Magnetic Interfaces and Nanostructures
Room 2006 - Session MI-TuM

Magnetic Nanostructures, Nanoparticles and Interfaces

Moderator: J. Shen, Oak Ridge National Laboratory

8:00am **MI-TuM1 Overview of Magnetic Recording Technologies**, ***D. Weller,*** Seagate Technology **INVITED**

The recording industry is currently undergoing a transition from longitudinal to perpendicular magnetic recording (PMR). Areal densities (AD) have reached more than 130 Gbit per sq.in. in products and 250 Gbit per sq.in. in laboratory demostrations. The key technology enablers are head, media and head-disk interface, which all face significant scaling challenges and limitations. Fundamental limitation include thermal stability of media grains and write fringe field of the recording heads, which will likely limit PMR recording to 500-1000 Gbit per sq.in.. At an AD growth rate of 40% per year it should take between 4-8 years to reach those limitations. Technologies beyond PMR include Heat-Assisted Magnetic Recording (HAMR), which eliminates the field constraint of the recording head and self-organized magnetic arrays (SOMA), which eliminate microstructural constraints of sputtered media. The current perspective is that both technologies will eventually be needed to push beyond Terabit per sq. in. recording and to continue to grow this industry.@footnote 1@ This talk is intended to lay out a future technology roadmap and to provide a perspective of "what's next". @FootnoteText@ @Footnote 1@Dieter Weller and Terry McDaniel, chapter 11, Media for Extremely High Density Recording in Advanced Magnetic Nanostructures, eds. David Sellmyer and Ralph Skomski, Springer 2006.

8:40am **MI-TuM3 Orbital Magnetism of Fe and Pt in Monodisperse FePt Nanoparticles**, ***M. Farle,*** *C. Antoniak,* Universitaet Duisburg-Essen, Germany*; K. Fauth,* MPI Stuttgart, Germany*; M. Spasova,* Universitaet Duisburg-Essen, Germany*; F. Wilhelm, A. Rogalev,* ESRF, France **INVITED**

X-ray absorption (XAS)and x-ray magnetic dichroic spectra (XMCD) were measured at both the Fe and Pt L@sub3,2@ edges on wet-chemically synthesized monodisperse Fe@sub50@Pt@sub50@ particles with a mean diameter of 6.3 nm before and after complete removal of the organic ligands and the oxide shell covering the particles by soft hydrogen plasma resulting in a pure metallic state. After thermal treatment of the metallic particles, the coercive field increased by a factor of 6, the orbital magnetic moment at the Fe site increased by 330% and decreased at the Pt site by 30%, while the effective spin moments did not change. A decrease of the frequency of oscillations in the extended x-ray absorption fine structure (EXAFS) at the Pt L@sub3,2@ edges provides evidence for crystallographic changes towards the L1@sub0@ phase. These results are discussed in context to recent results revealing a layerwise structural relaxation of the surface layers in FePt nanoparticles.

9:20am **MI-TuM5 Probing the Exchange Interactions Between Stable Photogenerated Carriers in Colloidal Magnetic Semiconductor Quantum Dots**, ***W.K. Liu***[1], University of Washington

A major obstacle in developing practical spin-based electronic devices is producing ferromagnetic semiconductors that exhibit a Curie temperature (Tc) higher than room temperature. Diluted magnetic semiconductors (DMSs), where a fraction of the host lattice cations are substitutionally replaced by 3d transition metal ions (TM@super 2+@), are promising candidates due to observation of high-Tc ferromagnetism in oxide DMSs. Recently, we have demonstrated a close link between the electronic structures and polarity-dependent high-Tc ferromagnetism of TM@super 2+@:ZnO DMSs.@footnote 1@ Our investigation, using complementary optical spectroscopic and photoelectrochemical probes, have identified light-induced donor- or acceptor-type ionizations states of the transition metal dopants immediately below the ZnO band edge in Co@super 2+@:ZnO and Mn@super 2+@:ZnO. These charge transfer electronic states clearly relate the observed high-Tc ferromagnetism in these materials to mediation by shallow donors or acceptors, as well as to the polarity of the mediating charge carrier. To further examine the interplay between the charge carriers and magnetic dopant ions we have successfully generated stable carriers in colloidal Co@super 2+@:ZnO and Mn@super 2+@:ZnO DMS quantum dots using photochemical methods.@footnote 2@ The carriers were identified as conduction band electrons and the resulting electron-magnetic dopant ion interactions were studied by electron paramagnetic resonance spectroscopy. This new motif of colloidal charged magnetic semiconductor nanocrystals provides new opportunities for examining spin effects in DMS nanostructures relevant to proposed spintronics technologies. @FootnoteText@ @footnote 1@K.R. Kittilstved, W.K. Liu, D.R. Gamelin, Nat. Mat. 5 (2006) 291.@footnote 2@W.K. Liu, K.R. Kittilstved, K.M. Whitaker, D.R. Gamelin, J. Am. Chem. Soc. 128 (2006) 3910.

9:40am **MI-TuM6 Single Domain and Vortex State Phase Fractions in Arrays of sub-100nm Fe Nanodots***, ***R.K. Dumas***[2], University of California - Davis*; C.-P. Li, I.V. Roshchin, I.K. Schuller,* University of California - San Diego*; K. Liu,* University of California - Davis

Deep sub-100 nm magnets have been the focus of intense research interest due to their fascinating fundamental properties and potential technological applications. Here we report the investigation of magnetization reversal in arrays of Fe nanodots prepared by a nanoporous alumina shadow mask technique.@footnote 1@ In particular we have examined the single domain to vortex state transition in 52, 58, and 67 nm nanodots, using a first order reversal curve (FORC) method.@footnote 2-5@ Striking differences in the FORC diagrams have been observed, despite only subtle differences in their major hysteresis loops. The 52 nm nanodots exhibit single domain behavior. The extracted coercivity distribution agrees well with a simple theoretical calculation. The 67 nm dots have more complex FORC characteristics which clearly indicate reversal via a vortex state. These experimental FORC features have been confirmed by OOMMF micromagnetic simulations. The 58 nm dots show characteristics common to both the 52 and 67 nm samples. By selectively integrating the normalized FORC distribution corresponding to the single domain phase, we have determined that 43% and 10% of the nanodots in the 58 and 67 nm sample, respectively, are in the single domain state. Additionally, we have studied the single domain phase fraction as a function of temperature in the 67 nm dots. With decreasing temperature, it is more difficult to nucleate vortices within the dots and the single domain phase fraction increases. @FootnoteText@ *Supported by NSF, ACS-PRF, AFOSR, UC-CLE, and the Alfred P. Sloan Foundation. @footnote 1@K. Liu, et al, Appl. Phys. Lett. 81, 4434 (2002). @footnote 2@C. P. Pike, et al, J. Appl. Phys. 85, 6660 (1999). @footnote 3@H. G. Katzgraber, et al. Phys. Rev. Lett. 89, 257202 (2002). @footnote 4@J. E. Davies, et al, Phys. Rev. B 70, 224434 (2004). @footnote 5@J. E. Davies, et al, Appl. Phys. Lett. 86, 262503 (2005).

10:40am **MI-TuM9 Nanostructured Ultrathin Films and Nanowires: A Playground for Manipulating the Magnetic Anisotropy**, ***F. Bisio,*** CNR-INFM Unita' di Genova, Italy*; R. Moroni,* CNISM Unita' di Genova, Italy*; F. Buatier de Mongeot, M. Canepa, U. Valbusa, L. Mattera,* University of Genova, Italy

We report the investigation of the magnetic anisotropy of nanorippled ultrathin magnetic films and magnetic nanowires fabricated by means of the ion sculpting technique. The nanoscale rippled morphology that develops under grazing incidence ion irradiation unbalances the number of surface atomic steps oriented parallel and perpendicular to the ripple direction, thus inducing a clearly observable in-plane uniaxial anisotropy. We have isolated the atomic-step-contribution to the magnetic anisotropy of the nanostructures and experimentally measured the uniaxial anisotropy energy of Co and Fe monoatomic steps located at the surface of Co/Cu(001) and Fe/Ag(001) films. We show that the simmetry and intensity of the magnetic anisotropy of these systems can be manipulated by varying the irradiation conditions and by functionalization of the nanostructures surface by magnetic or nonmagnetic overlayers.

