Magnetic Interfaces and Nanostructures
Room: 6 - Session MI+EN+BI-TuA

Fundamental Problems in Magnetism
Moderator: G.J. Szulczewski, The University of Alabama

2:00pm **MI+EN+BI-TuA1 Spintronics – Implications for Energy, Information and Medical Technologies**, ***S.D. Bader***, Argonne National Laboratory and Northwestern University **INVITED**

Spintronics encompasses the ever-evolving field of magnetic electronics.[1,2] Fields such as spintronics are hold the potential to extend the information technology revolution as the semiconductor road map reaches its end . A major issue with present day electronics is in its demand for increased power. Spintronics offers the possibility to communicate via pure spin currents as opposed to electric charge currents. The talk provides a brief perspective of recent developments to switch magnetic moments by spin-polarized currents, electric fields and photonic fields. Developments in the field of spintronics continue to be strongly dependent on the exploration and discovery of novel nanostructured materials and configurations. An array of exotic transport effects dependent on the interplay between spin and charge currents have been explored theoretically and experimentally in recent years. The talk highlights select promising areas for future investigation, and, features recent work at Argonne, [3,4] including, most strikingly, in the realm of medical applications. [5]

∗ Work supported by the U.S. Department of Energy, Office of Science, Basic Energy Sciences, under contract No. DE-AC02-06CH11357.

1. S. D. Bader and S. S. P. Parkin, "Spintronics," in *Ann. Rev. of Cond. Matt. Phys.*,1, 71-88 (2010).

2. S. D. Bader, *Rev. Mod. Phys.*78, 1-15 (2006).

3. O. Mosendz, J. E. Pearson, F. Y. Fradin, G. E. W. Bauer, S. D. Bader, A. Hoffmann, *Phys. Rev. Lett.*104, 046601 (2010).

4. J. S. Jiang, J. E. Pearson, S. D. Bader, *Phys. Rev. Lett.* 106, 156807 (2011).

5. D.-H. Kim, E. A. Rozhkova, I. V. Ulasov, S. D. Bader, T. Rajh, M. S. Lesniak, V. Novosad, *Nature Mat.*9, 165-171 (2010).

Samuel D. Bader, Materials Science Division and Center for Nanoscale Materials, Argonne National Laboratory, Argonne, Illinois 60439, and Department of Physics and Astronomy, Northwestern University, Evanston, Illinois 60208 USA

2:40pm **MI+EN+BI-TuA3 Multiscale Modeling for Spintronics**, ***K.A. Mewes, T. Mewes, W.H. Butler***, University of Alabama **INVITED**

The next generation of spintronic devices relies strongly on the development of new materials with high spin polarization, optimized intrinsic damping and tunable magnetic anisotropy. Therefore technological progress in this area depends heavily on the successful search for new materials as well as on a deeper understanding of the fundamental mechanisms of the spin polarization, the damping and the magnetic anisotropy. My talk will focus on different aspects of materials with high spin polarization, low intrinsic relaxation rate and perpendicular anisotropy. Our results are based on first principles calculations in combination with a non-orthogonal tight-binding model to predict those material properties for complex materials which can be used for example in new spin based memory devices or logic devices. Future progress in spintronics not only requires a better understanding of the underlying physical principles but also hinges strongly on the development of theoretical models capable of describing the expected performance of realistic device structures. As an example I will discuss the challenges in the Spin Transfer Torque Random Access Memory. This memory is dense, fast and nonvolatile and has the capability of a universal memory possibly even replacing today's Dynamic Random Access Memory (DRAM).

4:00pm **MI+EN+BI-TuA7 Anomalous Magneto Transport in Amorphous TbFeCo Film with Perpendicular Magnetic Anisotropy**, ***N. Anuniwat, M. Ding, J. Poon, S.A. Wolf, J.W. Lu***, University of Virginia

TbFeCo has attracted some interests because of its high perpendicular anisotropy and tunable magnetic properties for nanomagnetic and spintronics application. Due to the fact that electronic device is getting smaller, fundamental understanding of size and geometry dependent is crucial . In this study, we report a strong size dependence of the coercive field in 15 - 100nm thick Tb30Fe63.5Co6.5 films with MgO capping. Magneto Optical Kerr effect (MOKE) and Vibrating Sample Magnetometer are performed on unpatterned films. The films exhibited strong PMA characteristics. The films were then fabricated into Hall bars with 10 μm, 50 μm, 100 μm and 500 μm in width. From anomalous Hall effect (AHE), HC was determined for these patterned films. We observed coercivity enhancement as the width of the hall bar decreases (up to 200% at room temperature). The temperature dependent of the coercivity is also studied. There exhibits the local minimum as the temperature change from 50 - 300K. The correlation between HCmin and dimensions of the hall bar are discussed. The magnetic domain structures and surface morphology analysis were performed using magnetic force microscopy and atomic force microscopy respectively. The variation in domain sizes , structures for different hall bars as well as possible origins of the coercivity enhancement are also discussed.

