008 (the second phase of the project):</u>
<u>Research highlights:</u>

1. Demonstration of electrical as well as dual tunability in PLD-grown BST/BaM bilayers

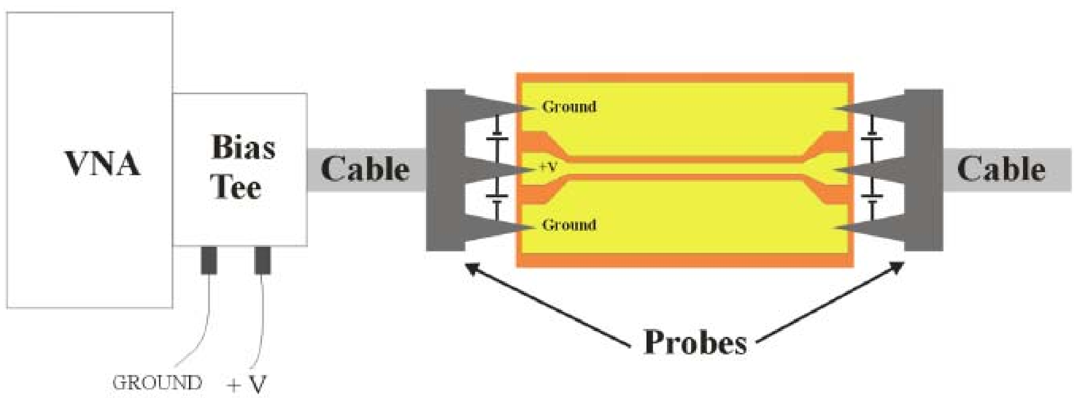
2. Major outcome: PhD dissertation "Ferrite-Ferroelectric thin films with tunable electrical and magnetic properties" of PI's student Dr. Ranko Heindl.
3. Observation of anomalous magnetism and novel exchange bias phenomena in coupled nanostructures
4. Study of magnetism and magnetocaloric effect in gadolinium garnet nanostructures

We now briefly describe the scientific progress achieved during this phase of the project.

1. <u>Microwave tunability of ferrite-ferroelectric bilayers</u>

Our main goal in the final phase of this project was to clearly demonstrate electrical and magnetic tunability of the microwave impedance. We have done this and reported the results in major conferences as well as published them.

Our efforts concentrated on optimizing the best way to acquire microwave data on the thin film heterostructures. A coplanar waveguide (CPW) phase shifter geometry as shown in the figure below was identified as the most promising method.



Considerable time was spent in using lithography and patterning to control the gold lines on the film surface and capacitive gaps down to 5 micron widths. A vector network analyzer (going up to 65 GHz) was used for the microwave S-parameter measurements. The sample stage was placed in our previously designed microwave magnetic probe station (MMPS). Electric and magnetic fields were simultaneously applied and the phase shift was measured precisely. Representative data that we reported in our Applied Physics Letters paper is reproduced as a sample here.

A number of BaM/BST configurations grown on different substrates were investigated and correlations were obtained between thickness, geometry, substrate used, quality of films directly with the microwave propagation. Impedance matching was a major issue since these materials are complex oxides with a range of transport properties. All these technical issues were overcome and the culmination of our work yielded excellent results that we present below.

For the first time, we demonstrated excellent phase shifter characteristics of BST/BaM films and observed that they were quite comparable to some of the best BST phase shifters reported in the literature. The presence of BaM provided the additional advantage of dual tunability. **We also found that our BST/BaM bilayer structure (with the BaM as the top layer) has the additional potential of avoiding leakage currents that tend to damage and curb the lifetime of BST based phase shifters.** This novel concept has to be tested in actual device configurations and will be the subject of focus of future research on all-oxide, tunable devices.

