Magnetic Interfaces and Nanostructures
Room: Zuni - Session MI+TF-ThM

Magnetic Nanostructures, Thin Films and Heterostructures
Moderator: C. Clavero, College of William & Mary

8:00am **MI+TF-ThM1 AC Susceptibility of Ni Bars with Magnetic Single Domain**, *X.G. Zhang, I.I. Kravchenko, S.T. Retterer, J.F. Wendelken*, ***Z. Gai***, Oak Ridge National Laboratory

For thin films, the generalized Curie-Weiss law extends the power law scaling well above Tc by replacing the linear reduced temperature t_L by a nonlinear reduced temperature t_{NL}=1-Tc/T. The film thickness d and temperature T are usually not independent variables in the scaling. Using the nonlinear reduced temperature, the power law scaling was shown to be accurate over the entire paramagnetic regime [1-3]. However, at low temperature, thermally activated domain wall motion is expected to contribute significantly to the temperature dependence of magnetic properties, therefore the scaling law is generally believed not to extend far below Tc. Such belief was contradicted by a very recent experiment [4] that showed a surprising power law scaling for the in-plane susceptibility of sputtered Ni films deposited on silicon for the entire temperature range between zero and Tc. In addition, thickness and temperature dependence are completely decoupled. This scaling result implies that even in the ferromagnetic regime, there is no domain wall motion contribution to the low field susceptibility [4]. To clarify the role of domain wall motion, arrays of single domain Ni microstructures are studied experimentally and theoretically. We will show the results of the AC susceptibility measurements of Ni microstructures with magnetic single domain, in which the contributions of domain wall motion and spin fluctuation to the susceptibility are separated.

This research at Oak Ridge National Laboratory's Center for Nanophase Materials Sciences was sponsored by the Scientific User Facilities Division, Office of Basic Energy Sciences, U.S. Department of Energy.

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8:20am **MI+TF-ThM2 Deuterium Absorption in Co/Pd Multilayers**, ***K. Munbodh***, *F.A. Perez, D. Lederman*, West Virginia University, *M. Zhernenkov, M. Fitzsimmons*, Los Alamos National Laboratory

The absorbed concentration of deuterium was calculated in Co/Pd multilayers at standard temperature and pressure using in-situ neutron reflectometry. The out-of-plane film expansion and deuterium concentration-depth profiles were determined from the fitting of the neutron reflectivity data. The measurements demonstrated that deuterium is absorbed in all the Pd layers. However, the concentration of the hydrogen varies with Pd layer thickness. Polarized neutron reflectometry with applied field of 6.5 kOe in the plane of the sample was performed and the detailed magnetic depth profile was established. These results showed an overall increase in magnetization upon deuterium absorption.

8:40am **MI+TF-ThM3 Correlated Structural and Magnetic Studies of Capping and Seed Layer Dependent Epitaxial FePd Thin Films**, ***L. Wang***, *J.R. Skuza*, College of William & Mary, *T. Mewes*, University of Alabama, *C. Clavero, R.A. Lukaszew*, College of William & Mary

FePd binary alloys can form a chemically ordered phase ($L1_0$) that exhibits interesting properties such as high perpendicular magnetic anisotropy (PMA). This property has drawn great attention for many technological applications such as ultrahigh density magnetic recording media and spin transfer torque random access memory (STT-RAM). We investigate the influence of different capping layers (Au, Pd and V and compare with an insulating capping layer such as MgO) on the magnetic properties, particularly the magnetic anisotropy and damping, of highly anisotropic $L1_0$ FePd films which were grown onto MgO (001) substrates using magnetron sputtering in an ultra-high vacuum deposition system. We use x-ray diffraction techniques to study the chemical ordering of the films, and vibrating sample magnetometry (VSM), magnetic force microscopy (MFM) and ferromagnetic resonance (FMR) to investigate the magnetic properties. Our aim is to investigate and tailor the structural and magnetic properties of highly ordered FePd thin films with strong PMA via adequate choice of capping and seed layer materials.

We thank W. Chen and S. A. Wolf for their collaboration. Funding for this project was obtained from NSF grants DMR 0804243 and DMR 0605661 and a Cottrell Scholar Award from the Research Corporation.