4:20pm **MI+EN+BI-TuA8 Magnetic Properties of Fe Clusters: A DFT+U vs Nano DFT+DMFT Analysis**, ***A.K. Kabir, V. Turkowski, T.S. Rahman***, University of Central Florida

We use our recently proposed combined density-functional-theory/dynamical-mean-field-theory (DFT + DMFT) approach for molecules and nanosystems [1] to study the magnetic properties of Fe clusters consisting of 15, 17 and 19 atoms. This method has several advantages compared with the widely-used DFT + U approach for systems with localized electron states, the most important of which is that it takes into account dynamical correlation effects. These effects are especially important in the case when the kinetic (hopping) and the local Coulomb repulsion energies have the same order of magnitude. In particular, we study the size-dependence of the magnetic properties of the clusters by using the nanoDMFT code developed in our group using the iterated-perturbation theory approximation in the impurity solver. We find that the DFT+DMFT approach yields much better agreement for the magnetization with experimental data as compared to DFT and DFT+U methods, both of which generally overestimate the magnetization.

Work supported in part by DOE Grant No. DOE-DE-FG02-07ER46354

1. V. Turkowski, A. Kabir, N. Nayyar and T.S. Rahman J. Phys.: Condens. Matter 22, 462202 (2010) and J. Chem. Phys. 136, 114108 (2012)

4:40pm **MI+EN+BI-TuA9 Rationally-designed Iron Oxide Nanostructures for Bioimaging**, ***Y. Bao***, The University of Alabama **INVITED**

Iron oxide nanoparticles have been extensively studied in targeted delivery, localized therapy, and as contrast agents for magnetic resonance imaging (MRI). In fact, sugar coated iron oxide NPs have been clinically used as the liver/spleen-specific contrast agents in MRI, indicating the biocompatibility and potential of iron oxide nanoparticles in nanomedicine. This presentation will discuss how rationally designed iron oxide nanoparticles can achieve highly effective MRI contrast agents. The talk will primarily focus on the shape control of iron oxide nanoparticles and the surface functionalization. The formation and magnetic properties of various shaped-iron oxides (e.g., cubes, nanoworms, nanoplates, and nanowires) will be elaborated. In particular, ultrathin iron oxide nanowires will be discussed in details, such as synthesis, property, and their potential as MRI contrast agents.

5:40pm **MI+EN+BI-TuA12 3D Vector Magnetometry of Thin-Films using Generalized Magneto-Optical Ellipsometry (GME)**, ***J.A. Arregi, J.B. González-Díaz, O. Idigoras, A. Berger***, CIC nanoGUNE Consolider, Spain

Generalized Magneto-Optical Ellipsometry (GME) has emerged in the last decade as a methodology to characterize magnetic materials with a high degree of precision, by means of utilizing the magneto-optical Kerr effect [1]. Compared to other magneto-optical characterization methods based on the same effect, GME has two key advantages: it can measure both the optical and magneto-optical constants, and it allows full vector magnetometry, all with one simple experimental set-up. The technique has been successfully employed in the study of diverse magnetization reversal processes, for the purpose of identifying spin-polarized electronic states in multiferroic materials [2], as well as for the measurement of the magnetization orientation using 2D vector magnetometry [3].

Even if some works have suggested the possibility to perform quantitative 3D vector magnetometry using the GME technique [4], actual measurements have not been demonstrated so far. Here, we extract the field dependent evolution of the three magnetization components during the reversal process. In order to do so, we exploit the different symmetries of the longitudinal, transverse and polar Kerr effect around different polarizer/analyzer crossing points, which allows us to separate the information of each of the magnetically induced contributions to the non-diagonal reflection matrix elements. By combining the presence of in-plane uniaxial anisotropy as well as out-of-plane applied magnetic fields in our

Co and Co-alloy based thin films, we manage to monitor the evolution of the full magnetization vector as a function of the field.

In addition to this full vector magnetometry capability, we have recently improved this technique to enhance measurement reliability [5] and we also extended its capabilities to characterize materials that are magneto-optically active and optically anisotropic at the same time [6].

References:

[1] A. Berger and M. R. Pufall, *Appl. Phys. Lett.* **71**, 965 (1997)

[2] M. Bastjan, S. G. Singer, G. Neuber *et al.*, *Phys. Rev. B* **77**, 193105 (2008)

[3] A. Berger and M. R. Pufall, *J. Appl. Phys.* **85**, 4583 (1999)

[4] K. Mok, N. Du, and H. Schmidt, *Rev. Sci. Instrum.* **82**, 033112 (2011)

[5] J. A. Arregi, J. B. Gonzalez-Diaz, E. Bergaretxe, O. Idigoras, T. Unsal, and A. Berger, accepted for publication in *J. Appl. Phys.*

[6] J. B. González-Díaz, J. A. Arregi, E. Bergaretxe, M. J. Fertin, O. Idigoras, and A. Berger, submitted to *Appl. Phys. Lett.*

Authors Index

Bold page numbers indicate the presenter