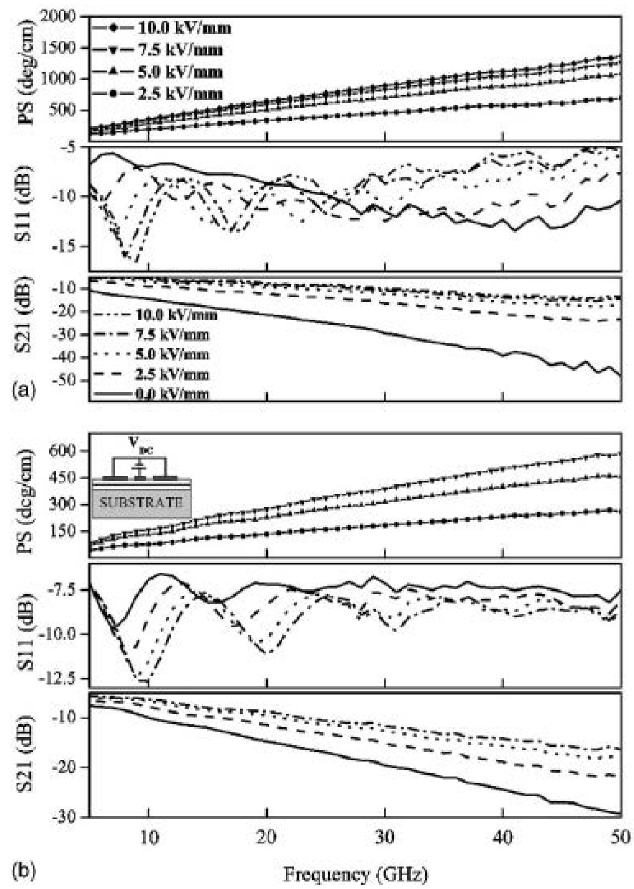


FIG. 3. Phase shift (°/cm), S_{11} (dB), and S_{21} (dB) of (a) MgO‖BST‖BaM and (b) sapphire‖BaM‖BST bilayer thin films. The inset shows a cross section of the CPW and the electrical biasing.

2. Anomalous magnetism and exchange bias in coupled Au-Fe_3O_4 nanoparticles

Spin disorder in nanoparticle surfaces of ferrites is known to result in interesting magnetic response with the core spins often forming an ordered structure and the surface spins exhibiting spin glass characteristics (*Kodama et al. Phys. Rev. Lett. 77, 394 (1996*). This configuration could arise to exchange bias (EB) phenomenon. The origin of EB in nanostructures is still poorly understood (*Nogues et al. Phys. Rep. 422, 65 (2005*) and the question remains whether one can control the interface coupling between the surface and core spins in nanoparticles. In a recent study, we reported the observation of anomalous magnetism and exchange bias in coupled Au-Fe_3O_4 nanoparticles that resemble the shape of “dumbbells” or “flowers” with 8 nm Au acting as the seed particle to which 9 nm Fe_3O_4 particles bind in various configurations (*Frey et al. IEEE Trans. Magn. 46, 3094 (2007*). We have further extended our investigation of these exotic nanostructures in this project and gained a thorough understanding of the exchange bias and spin frustration. Our detailed experiments ranging from DC, AC susceptibility to magnetic training and memory effect studies yield a remarkable picture with the coupling across the Au interface playing a major role in preferential spin pinning of the Fe_3O_4 surfaces. This results in dramatically large EB of the order of 1200 Oe in flower shaped nanoparticles