11:00am **MI-TuM10 Fingerprinting Magnetization Reversal in Magnetic Nanostructures**, ***K. Liu,*** *J.E. Davies, R.K. Dumas, G.T. Zimanyi,* UC Davis*; O. Hellwig, E.E. Fullerton,* Hitachi Global Storage Tech.*; J.S. Jiang, S.D. Bader,* Argonne National Lab*; G. Denbeaux,* Univ. at Albany*; J.B. Kortright,* Lawrence Berkeley National Lab*; C.-P. Li, I.V. Roshchin, I.K. Schuller,* UC San Diego **INVITED**

Magnetization reversal is often complex, yet critical for the understanding and applications of magnetic nanostructures. Here we present recent studies using a first order reversal curve (FORC) method@footnote 1-4@ on a few technologically important systems. In Co/Pt multilayers,@footnote 2@ we have found three distinct stages for reversal domain nucleation, propagation, and annihilation. Interestingly, significant irreversible switching persists for applied fields well beyond the apparent saturation field due to residual bubble domains. In exchange spring magnets,@footnote 3@ we have investigated the effect of the hard layer crystallinity on irreversible switching. In Fe/epitaxial-SmCo films, the

[1] **Falicov Student Award Finalist**

[2] **Falicov Student Award Finalist**

reversal proceeds by a reversible rotation of the Fe soft layer, followed by an irreversible switching of the SmCo hard layer. In FeNi/polycrystalline-FePt films, the FeNi and FePt layers reverse in a continuous process via a vertical spiral. The successive vs. continuous rotation of the soft/hard layer system is primarily due to the different hard layer anisotropy. In arrays of Fe nanodots,@footnote 5@, we have studied a vortex state to single-domain transition as the dot size decreases. Striking differences in the FORC diagrams have been observed. The 52nm dots exhibit single domain behavior, whereas the 58 and 67nm dots exhibit vortex states. The FORC method gives quantitative measures of the magnetic phase fractions and vortex nucleation and annihilation fields. These results demonstrate that FORC is a powerful method for magnetization reversal studies, due to its capability of capturing distributions of magnetic properties, sensitivity to irreversible switching, and the quantitative phase information it can extract. @FootnoteText@ *Supported by NSF, ACS-PRF, DOE, UC-CLE, and Sloan Foundation. @footnote 1@Pike, et al, JAP, 85, 6660 (1999). @footnote 2@Davies, et al, PRB 70, 224434 (2004). @footnote 3@Davies, et al, APL 86, 262503 (2005). @footnote 4@Davies, et al, PRB 72, 134419 (2005). @footnote 5@Liu, et al, APL 81, 4434 (2002).

11:40am **MI-TuM12 Ultrathin Film Magnetism by Surface Manipulation**, ***X.F. Jin,*** Fudan University, China **INVITED**

The lattice-constant of a solid-state material is a key parameter in determining its physical and chemical properties. By varying the lattice constant one can tune the electronic band structure as well as the density of states at the Fermi level, therefore change correspondingly all the physical and chemical properties. In this work, by using the "composition wedge" and "lattice-constant wedge" techniques with molecular beam epitaxy, we show that one can manipulate independently the surface chemistry and lattice constant of a single crystal substrate. Applying them to ultrathin Fe and Ni on Cu(001), two of the most important yet still controversial nanomagnetic systems, we show how to manipulate their magnetic properties including magnetic ordering and anisotropy in a well controlled way which is helpful to clarify some longstanding critical issues of the systems.

Magnetic Interfaces and Nanostructures
Room 2006 - Session MI-TuA

Magnetic Thin Films and Multilayers

Moderator: F.C.S. da Silva, University of Colorado at Denver and Health Science Center

2:20pm **MI-TuA2 Spin-Polarized Quantum-Well States in Ni/Cu Thin-Film Structures**, ***V. Renken,*** Westfälische Wilhelms-Universität, Germany; *D.H. Yu,* Australian Nuclear Science and Technology Organisation; *M. Donath,* Westfälische Wilhelms-Universität, Germany

The unoccupied quantum-well states (QWS) in ultrathin films of Ni on Cu(001) and Cu on Ni/Cu(001) have been investigated by spin- and angle-resolved inverse photoemission. In ferromagnetic Ni films on Cu(001), three spin-polarized quantum-well features are clearly resolved. As predicted by the phase accumulation model, the energies of the QWS increase with increasing Ni overlayer thickness. Eventually they converge to the top of the bulk sp-band at the lower band-gap boundary as a result of a crossover from two- to three-dimensional behavior. In ultrathin Cu films on Ni/Cu(001), QWS in both the Cu and the Ni layers have been experimentally identified. For small Cu coverages up to 2.5 monolayers (ML), discrete QWS within the Cu layers are observed with the expected behavior: they shift to higher energies with increasing Cu thickness. The energetics of the QWS within the Ni layers is not influenced but their intensities are attenuated by the Cu overlayer. For Cu films thicker than about 5 ML, the discrete QWS in Cu cannot be distinguished any more. Only one spectral feature remains: the transition into the Cu sp-band. However, this transition appears at higher energy compared to bulk Cu. Upon further increase of the Cu film thickness, the sp-band transition continuously shifts to lower energies. Finally, for a thickness of more than 20 ML, it approaches the value known from the (001) surface of bulk Cu.

2:40pm **MI-TuA3 Element-Resolved Phase and Amplitude of Magnetization Dynamics in Thin Magnetic Films**, ***D.A. Arena***, *E. Vescovo, C.C. Kao,* Brookhaven National Laboratory; *Y. Guan, L. Cheng, W.E. Bailey,* Columbia University **INVITED**

In high-speed (GHz range) magneto-electronics, both the phase and amplitude of precession of different constituents (e.g. layers, impurities) determines the dynamic response of the device. To date, most information on the relative phase and amplitude of precession of different elements in ferromagnetic (FM) films must be deduced from theoretical models developed to analyze dynamic measurements which average over the sample. We present the first measurements of element- and time-resolved ferromagnetic resonance (ETR-FMR) in magnetic thin films at GHz frequencies. With ETR-FMR the dynamic response of individual layers in complex structures can be measured as well as the precession of individual elements in an alloy or compound. ETR-FMR also provides extremely accurate measurements of the precession cone angle (to 0.2°) and the phase of oscillation (to 2°). With this degree of precision and the ability to detect the dynamics of individual elements, fundamental assumptions implicit in phenomenological theories such as the Landau-Lifschitz-Gilbert approach can be investigated in a direct fashion. We have used ETR-FMR to measure the response of specific elements and separate layers in several alloys and structures. These include the Fe and Ni moments in a single film of Ni@sub 81@Fe@sub 19@, layer-resolved FMR measurements of a pseudo-spin valve structure of two FM layers separated by a non-magnetic spacer (Ni@sub 81@Fe@sub 19@ / Cu / Co@sub 93@Zr@sub 7@), magnetic bilayers with dissimilar resonant frequencies, and magnetic alloys with engineered precession damping. In the pseudo-spin valve structure, ETR-FMR reveals weak coupling between the Ni@sub 81@Fe@sub 19@ and Co@sub 93@Zr@sub 7@ layers; such coupling is difficult to resolve in conventional FMR measurements. The unique capabilities of ETR-FMR in measuring precessional phase lags between different elemental moments will be discussed in relation to magnetic bilayers and engineered magnetic alloys.