9:00am **MI+TF-ThM4 Microstructural, Magnetic Anisotropy, and Magnetic Domain Structure Correlations in $L1_0$ Ordered Thin Films**, ***J.R. Skuza***, *L. Wang*, College of William & Mary, *W. Chen, J. Lu*, University of Virginia, *T. Mewes*, University of Alabama, *C. Clavero, R.A. Lukaszew*, College of William & Mary

Understanding microstructural, magnetic anisotropy, and magnetic domain structure correlations in materials with strong perpendicular magnetic anisotropy (PMA) is of fundamental interest and it is also important in many technological applications such as next generation magneto-recording, magneto-optical, and patterned media. The $L1_0$ ordered phase of some binary alloys (FePt, FePd, MnAl, etc.) has strong PMA due to chemical ordering that can be controlled with adequate thin film deposition parameters and/or subsequent thermal annealing treatments. A detailed structural (XRD and AFM) and magnetic (MFM, SQUID, and FMR) study on two of these $L1_0$ ordered alloys will be presented. Epitaxial FePd thin films with various capping layers were grown by dc magnetron sputter deposition onto MgO(001) substrates. A quantitative analysis and correlation of the strong PMA to magnetic domain structure in these FePd films was accomplished with good agreement using an analytical energy model [1]. MnAl thin films were grown by reactive biased target ion beam deposition onto MgO(001) substrates. Effects of the growth conditions and subsequent thermal annealing treatments on the microstructure and magnetic properties will be discussed.

This work was supported by the Virginia Space Grant Consortium, National Science Foundation (DMR Grants #0355171, #0605661, and #0804243), the American Chemical Society (PRF Grant #41319-AC), and the Research Corporation Cottrell Scholar Award. K. Yang, B. Wincheski, and S. A. Wolf are acknowledged for their collaboration.

[1] J. R. Skuza, C. Clavero, K. Yang, B. Wincheski, and R. A. Lukaszew, IEEE Trans. Magn. **46**, 1886 (2010).

9:20am **MI+TF-ThM5 Correlating Microstructure with Magnetic Properties Variation in Patterned Magnetic Nanostructures with Transmission Electron Microscopy**, ***J.W. Lau***, National Institute of Standards and Technology **INVITED**

Patterned magnetic nanostructures are keystone components in technologies such as hard drive media, sensors, and the magnetoresistive device variants (read-head, random access memory, logic). During manufacturing, different processes produce defects that are the source of variations in magnetic properties in magnetic nanostructures. One example is the Co/Pd nanodot array, interesting for its potential in realizing the bit-patterned media data storage platform. We showed that grains of a particular orientation formed during the film deposition can act as trigger sites for magnetization reversal. Therefore, the ease of switching a particular nanodot among millions of nominally identical nanodots depends on the random presence of trigger grains within it. When considered as an ensemble, the nanodot array will exhibit a switching field distribution; this is the superposition of the individual switching fields unique to each nanodot. In general, switching field distribution and other magnetic property variations in patterned magnetic nanostructures can present major problems for devices development where uniform magnetic performances are required.

The fact that magnetic phenomena in patterned magnetic nanostructures, whether it be magnetization reversal or magnetoresistance, are always observed as distributions means that it is import to identify the root causes to these distributions. An essential aspect to furthering the progress in developing magnetic nanostructure devices is therefore, to correlate nanostructure, defects and interfaces, and chemical composition to magnetic behaviors on the nanoscale. To this end, one of our main focuses is in developing ways to measure variations in magnetic properties using transmission electron microscopy (TEM). TEM is one of the few tools that can provide structural, chemical and magnetic information all at the same time.

In this presentation, I will highlight specific examples of measurements developed for patterned magnetic nanostructures using a TEM. The first example is the microstructure correlation to the switching field distribution in Co/Pd nanodots, described earlier. The second example is a set of *in situ* tunneling measurements where we succeeded in measuring unique energy barrier height and tunneling magnetoresistance (TMR) on fully functional nano-magnetic tunnel junctions (MTJ) built as a TEM sample. Finally, I will show how single nanostructure magnetometry can be achieved within a TEM.