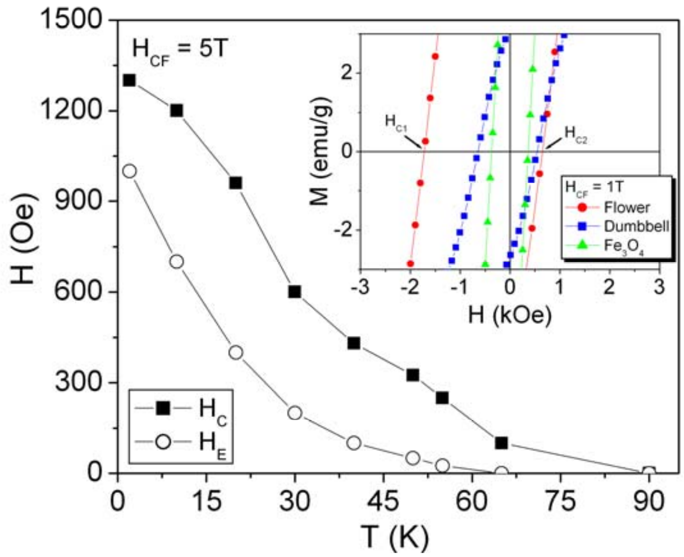


Fig. 10 Exchange bias and coercivity enhancement in coupled Au- Fe_3O_4 nanoparticles

(possessing multiple Au- Fe_3O_4 interfaces across multiple faces) whereas dumbbell shaped coupled particles with a single interface of Au-Fe_3O_4 show smaller EB (~ 120 Oe). No EB is seen Fe_3O_4 nanoparticles of similar size but without any Au confirming the role of Au interface.

Fig. 10 summarizes one of the key findings from our investigations. The main panel shows the temperature dependence of exchange bias field and coercivity when cooled in 5T for Au- Fe_3O_4 flower-shaped nanoparticles. The inset is a comparison of the shift in M-H loops for bare Fe_3O_4, dumbbell shaped and flower shaped Au- Fe_3O_4 particles. Our research on surface and interface magnetism in nanostructures and heterostructures has been widely acknowledged by peers in the field. The PI gave invited talks in March 2008 at the American Physical Society March meeting in New Orleans and the Materials Research Society Spring meeting in San Francisco that featured this work.

3. Investigations of particle size effect on spin frustration in Gd-Fe garnet nanostructures

A final investigation we undertook in Fall 2007-Summer 2008 period of the project was to study magnetism and magnetocaloric effect in $Gd_3Fe_5O_{12}$ garnets in bulk and nanostructured forms. Garnets are known to have a wide range of applications in tunable high frequency microwave and magneto-optical devices. While spin frustration and magnetism in bulk garnets have been studied in the past, ours was the first study of these effects in nanostructured garnets. The materials were grown in the laboratory of Prof. Vince Harris at Northeastern University, who is a pioneer in the field of ferrites and microwave materials. Preliminary results indeed show a very interesting competition between intrinsic spin frustration (due to the triangular lattice configuration) in the garnet structure and the glassy behavior caused by particle size becoming smaller (in 30 to 50 nm range) and the resulting blocking transition. The magnetocaloric effect also changes character with spin frustration dominant in bulk materials and surface spin disorder dominant in nanoparticles. More experiments are under way to systematically study the regime where the crossover happens with one effect dominating the other.

Research Personnel supported on the grant:

1. Dr. Hariharan Srikanth (PI): 1 month summer salary on the grant. Supervised all aspects of the project

2. Mr. Ranko Heindl: Ph.D. student supported full-time on this grant from 2004-2006.

3. Ms. Natalie Frey: Ph.D. student supported full-time on this grant from 2006-2008

4. Ms. Melody Miner: Undergraduate student supported through an REU that worked on this project

4. Dr. Srinath Sanyadanam: Postdoctoral Researcher supported on the grant

5. Dr. Pankaj Poddar: Visting postdoctoral scientist supported on the grant

Publications related to the project: (reverse chronological order)