3:20pm **MI-TuA5 The Electronic Band Structure of CoS2**, ***N. Wu,*** University of Nebraska-Lincoln; *Y. Losovyj,* Louisiana State University; *D. Wisbey, L. Wang, M. Manno,* University of Nebraska-Lincoln; *C. Leighton,* University of Minnesota; *P. Dowben,* University of Nebraska-Lincoln, U.S.A

We have undertaken angle resolved photoemission studies of CoS2(100) in order to map out the surface and bulk band structure of this high polarization material. The spectral features have been assigned from resonant photoemission, while the inner potential has been obtained from the critical points of the experimental band structure. Several photoemission resonances have been identified in this system for a variety of occupied "valence" electronic bands, with particularly strong resonances at the Co 3p core edges. Surface composition and surface order is seen to be strongly dependent upon surface preparation, with sulfur segregation seen to be easily facile. The surface is seen to be highly ordered in low energy electron diffraction under some conditions and both surface and bulk band states can be identified. A strongly dispersing s-p band dominates the Fermi level near the Brillouin zone edge, while Co d-band states dominate the Fermi level near the Brillouin zone center. These results are discussed in terms of the conduction electron spin polarization of this system.

3:40pm **MI-TuA6 Magnetic Properties of the Thin Cr@sub 1-x@ V@sub x@ Films**, ***O. Krupin,*** University of Oregon; *E. Rotenberg,* Lawrence Berkeley National Laboratory; *S.D. Kevan,* University of Oregon

Fabrication of the artificial magnetic structures having targeted properties is the key aspect for getting progress in the realization novel spintronic devices. Chromium is the prototypical spin density wave (SDW) antiferromagnet which attracts considerable attention in the context of its use as a spacer layer in the magnetic multilayer structures showing giant magnetoresistance and the spin-valve effect. Tuning of the SDW periodicity of the thin Cr-based films is therefore of the high importance. Impact of the confinement and the electron structure modification on SDW can be systematically studied by ARPES that allows mapping the SDW periodicity as well as the evolution of the Fermi surface topology. It is shown that the SDW periodicity can be driven by direct modification of the Fermi surface topology as well as by modification of the boundary conditions at the interfaces. That allows probing the interplay between spatial confinement and the Fermi surface topology underling the spin structure of the thin Cr-based films giving ideas how to design the layers with predefined spin structures.

4:00pm **MI-TuA7 Angle-Resolved Photoelectron Spectroscopy Study of Epitaxial CrO@sub 2@ Films Grown on TiO@sub 2@ Substrates**, *D.R. Borst,* ***C.A. Ventrice,*** University of New Orleans; *G.X. Miao, A. Gupta,* University of Alabama

Chromium dioxide is predicted to be a half-metallic oxide. Although there is experimental evidence that CrO@sub 2@ is half-metallic at low temperature, attempts to make devices based on CrO@sub 2@ have yielded very low efficiencies. One possible reason for these poor device performances is a non-stoichiometric surface region, in particular the formation of Cr@sub 2@O@sub 3@. To study the electronic properties of the surface region of CrO@sub 2@, ARUPS measurements have been performed at the 3m-TGM beamline of the CAMD synchrotron on epitaxial CrO@sub 2@ films. The CrO@sub 2@ thin films have been deposited on (100) and (110)-oriented TiO@sub 2@ substrates by chemical vapor deposition. The effects of sputtering of the CrO@sub 2@ films to remove the outer non-stoichiometric layer and of annealing the films in oxygen to heal surface defects has been studied. Sputtering results in shifts in the onset of valence emission away from the Fermi edge by as much as 0.5 eV. Annealing of the films in 10@super -6@ Torr of oxygen heals the surface and shifts the onset of emission towards the Fermi level. However, none of our spectra show evidence of a true Fermi edge. From analysis of the Cr 3p to O-2s core emission ratios for epitaxial CrO@sub 2@/TiO@sub 2@ films and Cr@sub 2@O@sub 3@(0001)/Pt(111) films grown in-situ by vapor deposition of Cr in an O@sub 2@ atmosphere and the observation of the correct symmetry in our CrO@sub 2@ LEED images, we conclude that the surface region of our epitaxial CrO@sub 2@ films is primarily CrO@sub 2@, not Cr@sub 2@O@sub 3@, even after annealing to 450 °C. These results indicate that CrO@sub 2@ is actually a narrow gap semiconductor at room temperature, not a metallic oxide as previously assumed.

4:20pm **MI-TuA8 Growth and Magnetic Properties of Ferrimagnetic Mn@sub 4@N(111) Films on GaN(0001)**, ***R. Yang,*** *E. Lu, M.B. Haider, A.R. Smith,* Ohio University; *F.Y. Yang,* Ohio State University

Heteroepitaxial growth of ferromagnet/semiconductor (FM/SC) bilayers is a topic of high importance because of the potential for spin injection systems.@footnote 1@ The FM/GaN is a system of particular interest due to the possibility to grow spin-polarized blue and ultra-violet light emitters. If we broaden this from FM@super '@s to include ferri-magnets (FiM@super '@s) having non-zero magnetization, then Mn@sub 4@N is a promising candidate since it allows to maintain a common nitrogen-bonded system for both magnetic and SC layers. Mn@sub 4@N is a FiM material with a Curie temperature of 738K and an effective moment of 1.0-1.2 uB per unit cell.@footnote 2@ Using a rf N-plasma molecular beam epitaxy

(MBE) system, we have successfully grown Mn@sub 4@N films on GaN(0001). The growth is monitored by reflection high-energy electron diffraction (RHEED). Streaky RHEED patterns indicate a smooth Mn@sub 4@N surface. RHEED and x-ray diffraction (XRD) results confirm that the epitaxial Mn@sub 4@N thin films have (111) orientation. Vibrating sample magnetometry (VSM) show that the films have magnetic hysteresis at room temperature, with the in-plane saturation magnetization M@sub s@ being larger than the out-of-plane M@sub s@ for Mn@sub 4@N(111)/GaN(0001) thin films. The authors acknowledge support from NSF and ONR. @FootnoteText@ @footnote 1@G. A. Prinz, Science 250,1092(1990).@footnote 2@W. J. Takei, R. R. Heikes and G. Shirane, Phy. Rev. 125, 1893 (1962).

4:40pm **MI-TuA9 Anisotropic X-Ray Magnetic Linear Dichroism at the Fe L@sub 2,3@ Edges in Fe@sub 3@O@sub 4@ Thin Films**, ***E. Arenholz,*** Lawrence Berkeley National Laboratory*; G. van der Laan,* Daresbury Laboratory, UK*; R.V. Chopdekar,* UC Berkeley and Cornell University*; Y. Suzuki,* UC Berkeley

X ray magnetic dichroism (XMD) spectroscopies utilizing synchrotron radiation are important tools for the study of magnetic solids. XMD is unique in its intrinsic element specificity and chemical-site sensitivity that allows the separation of the contributions of multiple magnetic species in alloys or layered systems. Most importantly, theoretically derived sum rules link, for example, x-ray magnetic circular dichroism intensities to spin and orbital magnetic moments enabling the use of polarized x rays for quantitative magnetometry. Although magnetic spectroscopy techniques have found widespread use for the study of magnetic systems, very fundamental aspects like the dependence of the XMLD signal on the relative orientation of external magnetic field, x-ray polarization, and crystalline axes have not been studied in detail to date. In this contribution, we present a systematic study of the Fe L@sub 2,3@ XMLD in ferrimagnetic Fe@sub 3@O@sub 4@(001) and (011) thin films. The Fe L@sub2,3@ XMLD is found to exhibit a strong dependence on the relative orientation of external magnetic field, x-ray polarization, and crystal lattice. These spectra can be used as a sensitive probe for the electronic and magnetic structure. We will show that all XMLD spectra can be described as a linear combination of three fundamental spectra and that the angular dependence can be derived from atomic calculations based on the crystal field symmetry.