10:40am **MI+TF-ThM9 Partial Perpendicular Anisotropy of CoFeB with Vanadium Capping**, ***A. Natarajarathinam***, *Z.R. Tadisina*, *S. Gupta*, University of Alabama

Magnetic tunnel junctions with vanadium-based capping layers on top of the CoFeB free layer have been studied. The interest in the effect of capping on the free layer originated from reports(1) that cap layers influence the crystallization of the CoFeB free layer through diffusion of the B into the cap, as well as induce a partial perpendicular magnetic anisotropy (PPMA or PPA) in the free layer(2,3). Different cap layers differently accelerate the diffusion of the B from the free layer. In this study, we have sputter-deposited V/Ru and V/Ta capping layers on CoFeB and subsequently characterized these films by magnetometry and ferromagnetic resonance (FMR). We have found that V/Ru and V/Ta capping of CoFeB induces partial perpendicular anisotropy (PPA) in CoFeB, as well as reduces the Gilbert damping parameter, confirming results reported by other researchers(4). The origin of this PPA is believed to be caused by the interface anisotropy between the free layer and the capping layer. The effect of post-deposition annealing, CoFeB thickness, and doping of CoFeB with vanadium on the anisotropy and damping of these V/Ru and V/Ta capped samples has been studied for the free layers. Doping CoFeB with vanadium greatly reduces the $4\pi M_s$ and $4\pi M_{eff}$ values, resulting in an effective increase in the PPA, as well as the damping parameter. X-ray magnetic circular dichroism (XMCD) has also been performed on a series of V-doped films over a range of V concentrations. Magnetic tunnel junctions were fabricated to study device properties of the V-capped and V-doped films. The mechanisms for increasing TMR in these types of pMTJ's will be discussed.

This work is supported by the U.S. Department of Defense DARPA-MTO STT-RAM Universal Memory contract, and Grandis Inc., Milpitas, CA.

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11:00am **MI+TF-ThM10 Magnetic Properties of $Fe_xNi_{1-x}Fe/Co$ Bilayers**, ***F.A. Perez***, *D. Lederman*, West Virginia University

$Fe_xNi_{1-x}Fe/Co$ bilayers were deposited on single-crystal MgF_2 (110) substrates via molecular-beam epitaxy. The RHEED patterns were used to characterize the surface crystallinity during growth. The high angle x-ray diffraction (XRD) allowed establishing epitaxial growth directions and in- and out-of-plane crystallinity coherences. The x-ray reflectivity (XRR) patterns were used to establish the layer thicknesses and the interface roughness parameters. The Fe-concentration was estimated from XRD lattice parameters and the XRR fittings and it was according with that from XPS analysis. The magnetic anisotropies of the Co layer were measured via standard magnetometry measurements.

11:20am **MI+TF-ThM11 Electrical Properties of $Ni.Fe_2O_3$ and $NiO.Fe_{1.925}Sm_{0.075}O_3$ Thin Films**, ***K.B. Karuppanan***, University of Texas at El Paso, *M. Garimalla*, IIT Madras, India, *C.V. Ramana*, University of Texas at El Paso

Nickel ferrite is one of the most versatile and technologically important ferrite materials because of its high Curie temperature, high saturation magnetization, low conductivity and thus lower eddy current losses, high electrochemical stability, catalytic behavior. The focus of the present work was to grow $Ni.Fe_2O_3$ and $NiO.Fe_{1.925}Sm_{0.075}O_3$ thin films by RF magnetron sputtering and study their structural and electrical properties. $Ni.Fe_2O_3$ and $NiO.Fe_{1.925}Sm_{0.075}O_3$ films were grown by sputtering the bulk $NiO.Fe_2O_3$ and $NiO.Fe_{1.925}Sm_{0.075}O_3$ targets prepared by solid state chemical reaction. The results indicate that the as-grown films were amorphous. Samples annealed at 1073 K were crystalline. DC electrical conductivity measurements performed in the temperature range 60-300 K indicate the insulating behavior of the materials. The room-temperature conductivity of the $NiO.Fe_{1.925}Sm_{0\text{-}075}O_3$ film is less than that of pure Ni ferrite film. Analysis of the conductivity indicates that the small polaron and variable-range-hopping (VRH) mechanisms are operative in 180–300 K and 60–180 K temperature regions, respectively. Frequency variation of the electrical resistivity measurements in the range 1 kHz - 13 MHz indicate that the resistivity decreases with increasing frequency. The mean relaxation time and spreading factor values were found to be larger for the $NiO.Fe_{1.925}Sm_{0\text{-}075}O_3$ film which could be due to the fact that larger Sm^{3+} ion leads to increased bond distance.

11:40am **MI+TF-ThM12 Structural, Transport and Magnetic Properties of $SrSn_{0.95}Fe_{0.05}O_3$ Thin Films**, ***G. Prathiba***, IIT Madras, India, *S. Venkatesh*, Tata Institute of Fundamental Research (TIFR), India, *N. Harish Kumar*, IIT Madras, India

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