1. "Measurement of spin polarization of doped strontium ruthenates using point contact Andreev reflection (PCAR)" –G. T. Woods, *J. Sanders*, S. Kolesnik, T. Maxwell, **H. Srikanth**, B. Dabrowski, M. S. Osofsky and R. J. Soulen., Jr., **Journal of Applied Physics 104**, 083701 (2008)
2. "Transverse susceptibility study of the effect of varying dipolar interactions on anisotropy peaks in a 3D assembly of soft ferrite nanoparticles" –*P. Poddar*, *M. B. Morales*, *N. A. Frey*, S. A. Morrison, E. E. Carpenter and **H. Srikanth**, **Journal of Applied Physics 104**, 063901 (2008)
3. "Static and dynamic magnetic properties of Co nanoparticles" –*S. Srinath*, *P. Poddar*, D. S. Sidhaye, B. L. V. Prasad, *J. Gass* and **H. Srikanth**, **Journal of Nanoscience and Nanotechnology 8**, 4086 (2008**)**
4. **"**Magnetization and magnetocaloric effect in ball milled zinc ferrite powder" –*J. Gass*, **H. Srikanth**, N. Kislov, S. Srinivasan and Y. Emirov, **Journal of Applied Physics 103**, 07B309 (2008)
5. "Multifunctional ferromagnetic-ferroelectric thin films for microwave applications" –*R. Heindl*, **H. Srikanth**, S. Witanachchi, P. Mukherjee, A. Heim, G. Matthews, S. Balachandran, S. Natarajan and T. Weller, **Applied Physics Letters 90**, 252507 (2007)
6. "Transverse susceptibility as a probe of interface magnetism in functional multilayers and nanostructures" –*N. A. Frey*, *M. B. Morales*, **H. Srikanth** and *S. Srinath*, **Encyclopedia of Advanced Materials: Science and Engineering** (Pan Stanford Publishers, in press 2007)
7. "Growth of barium hexaferrite nanoparticle coatings by laser-assisted spray pyrolysis" –G. Dedigamuwa, P. Mukherjee, **H. Srikanth** and S. Witanachchi, **J. Amer. Ceram. Soc.** (accepted 2007)
8. "Static and dynamic magnetic properties of composite Au-Fe_3O_4 nanoparticles" –*N. A. Frey*, *S. Srinath*, **H. Srikanth**, T. Chao and S. Sun, **IEEE Transactions on**

Magnetics 43, 3094 (2007)

9. "Structure, magnetism and tunable microwave properties of PLD-grown Barium ferrite/Barium strontium titanate bi-layer films" –*R. Heindl*, **H. Srikanth**, S. Witanachchi, P. Mukherjee, T. Weller, A. S. Tatarenko and G. Srinivasan, **Journal of Applied Physics 101**, 09M503 (2007)

10. "Exchange bias in CrO_2/Cr_2O_3 bilayer thin films" –*S. Srinath, N. A. Frey*, **H. Srikanth**, G. Miao and A. Gupta, **Advances in Science and Technology 45**, 2528 (2006) Trans Tech Publications

11. "Magnetic anisotropy in CrO_2 and epitaxial CrO_2/Cr_2O_3 bilayers" –*N. A. Frey, S. Srinath*, **H. Srikanth**, M. Varela, S. Pennycook, G. Miao and A. Gupta, **Physical Review B 74**, 024420 (2006)

12. "Magnetization in insulating phases of Ti^{4+} doped $SrFeO_{3-\delta}$" –*S. Srinath*, M. Mahesh Kumar, K. Sahner, M. L. Post, M. Wickles, R. Moos and **H. Srikanth**, **Journal of Applied Physics 99**, 08S904 (2006)

13. "Magnetization and magnetoresistance in insulating phases of $SrFeO_{3-d}$" –*S. Srinath*, M. Mahesh, M. L. Post and **H. Srikanth**, **Phys. Rev. B 72**, 054425 (2005)

14. "Microstructure and magnetism in Barium Strontium Titanate (BSTO) – Barium Hexaferrite (BaM) multilayers –*N. A. Frey, R. Heindl, S. Srinath*, **H. Srikanth** and N. J. Dudney, **Materials Research Bulletin 40**, 1286 (2005)

15. "Superparamagnetism and magnetocaloric effect in functional magnetic nanostructures" –**H. Srikanth** and *J. Gass*, **Reviews of Advances in Materials Science 10**, 398 (2005)