Magnetic Interfaces and Nanostructures
Room 3rd Floor Lobby - Session MI-TuP

Magnetic Interfaces and Nanostructures Poster Session

MI-TuP1 Facile Fabrication of High Resolution Magnetic Force Microscopy Probes via Localized Electrochemical Reduction of Cobalt Species, ***M. Rolandi,*** University of California, Lawrence Berkeley National Laboratory; *S.A. Backer, D. Okawa,* University of California, Berkeley; *J.M.J. Fréchet,* University of California, Lawrence Berkeley National Laboratory

Magnetic force microscopy (MFM) is a scanning probe technique capable of characterizing the ever smaller nanostructures developed for the next generation data storage. Advancements in imaging resolution require new approaches in probe design and fabrication, an ideal probe consists of an ultra-sharp tip with magnetic material confined only at the apex. We propose a novel technique for fabricating high resolution MFM probes based on the localized electrochemical reduction of Cobalt (II) species in solution. Specific Co deposition at the apex of the tip is obtained by localizing the reaction in the small gap between the negatively biased probe and the sample while the probe is immersed in an AFM fluid cell. We demonstrate that specific deposition also occurs in a macroscopic electrochemical cell geometry when a high frequency alternating potential is applied. Once fabricated, the functional probes are characterized using scanning electron microscopy and energy dispersion elemental analysis. MFM is performed on the track of a longitudinal recording medium and features as small as 50 nm are clearly resolved. Power spectral density analysis of the images suggests a resolution as high as 25 nm can be achieved. In conclusion, we have developed a facile method for MFM tip fabrication easily scalable for parallel production.

MI-TuP2 RF Atmospheric Plasma Systems for Nanopowder Production and Deposition of Nanocrystallines, ***Y. Glukhoy,*** American Advanced Ion Beam, Inc.; *I. Ivanov,* 4 Star, Inc.

Two types of RF atmospheric plasma systems were developed for production of magnetic nanopowder. DC-RF-RF system is supplied by a retrofitted DC plasmatron to convert precursor in powder or aqueous substance into the flow of melted droplets. The DC torch provides a high temperature in the small area in vicinity of the cathode where precursor with a high enthalpy is injected in the discharge through the axial hole. This torch triggers also following atmospheric inductively coupled plasma (ICP) discharge up to self sustaining. So total evaporation and gas-vapor plasma chemical reaction in the fly were implemented in the large high temperature area of the RF reactor where two RF coils at frequencies 13.56 MHz and 27.12 MHz with total RF power up to 18 kW sustain the ICP discharge in the water-cooled 12" long quartz tube with 4.5" OD. The melted droplets were pinched in an axial vapor flow mixed with the process gases. The Laval nozzle at the end of the reactor provides quenching of such a gas-vapor flow and nucleation of mixture in the fly. It simultaneously protects the oil mist that captures the nanoparticles in nanopowder production mode or the polymer substrate in the nanocoating one from the heat flux irradiated by plasma. But production of the ultra-high purity magnetic nanopowder, particularly for drag delivery in the cancer therapy requests the ultra clean technology. We have built a second device where a commercial ICP plasma torch as a melted droplet generator and trigger of the RF reactor was used. The length of the following RF reactor was reduced twice due to the relatively low velocity of the flow. Therefore, just one saddle-like RF antenna that concentrates all RF power inside the inner volume was used in the second stage. Estimation of the atmospheric plasma parameters and of the cooling time in the Laval nozzle is presented. @FootnoteText@Y.Glukhoy, el: Method and apparatus for manufacturing of nanoparticles. US Patent Appl. 20050258149 Nov 24, 2005.

MI-TuP4 Properties of LT-MBE Ga@sub 1-x@Mn@sub x@As Regrown on InGaP/GaAs Prepared Substrates, ***J.S. Lee,*** *H.K. Choi, W.O. Lee, Y.D. Park,* Seoul National University, Korea

We report on the structural, magnetic, and transport properties of LT-MBE Ga@sub 1-x@Mn@sub x@As regrowth on MOCVD prepared GaAs(500 nm)/In@sub 1-y@Ga@sub y@P(500 nm)/GaAs(001) and In@sub 1-y@Ga@sub y@P(500 nm)/GaAs(001) substrates. In-situ RHEED indicate a layer-by-layer growth with typical 2 x 4 pattern during regrowth of a GaAs buffer layer preceding 1 x 2 pattern during 100 nm of Ga@sub 1-x@Mn@sub x@As. @theta@-2@theta@ HRXRD measurements show characteristic features for only the Ga@sub 1-x@Mn@sub x@As epilayers and In@sub 1-y@Ga@sub y@P/GaAs(001) substrate. SQUID magnetization measurements indicate magnetic ordering temperatures (T@sub C@'s) of regrown Ga@sub 1-x@Mn@sub x@As to be similar to Ga@sub 1-x@Mn@sub x@As/GaAs(001), with indications of an increase in in-plane uniaxial anisotropy field terms from BH loops measurements at 5 K with H || to (110) and (1-10). Similar to Ga@sub 1-x@Mn@sub x@As/GaAs(001), annealing at low temperatures (250°C for 1 hour) increases T@sub C@. Transport measurements show insulator-like behavior for as-grown samples with Mn content. For similar Mn content, Ga@sub 1-x@Mn@sub x@As/GaAs(001) show metallic-like behavior. We will also discuss realization of Ga@sub 1-x@Mn@sub x@As suspended NEMS and MEMS structures suitable for further investigations on the origins of magnetic ordering in Ga@sub 1-x@Mn@sub x@As diluted magnetic semiconductors.

MI-TuP8 Low Noise, High Sensitivity Anisotropic Magnetoresistive Sensors with Second Harmonic Readout, ***S.T. Halloran,*** *H. Fardi, F.C.S. da Silva,* University of Colorado; *D.P. Pappas, R.R. Owings,* National Institute of Standards and Technology; *E.W. Hill,* University of Manchester

Low noise magnetic field sensors have a wide range of applications. At present, the best signal-to-noise ratio (SNR) sensors on the market are based on anisotropic magneto-resistance (AMR). In this work we demonstrate low noise sensors that operate by modulating the bias on soft-adjacent-layer (SAL)-biased AMR devices and sensing the second harmonic signal. The 2f technique allows us to move the signal above the 1/f noise regime and into a less noisy bandwidth. We have measured the noise response of these sensors and demonstrated the scalability of the noise with the volume of the sensor. Using the Johnson noise limit, we show that a sensitivity of 1 pT/@sr@Hz is achievable in these devices at reasonable power levels. In addition, we show that the 2f detection is capable of providing high-contrast magnetic field images that reject thermal asperities. This is due to the fact that the interaction of the bias current and magnetic moment of the sensor is independent of the sign of the bias current. Sensors are fabricated by DC sputtering (80)Ni(20)Fe onto a Ta seed layer in a needle pattern. The SAL bias is achieved with NiFe as well, separated from the MR layer by a thin SiN insulating layer. The needle is 20 µm wide by 200 µm long with an overall thickness of 0.450 µm. The needle aspect ratio of 4:1 (or a needle angle of 30 degrees) is chosen to optimize the single-domain formation by preventing vortices from forming. The magneto-resistor (MR) layer was sputtered in a 200 Oe field along the easy axis of the sensor. Full bias is provided by the SAL. Initial findings show a preferred bias at 15 mA which corresponds to a RMS voltage (peak to peak) of 5.2 at 1 KHz. We used a lock-in technique to generate the 2f signal from the differential output of the bridge. A custom MR looper was built to characterize these sensors. Applications include arrays of bridges for high-resolution scanned MR microscopy including room temperature magnetocardiograms.