16. "Magnetic properties of polydisperse and monodisperse NiZn ferrite nanoparticles interpreted in a surface structure model" –R. Swaminathan, M. McHenry, *P. Poddar* and **H. Srikanth**, **Journal of Applied Physics 97**, 10G104 (2005)

17. "Growth and characterization of sputtered BSTO/BaM multilayers" –*S. Srinath, N. A. Frey, R. Hajndl*, **H. Srikanth**, K. R. Coffey and N. J. Dudney, **Journal of Applied Physics 97**, 10J115 (2005)

18. "Spin polarization measurements on polycrystalline strontium ruthenates using point contact Andreev reflection" –*J. T. Sanders*, G. T. Woods, *P. Poddar*, **H. Srikanth** and B. Dabrowski, **Journal of Applied Physics 97**, 10C912 (2005)

19. "Observation of charge ordering and the ferromagnetic transition in single crystal LSMO using RF transverse susceptibility" –G. T. Woods, *P. Poddar*, **H. Srikanth** and Y. M. Mukovskii, **Journal of Applied Physics 97**, 10C104 (2005)

20. "Probing magnetic anisotropy and spin polarization in spintronic materials" –*P. Poddar*, G. T. Woods, *S. Srinath* and **H. Srikanth**, **IEEE Transactions on Nanotechnology 4**, 59 (2005)

21. "Inter-particle interactions and magnetism in manganese-zinc ferrite nanoparticles" –*P. Poddar*, **H. Srikanth**, S. A. Morrison and E. E. Carpenter, **Journal of Magnetism and Magnetic Materials 288C**, 443 (2005)

22. "Surface modification and magnetism in Co-implanted BSTO/Barium Hexaferrite composite films" –*R. Hajndl, S. Srinath* and **H. Srikanth**, **Journal of the American Ceramics Society** (ICF-9 Proceedings, p. 155, 2005)

23. "Magnetism and RF dynamics in nanocomposite materials" **–H. Srikanth** and *P. Poddar*, **Journal of Metastable and Noncrystalline Solids 23**, 355 (2005) Trans

Tech Publications

24. Conference report on Seeheim Conference on Magnetism (SCM2004) –**Srikanth Hariharan**, **Physica Status Solidi (a) 201**, 2611 (2004) [Report at the invitation of the publisher, Wiley-VCH]
25. "Magnetic properties of conducting polymer doped with Mn-Zn ferrite nanoparticles" – *P. Poddar, J. L. Wilson*, **H. Srikanth**, S. A. Morrison and E. E. Carpenter, **Nanotechnology 15**, S570 (2004)
26. "Analyzing point contact Andreev reflection" –G. T. Woods, R. J. Soulen, Jr., I. I. Mazin, M. S. Osofsky, B. Nadgorny, *J. Sanders*, **H. Srikanth**, R. Datla and C. B. Eom, **Physical Review B 70**, 054416 (2004)

Conference presentations by PI and his group on work supported by the grant:

Invited talks:

1. **Invited Speaker,** York post-Intermag workshop, University of York (UK), May 13, 2008
2. **Condensed Matter Seminar**, University of Leeds, Leeds, UK, May 14, 2008
3. **Device Materials Group Seminar**, MS&E, Cambridge University, UK, May 15, 2008
4. **Materials Science Colloquium**, Argonne National Laboratory, April 10, 2008
5. **Invited Speaker**, Symposium I: Synthesis and metrology of nanoscale oxides and thin films, 2008 Materials Research Society (MRS) Spring meeting, San Francisco, CA, March 2008
6. **Invited Speaker,** 2008 American Physical Society (APS) March meeting in the Focus Topic on Complex Oxides, New Orleans, LA, March 2008
7. **Colloquium**, Department of Physics, University of Wyoming (Feb 22, 2008)
8. **Seminar**, NIST (Boulder), Feb 21, 2008
9. **Condensed Matter Seminar**, Physics Department, Washington University – St. Louis, Feb. 11, 2008
10. **Condensed Matter Seminar**, Oak Ridge National Laboratory, Jan. 28, 2008
11. **Condensed Matter Seminar**, Department of Physics, Indian Institute of Science, Bangalore, India (Oct. 11, 2007)
12. **Invited Speaker –**Magnetism and Spintronics, IUMRS-International Conference on Advanced Materials(ICAM), Bangalore, India, Oct. 2007
13. **Invited Speaker**, 13th Czech and Slovak Conference on Magnetism (CSMAG 2007), Kosice, Slovakia, July 2007
14. **Invited Speaker** in Symposium J "Materials for Advanced Sensors and Devices" at the International Conference on Materials for Advanced Technologies (ICMAT 2007), Singapore, July 2007
15. **Seminar –**Physics Department, Nanyang Technical University, Singapore, July 6, 2007
16. **Seminar –**Department of Physics, Indian Institute of Technology, Madras, June 25, 2007