Magnetic Interfaces and Nanostructures
Room 2006 - Session MI-WeM

Magnetic Imaging
Moderator: D.P. Pappas, NIST

8:00am **MI-WeM1 Imaging Magnetic Nanostructures via Resonant Soft X-Ray Spectro Holography**, ***O. Hellwig***, Hitachi Global Storage Technologies **INVITED**

I will present how to exploit the coherence and tunable polarization of soft X-ray synchrotron radiation for imaging magnetic nanostructures via Fourier Transform Holography. This new lensless imaging technique is based on the direct Fourier inversion of a holographically formed soft x-ray interference pattern. Our implementation is particularly simple and is based on placing the sample behind a lithographically manufactured mask with a micron-sized sample aperture and a nano-sized reference hole. The technique avoids costly zone plate X-ray lenses as used in conventional X-ray microscopy. By exploiting the magnetic dichroism in resonance at the L3 edges of the magnetic transition metals (wavelength ~ 1-2 nm (700-900 eV), images of magnetic nanostructures have been obtained with a spatial resolution below 50 nm. Different examples will be presented. The technique is transferable to a wide variety of specimen, appears scalable to diffraction-limited resolution (about 2 nm), and is well suited for ultra-fast single-shot imaging with future X-ray free electron laser sources. @FootnoteText@Experiments have been performed at BESSY in Berlin in collaboration with Stefan Eisebitt and Wolfgang Eberhardt, BESSY GmbH, Albert-Einstein-Str.15, 12489 Berlin, Germany and Jan Luening, William F. Schlotter and Joachim Stoehr SSRL, Stanford Linear Accelerator Center, 2575 Sand Hill Road, Menlo Park CA 94025, USA and Department of Applied Physics, 316 Via Pueblo Mall, Stanford University, Stanford, CA 94305-4090 .

8:40am **MI-WeM3 Magnetic Moment Measurements Using Anisotropic Magnetoresistance**, ***F.C.S. da Silva***, University of Colorado at Denver and Health Science Center; *S.T. Halloran, R.R. Owings, A.B. Kos, W.C. Uhlig, J. Unguris, D.P. Pappas,* National Institute of Standards and Technology

The Anisotropic Magnetoresistive (AMR) effect is used to estimate the magnetic moment of thin-film Permalloy discs. The method uses the angular dependence of the AMR to measure the shape anisotropy field of a high aspect ratio (100:1) needle positioned near the disc. The measurement is directly related to the product (saturation magnetization)x(thickness) of the sample via the demagnetizing factor. Uncertainties in the absolute value of the magnetic moment are mainly due to sistematic deviations of magnetization from the single domain state. The AMR results are supported by scanning electron microscopy with polarization analysis, conventional magnetometry measurements, and micromagnetic simulations.

9:00am **MI-WeM4 Measuring Spin Dependant Hot Electron Transport using Spin-Polarized Ballistic Electron Emission Microscopy**, ***A.J. Stollenwerk***, University at Albany, SUNY; *M.R. Krause,* Thompson, Germany; *D.H. Idell, V.P. LaBella,* University at Albany, SUNY

Devices that utilize the spin degree of freedom rely on transport of electron spin through materials and material interfaces. Further knowledge of spin-polarized electron transport can aid in the development of these and other spintronic devices. To this end, we developed spin polarized ballistic electron emission microscopy (SP-BEEM), where a ferromagnetic STM tip is utilized to inject spin-polarized electrons into a ferromagnetic metal semiconductor Schottky diode. This technique allows measurement of spin polarized hot electron transport as a function of angle between the magnetic field of the tip and the magnetic field of the sample. This provides a powerful instrument to study spin dependant transport due to the full 2Ï? rotational capability and the nanoscale positioning of the STM tip. The talk will discuss this technique and how to use it to extract spin dependent attenuation lengths of ferromagnetic metals.

9:20am **MI-WeM5 Spin-polarized STM as a Tool to Study Non-Periodic Magnetic Structures**, ***W. Wulfhekel***, Universitaet Karlsruhe, Germany; *U. Schlickum,* EPFL, Switzerland; *C.L. Gao, J. Kirschner,* Max-Planck Institut fur Mikrostrukturphysik, Germany **INVITED**

The high lateral resolution of spin-polarized scanning tunneling microscopy (Sp-STM) offers the possibility to study the influence of crystal defects on ferromagnetic and antiferromagnetic structures as well as combined systems. Atomic substrate steps in W(100) were found to influence the domain walls of thin Fe films leading to a reduced wall width and pinning. This is explained by the atomic arrangement at the step edges reducing ferromagnetic exchange and enhancing magnetic anisotropy. Further, steps in ferromagnetic substrates induce frustrations in thin antiferromagnetic films via the exchange interaction. The behavior of these topological frustrations in Mn films on Fe(100) was studied and linked with atomic exchange parameters in the film and across the ferromagnet-antiferromagnet interface. Similarly, in ferromagetic films grown on stepped antiferromagnets frustrations may arise due to the exchange across the interface as will be shown on the example of Co grown on NiMn(001). Finally, the use of Sp-STM to resolve the complex and non-collinear spin structure of reconstructed @alpha@-Mn films is demonstrated.

10:40am **MI-WeM9 Imaging Electrical Spin Injection in Lateral Ferromagnet/Semiconductor Devices**, ***S. Crooker***, Los Alamos National Laboratory **INVITED**

Using methods for low-temperature scanning magneto-optical Kerr microscopy, we directly image the electrical injection and subsequent transport of spin-polarized electrons in lateral ferromagnet/semiconductor devices.@footnote 1@ These structures have metallic ferromagnetic (Fe) source and drain tunnel-barrier contacts at opposite ends of a lightly-doped n:GaAs semiconductor channel. The images reveal efficient electrical spin injection extending out to 120 microns in the GaAs channel, and accumulation of spin polarized electrons within a diffusion length (10 microns) of the drain contact. Both injected and accumulated electrons have the same spin orientation (antiparallel to the contact magnetization). By controlling, in situ, the uniaxial strain applied to the device substrate, we show that the accumulated spin polarization actually flows away from the drain contact (against the net electron current), indicating that these electrons are polarized by spin-sensitive reflection from the ferromagnetic drain contact. Furthermore, we show that the electrical conductance of these devices is modulated by the spin orientation of electrons flowing through the drain, demonstrating that the Fe/GaAs Schottky tunnel barrier contacts function both as electrical spin injectors as well as detectors. These experiments are conducted in a geometry that is sensitive only to electron spin precession, allowing for detailed modeling of spin transport in the channel. @FootnoteText@ @footnote 1@ S.A. Crooker, M. Furis, X. Lou, C. Adelmann, D.L. Smith, C.J. Palmstrom, and P.A. Crowell, Science v309, p2191 (2005). This work was supported by the DARPA SPINS and Los Alamos LDRD programs, ONR, and the NSF MRSEC program under DMR 02-12032.

11:20am **MI-WeM11 Intrinsic Nanoscale Electronic Phase Separation and Simple Percolation in La1-xSrxCoO3**, ***J. Wu***, *J. Parker, M. Torija, C. Perrey, C.B. Carter,* University of Minnesota; *J. Lynn,* National Institute of Standards and Technology; *H. Zheng, J. Mitchell,* Argonne National Laboratory; *C. Leighton,* University of Minnesota

The doped pervoskite cobaltite La1-xSrxCoO3 has been advanced as a model system for studying magnetoelectronic phase separation. We present here a combination of chemically sensitive high-resolution TEM, SANS, and transport data that reveal interesting new features of this phase separation. The TEM data show that the material is chemically homogenous down to nm length scales, proving that the phase separation is truly intrinsic electronic phase separation. The SANS data, which were performed at several compositions below x = 0.18 (where long-range ferromagnetism (FM) sets in), reveal that the FM clusters have a maximum size of about 2-3 nm, independent of doping. This demonstrates that the percolation transition that occurs at x = 0.18 is due to an increasing density of clusters with increasing x, not an expansion of cluster size. These observations naturally explain the simple percolation observed in single crystal transport, i.e. conductivity exponents close to predicted values and a critical composition (x = 0.18) close to the expected value for the 3-D percolation limit. Comparisons to theoretical work on purely electronic phase separation provide insight into the physical mechanisms controlling the phase separation. Work supported by ACS PRF, NSF and DoE.

11:40am **MI-WeM12 Non-Fermi-Liquid Behavior in Quasi-One-Dimensional Li@sub 0.9@Mo@sub 6@O@sub 17@**, ***E.W. Plummer***, The University of Tennessee, Knoxville and Oak Ridge National Laboratory **INVITED**

Temperature dependent scanning tunneling spectroscopy data of the quasi-one-dimensional conductor Li@sub 0.9@Mo@sub 6@O@sub 17@ will be presented. The differential tunneling current in the low-temperature spectra shows a power-law beefier around the Fermi energy, which is expected for a clean Luttinger liquid. The power-law exponent is

found to be 0.6. Spectra for a temperature range of 5 to 55 K can be fitted fairly well with a model for tunneling into a Luttinger liquid at the appropriate temperature. A fit with a model based on a zero bias anomaly is significantly worse compared to the Luttinger liquid model. No signature of a phase transition at T= 24 K is observed in the data.

Electronic Materials and Processing
Room 2003 - Session EM+MI-WeA

Magnetic Semiconductors

Moderator: S.A. Chambers, Pacific Northwest National Laboratory

2:00pm **EM+MI-WeA1 Spectroscopy and Magnetism of Oxide Diluted Magnetic Semiconductors*, D.R. Gamelin,*** *K.R. Kittilstved, W.K. Liu,* University of Washington **INVITED**

Diluted magnetic semiconductor (DMS) nanostructures are pivotal architectural elements in many proposed spintronics devices. DMSs of ZnO are being intensely investigated for their potential use in spintronics technologies, but such applications have been hindered by their inconsistent magnetic properties. This talk will present our group's recent advances in the use of targeted chemical perturbations to manipulate high-Tc spin ordering in ZnO DMSs predictably and controllably.@footnote 1,2,3,4@ Apart from the technological advantages of reliable, controllable, and even switchable high-Tc ferromagnetic semiconductors, these experiments are motivated by the new fundamental insights they provide into the microscopic mechanisms behind magnetic ordering in this class of materials. The results from concomitant optical, magneto-optical, structural, X-ray absorption, and magnetic data collected on the same materials will be used to evaluate dopant electronic structure contributions to magnetic ordering, and the findings will be discussed in the context of current theoretical models of high-Tc ferromagnetism in oxide DMSs. @FootnoteText@ @footnote 1@Kittilstved, K. R.; Liu, W. K.; Gamelin, D. R. "Electronic Structure Origins of Polarity Dependent High-Tc Ferromagnetism in Oxide Diluted Magnetic Semiconductors." Nature Materials, 2006, 5, 291-297.@footnote 2@Kittilstved, K. R.; Norberg, N. S.; Gamelin, D. R. "Chemical Manipulation of 300K Ferromagnetism in ZnO Diluted Magnetic Semiconductors." Phys. Rev. Lett., 2005, 149049.@footnote 3@Kittilstved, K. R.; Gamelin, D. R. "Activation of High-Tc Ferromagnetism in Mn2+:ZnO using Amines." J. Am. Chem. Soc., 2005, 127, 5292-5293.@footnote 4@Schwartz, D. A.; Gamelin, D. R. "Reversible 300K Ferromagnetic Ordering in a Diluted Magnetic Semiconductor." Advanced Materials, 2004, 16, 2115-2119.

2:40pm **EM+MI-WeA3 Deposition of Doped ZnO by Pulsed Laser Deposition Utilizing Novel Ablation Targets*, T.C. Kaspar,*** *T. Droubay, S.M. Heald, V. Shutthanandan, P. Nachimuthu, C.M. Wang, S.A. Chambers,* Pacific Northwest National Laboratory*; K.R. Kittilstved, C.A. Johnson, K.M. Whitaker, D.R. Gamelin,* University of Washington

Zinc oxide (ZnO) is a promising material for optical, electro-optical, magneto-optical, and spintronic applications. The desired properties of ZnO are obtained by doping the material, in which case distribution and substitution of the dopants is of prime importance. Doped ZnO nanoparticles can achieve the necessary dopant dispersion and speciation to create high-quality material exhibiting, for example, the room temperature ferromagnetism necessary for spintronic applications. However, these nanoparticles may not be as useful in practical devices as high-quality epitaxial films. To this end, we have explored the deposition of epitaxial Co- and Mn-doped ZnO thin films by pulsed laser deposition (PLD), utilizing well-characterized doped ZnO nanoparticles as the basis for the PLD ablation target material. Ablating a target which already contains the dopant in the desired substitutional environment in ZnO should allow full substitution of the dopant into the epitaxial film and reduce or eliminate the formation of secondary phases. Initial results on Co-doped ZnO films deposited on Al@sub 2@O@sub 3@(0001) from a Co:ZnO nanoparticle target indicate that smooth, epitaxial ZnO films can be obtained. Co K-edge x-ray absorption near edge spectroscopy and extended x-ray absorption fine structure show full oxidation of Co to Co(II) for all oxygen pressures explored (5x10@super -5@ - 5x10@super -2@ Torr), with substitution of Co for Zn in the ZnO lattice. Issues associated with the nanoparticle ablation targets, such as target densification using low-temperature processing, particle and droplet ejection during ablation, and localized dopant diffusion in the ablated region, will be discussed.

3:00pm **EM+MI-WeA4 Room Temperature Ferromagneticism in Fe Implanted ZnO Nanotips*, R.A. Bartynski,*** *D. Hill,* Rutgers University*; D.A. Arena,* National Synchrotron Light Source*; P. Wu, Y. Lu, J.F. Al-Sharab, F. Cosandey,* Rutgers University

Transition metal- (TM-) doped ZnO is a promising candidate dilute magnetic semiconductor for room-temperature spintronics applications. Controlled synthesis of nanoscale structures of these materials offers the possibility to develop low-dimensional spin-dependent electronic devices. We have grown well-aligned ZnO nanotips on SiO@sub 2@/quartz substrates using MOCVD. The tips were subsequently Fe-doped to a dose 5 x 10@super 16@ cm@super -2@ using ion implantation at 200 keV. The magnetic, structural, and chemical properties of both as-implanted and post-implantation annealed nanotips were studied using SQUID magnetometry, electron energy loss (EELS) and X-ray Energy Dispersive (EDS) spectroscopy in high resolution transmission electron microscopy (HRTEM), X-ray diffraction (XRD) and soft X-ray absorption spectroscopy (SXAS). The as-implanted tips were ferro-magnetic at room temperature with a saturation moment of ~ 0.2 μ@sub B@/Fe-ion, a remnant magnetization of ~0.03 μ@sub B@/ion, and a coercive field of ~150 Oe. The tips exhibit a core-shell structure with a high concentration (~ 8%) of Fe in the first ~ 10 nm, and about 3% in the interior, with roughly equal concentrations of Fe@super +2@ and Fe@super +3@ oxidation states. Post implantation annealing to 700C for 10 minutes improves crystallinity, produces a more uniform ~ 5% concentration of Fe, and increases the Fe@super +3@:Fe@super +2@ ratio, but significantly reduces the saturation magnetization. However, the tips remain ferromagnetic up to at least room temperature. The reduction in magnetic response, despite the increased magnetic moment/ion expected from the increased Fe@super +3@ concentration, suggests that the redistribution of Fe ions dominates the ferromagnetic coupling in the system. @FootnoteText@ * Supported by NSF Grant ECS-0224166.