17. **Condensed Matter Seminar,** University of Central Florida, Orlando, FL, Jan. 29, 2007
18. **Invited Speaker –**Nanomaterials Symposium, TMS 2007, Orlando, FL, Feb. 2007
19. **Colloquium** at University of Illinois – Urbana Champaign, ECE Department, (Oct 19, 2006)
20. **Invited Talk -** "Transverse susceptibility as a probe of magnetic anisotropy in oxides" at the **CIMTEC 2006** (June 5 – 9, 2006, Acireale, Sicily).
21. **Invited speaker** on "Functional Magnetic Nanostructures Based on Polymer Nanocomposites and Self-Assembled Arrays" at the Materials Research Society (MRS) Fall 2005 meeting, Boston, MA (Dec. 2005)
22. **Colloquium** at University of Wisconsin – Milwaukee, Department of Physics, (Dec. 9, 2005)
23. **Colloquium** at Physics Department, Wayne State University, Detroit (Nov. 17, 2005)
24. **Colloquium** at INRS-EMT, University of Quebec, Montreal (Oct. 14, 2005).
25. **Colloquium** at Institute of Photonics, Lasers and Biophotonics, State University of New York at Buffalo, Buffalo, NY (Aug. 26, 2005)
26. "Magnetic anisotropy and spin dynamics in functional magnetic nanostructures" – **Srikanth Hariharan**, Colloquium, Department of Physics, Northeastern University, Boston, MA (Dec. 15, 2004)
27. "Materials processing and tunable magnetism in polymer nanocomposites" – **Srikanth Hariharan (invited)**, Thirteenth Processing and Fabrication of Advanced Materials (PFAM-13) conference, Singapore, Dec. 6 – 8 (2004).

Contributed presentations at major conferences:

1. Magnetism and magnetocaloric effect in multiferroic $LuFe_2O_4$ – Hari Srikanth, M. H. Phan, N. A. Frey, M. Angst, B. C. Sales and D. Mandrus, INTERMAG 2008, Madrid, Spain (May 4 – 8, 2008)
2. RF transverse susceptibility studies of effective magnetic anisotropy in nanoparticle assemblies – Hari Srikanth, P. Poddar, M. B. Morales, N. A. Frey, INTERMAG 2008, Madrid, Spain (May 4 – 8, 2008)
3. "Magnetocaloric effect in ferrite nanoparticles" J. Gass and H. Srikanth, APS March meeting, New Orleans, LA (March 10 – 14, 2008)
4. "Magnetic anisotropy and switching in Pr-Sr-Co-O using RF transverse susceptibility" –N. A. Frey, H. Srikanth, D. Stauffer and C. Leighton, APS March meeting, New Orleans, LA (March 10 – 14, 2008)
5. "Synthesis of surface functionalized nanoparticles and polymer nanocomposites" –M. Miner, M. B. Morales, S. Skidmore, T. Weller and H. Srikanth, APS march meeting, New Orleans LA (March 10 – 14, 2008)
6. "Normal to inverse spinel cation distribution and magnetocaloric effect (MCE) in ball-milled zinc ferrite particles" –J. Gass, H. Srikanth, M. J. Miner, N. Kislov, S. Srinivasan, Y. Emirov, 52nd annual Magnetism and Magnetic Materials (MMM) conference, Tampa, FL (Nov. 5-9, 2007)
7. "Unusual magnetic anisotropy and switching in Pr-Sr-Co-O probed by transverse susceptibility" –N. A. Frey, H. Srikanth, D. D. Stauffer, C. Leighton, 52nd annual