3:20pm **EM+MI-WeA5 X-ray Characterization of Oxide-based Magnetic Semiconductors*, Y.U. Idzerda,*** *A. Lussier, J. Dvorak, A. McClure, M. Liberati, J. Holroyd,* Montana State University*; E. Arenholz,* ALS/LBNL*; S.R. Shinde, S.B. Ogale, T. Venkatesan,* University of Maryland, College Park **INVITED**

Although the evidence for magnetic semiconductors (not simply semiconductors which are ferromagnetic) is compelling, there is much uncertainty in the mechanism for the polarization of the carriers, suggesting that it must be quite novel. Recent experimental evidence suggests that this mechanism is similar to the polaron percolation theory proposed by Kaminski and Das Sarma,@footnote 1@ which was recently applied specifically to doped oxides by Coey et al.@footnote 2@ where the ferromagnetism is driven by the percolation of polarons generated by defects or dopants. We have used X-ray absorption spectroscopy at the L-edges and K-edges for low concentrations transition metal (TM) doped magnetic oxides (including TiO@sub 2@, La@sub 1-x@Sr@sub x@O@sub 3@, HfO@sub 2@, and In@sub 2@O@sub 3@). We have found that in most cases, the transition metal assumes a valence consistent with being at a substitutional, and not interstitial site. We have also measured the X-ray Magnetic Circular Dichroism spectra (including TM doped GaN and GaAs systems). Although these materials show strong bulk magnetization, we are unable to detect a robust dichroism feature associated with magnetic elements in the host semiconductor. In the cases where a dichroism signal was observed, it was very weak and could be ascribed to a distinct ferromagnetic phase (TM metal cluster, TM oxide particulate, etc.) separate from the host material. This fascinating absence of a dichroic signal and its significant substantiation of important features of the polaron percolation model may help to finally resolve the issue of ferromagnetism in magnetically doped oxides. @FootnoteText@ @footnote 1@ Kaminski and S. Das Sarma, Physical Review Letters 88, 247202 (2002).@footnote 2@ J. M. D. Coey, M. Venkatesan, and C. B. Fitzgerald, Nature Materials 4, 173 (2005).

4:00pm **EM+MI-WeA7 Characteristics of Ti@sub 1-x@Co@sub x@O@sub 2@ Thin Films Deposited by MOCVD*, A. McClure,*** *A. Kayani, M. Liberati, J. Dvorak, R.J. Smith, Y.U. Idzerda,* Montana State University*; E. Arenholz,* Lawrence Berkeley National Laboratory

Polycrystalline anatase thin films of Ti@sub 1-x@Co@sub x@O@sub 2@ were prepared on TiO@sub 2@ (50nm)/Si (111) substrates using liquid delivery metal organic chemical vapor deposition (MOCVD). This growth technique allows for the arbitrary variation of the Co concentration. The precursors for these growths were titanium isopropoxide and Co(TMHD)@sub 3@ dissolved in tetrahydrofuran. These films were characterized by X-ray absorption spectroscopy (XAS) and X-ray magnetic circular dichroism (XMCD) to determine the phase of the TiO@sub 2@ host, the Co valency, and the presence of Co clusters. Film thicknesses and Co dopant concentrations were determined from Rutherford backscattering (RBS). A vibrating sample magnetometer (VSM) revealed room temperature ferromagnetism, allowing for a determination of the moment per Co atom vs. Co concentration. I will discuss these results in the context of the bound magnetic polaron model. Recent work@footnote 1@ suggests that this model may only need oxygen vacancies and

ferromagnetism may occur with nonmagnetic doping. Our experimental results on Pt:TiO@sub 2@ and its lack of ferromagnetism will also be presented. @FootnoteText@ @footnote 1@Osorio-Guillén, J., Lany, S., Barabash, S. V. and Zunger, A., Phys. Rev. Lett., 96, 107203 (2006).

4:20pm **EM+MI-WeA8 Detection of Nanometer-Sized Inclusions in Annealed Ga@sub 1-x@Mn@sub x@As from Atypical Scaling Behavior of the Anomalous Hall Coefficient**, ***H.K. Choi***, *S.S.A. Seo, W.O. Lee, Y.S. Oh, K.H. Kim, T.W. Noh, Y.D. Park,* Seoul National University, Korea

We report on the anomalous Hall coefficient (R@sub s@) and longitudinal resistivity (@rho@@sub xx@) scaling relationship (R@sub s@=c@rho@@sub xx@@super n@) on three series of annealed LT-MBE Ga@sub 1-x@Mn@sub x@As epilayers (x ~ 0.55). After growth, Mn@sub Ga@ were varied by low temperature annealing from 200°-350°C. Our report of the scaling relationship can provide new methods to detect metallic secondary phases could not be observed in HRXRD and SQUID magnetometer. As-grown samples exhibit scaling parameter n of 1, which can be attributed to extrinsic skew scattering origins of the anomalous Hall Effect@footnote 1@ or to AHE attributed to phonon-assisted hopping between localized states in the impurity band.@footnote 2@ For annealing temperatures near the optimal (~ 250°C), we find n ~ 2 to be consistent with recent theories on the intrinsic origins of AHE in Ga@sub 1-x@Mn@sub x@As.@footnote 3@ For annealing temperatures above the optimum, we note n > 3, which atypical behavior cannot be explained in terms of AHE from a DMS system. This atypical behavior is similar to nanometer-sized super-paramagnetic particles in a paramagnetic matrix such as CoAg granular systems.@footnote 4@ This observation from AHE measurements agree well with optical spectroscopy measurements with observed characteristic features attributable to spherical resonance from metallic inclusions.@footnote 5@ @FootnoteText@ @footnote 1@ J. Smit, Physica (Ultrecht) 21, 877 (1955).@footnote 2@ A. A. Burkov and L. Balents, PRL 91, 057202 (2003).@footnote 3@ T. Jungwirth, Q. Niu, and A. H. MacDonald, PRL 88, 207208 (2002).@footnote 4@ Peng Xiong et al., PRL 69 (22), 3220 (1992).@footnote 5@ S.S.A. Seo et al., APL 82, 4749 (2003); S.S.A. Seo et al., JAP 95, 8172 (2004).

4:40pm **EM+MI-WeA9 Effect of Growth Conditions on the Magnetic Properties of GaGdN**, ***J.K. Hite***, *R.M. Frazier, R.P. Davies, G.T. Thaler, C.R. Abernathy, S.J. Pearton,* University of Florida*; J.M. Zavada,* Army Research Office

Due to the increasing interest in spintronics, many attempts have been made at incorporating spin-based technology into the existing semiconductor technology, with a recent focus on rare earth doped GaN. GaGdN layers were grown by gas source MBE under a broad range of thicknesses and Gd cell temperatures. Magnetic measurements obtained using a SQUID magnetometer showed ferromagnetic behavior at room temperature. Magnetization of the material was dependent both on dopant cell temperature and crystalline quality. The Gd concentration was under the detection limit of secondary ion mass spectroscopy, and from the highly insulating nature of the films is estimated to be on the order of 10@super 16@ atom/cm@super 3@. In addition, the GaGdN films were also co-doped with Si at varying Si cell temperatures. In contrast to GaGdN, the co-doped material was conductive, with resistivities reaching 0.04 @ohm@-cm. Room temperature ferromagnetism was also retained, some of which exceeded that of the singly doped films. No evidence of second phases was seen in x-ray diffraction. These materials may be useful in the development of devices such as magnetic tunnel junctions and spin valves. This work is supported by the Army Research Office under W911-NF-04-10296.