Magnetism and Magnetic Materials (MMM) conference, Tampa, FL (Nov. 5-9, 2007)

8. "Magnetocaloric effect in nickel ferrite nanoparticles" –J. Gass, M. B. Morales, N. A. Frey, M. J. Miner, S. Srinath and H. Srikanth, APS March Meeting, Denver, CO (March 5-9, 2007)
9. "Magnetic properties of Fe3O4 and CoFe2O4 based ferrofluids" –M. B. Morales, J. Gass, S. L. Morrow and H. Srikanth, APS March Meeting, Denver, CO (March 5-9, 2007)
10. "Magnetic anisotropy and vortex dynamics in LCMO/YBCO heterostructures" – H. Srikanth, N. A. Frey, C. Visani and J. Santamaria, APS March Meeting, Denver, CO (March 5-9, 2007)
11. "Structure, magnetism and microwave properties of PLD-grown Barium Ferrite/Barium Strontium Titanate bilayer thin films" –R. Heindl, H. Srikanth, S. Witanachchi, P. Mukherjee, T. Weller, A. S. Tatarenko and G. Srinivasan, 10th annual joint INTERMAG/MMM conference, Baltimore, Jan 07
12. "Static and dynamic properties of 'dumbbell' and 'flower' shaped Au-Fe3O4 nanoparticles" –N. A. Frey, S. Srinath, H. Srikanth, T. Chao and S. Sun, 10th annual joint INTERMAG/MMM conference, Baltimore, Jan 07
13. "Magnetic anisotropy and exchange bias in epitaxial CrO2/Cr2O3 bilayer thin films" –S. Srinath, N. A. Frey, H. Srikanth, G. X. Miao and A. Gupta, 10th annual joint INTERMAG/MMM conference, Baltimore, Jan 07
14. "Exchange coupling, surface and configurational anisotropy in magnetic nanoparticles" –H. Srikanth, MRS Fall 2006, Boston, Nov. 2006
15. "Sensor applications and spin transport measurements in carbon nanotube composites" –J. Sanders, J. Gass, H. Srikanth, F. K. Perkins and E. S. Snow, APS March Meeting, Baltimore, March 2006
16. "Magnetocaloric effect in nanoparticle systems and clathrates" –D. J. Rebar, J. Gass, S. Srinath, H. Srikanth and G. S. Nolas, APS March Meeting, Baltimore, March 2006
17. "Synthesis and characterization of functional magnetic nanocomposites" –J. Gass, J. Sanders, S. Srinath and H. Srikanth, APS March Meeting, Baltimore, March 2006
18. "Magnetic anisotropy in CrO2 and CrO2/Cr2O3 bilayer thin films" –N. A. Frey, S. Srinath, H. Srikanth, G. Miao and A. Gupta, APS March Meeting, Baltimore, March 2006
19. "Microwave impedance and tunability of BSTO/BaM ferrite films" –R. Heindl, **H. Srikanth**, S. Balachandran, T. Weller, A. Kumar, P. Gadkari and K. R. Coffey, 50th Magnetism and Magnetic Materials (MMM) conference, San Jose, CA, Oct. 30-Nov. 3 (2005).
20. "Giant magnetocaloric effect (MCE) in clathrates" –**H. Srikanth**, S. Srinath, D. Rebar, J. Gass, G. Woods, M. Beekman, G. Nolas, 50th Magnetism and Magnetic Materials (MMM) conference, San Jose, CA, Oct. 30-Nov. 3 (2005).
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