Magnetic Interfaces and Nanostructures
Room 2006 - Session MI-WeA

Exchange Bias & TMR

Moderator: G.J. Mankey, University of Alabama

2:00pm **MI-WeA1 A Comprehensive Study of Exchange Bias**, ***I.K. Schuller***, *R. Morales, Z.-P. Li, C.-P. Li, I.V. Roshchin, S. Roy, S. Sinha,* University of California, San Diego*; M.J. Fitzsimmons,* Los Alamos National Laboratory*; X. Batlle,* Universitat de Barcelona, Spain*; J.B. Kortright,* Lawrence Berkeley National Laboratory*; D. Altbir,* Universidad de Santiago de Chile, Chile*; J. Mejia-Lopez,* Pontificia Universidad Catolica de Chile, Chile*; A. Romero,* Unidad Queretaro Libramiento Norponiente, Mexico **INVITED**

In recent years we have performed an extensive study of Exchange Bias in Antiferromagnetic (AF) Fluoride or Oxide/Metallic Ferromagnets (F) bilayers and nanostructures. To arrive at a comprehensive understanding of the phenomenon we have performed global (magnetization, Kerr effect, magnetotransport, ferromagnetic resonance), and local (magnetic circular dichroism, polarized neutron diffraction) magnetic measurements and combined these with detailed quantitative structural (X-ray and neutron diffraction) and growth studies. These studies were complemented by micromagnetic and Monte Carlo calculations to understand the role of various parameters in exchange bias and to clarify the importance of the various possible mechanisms. We discovered many unexpected surprises, such as large exchange bias in fully compensated surfaces, positive exchange bias, and reversal asymmetries. The overall emerging picture is that many phenomena can coexist even in the simplest exchange bias systems such as the one studied here. Domain walls and uncompensated spins in both the F and the AF, uncompensated spins and anisotropy in the AF, the interfacial coupling, inhomogeneities and roughness at the interface, and the detailed crystal structure of the constituents all play a major role. The overall picture that emerges is that pinned uncompensated spins in the bulk AF, coupled to pinned uncompensated spins at the interface, provide the unidirectional anisotropy needed for exchange bias. This together with interfacial inhomogeneities, interfacial coupling and the various anisotropies can explain the large variety of apparently disconnected phenomena. The origin and exact nature of the uncompensated spins remains a major unsolved issue. Time permitting, I will describe very recent attempts at beating the superparamagnetic limit and modification of the magnetism in magnetic nanostructures. Work supported by DOE and AFOSR

2:40pm **MI-WeA3 All Ferromagnetic Exchange Bias Systems**, ***A. Berger***, *D.T. Margulies, E.E. Fullerton,* Hitachi GST*; S. Polisetty, X. He, Ch. Binek,* University of Nebraska*; O. Hovorka, G Friedman,* Drexel University

We have recently demonstrated a novel pathway for studying exchange bias and the tuning of hysteresis loop properties by combining two ferromagnetic layers with very different properties.@footnote 1@ Specifically, we use one hard ferromagnetic layer (HL) that serves as the tuning element, hereby replacing the antiferromagnetic layer of conventional exchange biased systems, and one soft ferromagnetic layer (SL) that is the actual tunable magnetic film. This bilayer structure has the advantage that the pre-set tuning field and temperature ranges are more accessible than in the case of traditional exchange bias structures using antiferromagnets. Also, a ferromagnetic HL allows for simple magnetometry monitoring of its magnetic state, which enables further insight into its role as the tuning element. The structures that were successfully utilized in our approach consist of a 15 nm thick hardmagnetic CoPtCrB-film, the tuning layer HL, exchange coupled by means of a 0.6 nm thick Ru-interlayer to a 1-2 nm thick CoCr-film, which is the tunable layer SL. We observe that the SL bias field h@sub bias@ is proportional to the HL magnetization M@sub r@, which suggests that the effective bias field is determined by the volume-averaged magnetization of HL. We also studied the existence of training effects in these all ferromagnetic exchange bias systems and found it to be triggered by the SL magnetization reversal.@footnote 2@ Furthermore, we were able to demonstrate experimentally for the first time that the amount of training in exchange bias systems is correlated with the HL magnetization state, in particular its distance from equilibrium@footnote 2@. @FootnoteText@ @footnote 1@A. Berger et al., Appl. Phys. Lett. 85, 1571 (2004)@footnote 2@Ch. Binek et al., Phys. Rev. Lett. 96, 067201 (2006).

3:00pm **MI-WeA4 A Novel Scheme for Pinning Magnetic Layers in Current Perpendicular to the Plane Spin Valve Devices**, ***C. Papusoi***, *Z. Tadisina, S. Gupta, H. Fujiwara, G.J. Mankey, P. LeClair,* University of Alabama

When an antiferromagnetic (AF) film is used to create anisotropy in a ferromagnetic (F) layer, the thickness of the AF is usually chosen to be greater than 5 nm to produce large loop shift of the pinned F layer. In current perpendicular to the plane (CPP) spin valves it is desirable for ancillary layers such as the AF to have a small electrical resistance. This creates a problem, since a fundamental property of antiferromagnets is an intrinsic high resistivity. A possible solution to this problem is to fabricate a device with a thinner AF layer (~2-4 nm) such that the coercivity of the F layer is enhanced while the loop shift is not fully developed. In this regime, the relaxation time of the AF grains is short enough to allow the AF surface moments to follow the F moments in an irreversible manner, due to the AF anisotropy, resulting in a supplementary loss mechanism and a substantial increase in the coercivity of the F layer. If the F layer is then replaced by a synthetic antiferromagnet (SAF), the applied field range where the SAF moments are antiparallel is enhanced with a concurrent increase in the giant magnetoresistance ratio (GMR). The thermal stability of spin valve

stacks with the structure Ta(4)/Cu(10)/IrMn(x)/CoFe(3)/Ru(0.8)/CoFe(3)/Cu(2.5)/CoFe(1)/NiFe(3)/Ta(5) with x < 5 nm, is found to increase with increasing x. Magnetization and GMR measurements are compared to Stoner-Wohlfarth simulations which nicely show the applied field dependence of the relative orientations of the F layer magnetizations in the spin valve stack. These results will be compared to those obtained for similar spin valve stacks with thicker AF layers and stacks employing hard F layers to increase the pinned layer anisotropy.

3:20pm **MI-WeA5 Theory of Resonant Tunneling in Composite Fe/MgO/Fe Junctions with Nonmagnetic Interlayers**, ***J. Mathon,*** City University, UK **INVITED**

Epitaxial Fe/MgO/Fe tunneling junctions with nonmagnetic interlayers bewteen the MgO barrier and Fe electrods are interesting since Au/Ag interlayers create quantum wells in the minority-spin channel which may give rise to resonant tunneling. Because of a good match between Fe and Au/Ag majority-spin bands there are no quantum wells in the majority-spin channel. The idea is to engineer a junction with resonant tunneling in the minority-spin channel in the ferromagnetic(FM)configuration while tunneling in the antiferromagnetic (AF) configuration remains nonresonant. We investigated Fe/Au/MgO/Au/Fe junction with two Au interlayers. In the AF configuration all electrons see a single quantum well and no resonant tunneling occurs. However, in the FM configuration the minority-spin electrons see two quantum wells adjacent to the MgO barrier. A barrier sandwiched between two wells can give rise to resonant tunneling with 100\% transmission through the barrier. A resonant enhancement of TMR is thus expected.

4:00pm **MI-WeA7 The Role of Interfacial Moments in High TMR MgO-based Structures**, ***E. Negusse,*** *A. Lussier, J. Dvorak, Y.U. Idzerda,* Montana State University -- Bozeman*; S.R. Shinde, Y. Nagamine, S. Furukawa, K. Tsunekawa,* Canon-Anelva, Corporation

The large tunneling magnetoresistance (TMR) reported in MgO based magnetic tunneling junctions (MTJs) has attracted a great deal of attention for practical applications in spin-based electronic devices such as read-heads and nonvolatile memory.@footnote 1@ Recently it has been shown that adding boron to the cobalt-iron alloy electrodes created room temperature TMR of 230% by making the electrodes more amorphous and resulting in MgO barriers with good crystallinity.@footnote 2@ We used x-ray resonant magnetic scattering (XRMS), a nondestructive, element-specific and interface sensitive probe, to measure the effect of boron addition and annealing on the chemical and magnetic properties of the buried electrode-MgO interface. The specular and diffuse (interface-sensitive) scattered circularly polarized x-rays can be used to characterize the magnetic response of the moments at the interface compared to the entire film. The samples studied were 18 Å MgO films grown on 30 Å Co@Sub 70@Fe@Sub 30@ and Co@Sub 60@Fe@Sub 20@B@Sub 20@ electrodes using a UHV sputtering system (ANELVA C-7100). Our measurements showed that adding boron increased the squareness of the hysteresis loop and resulted in a significant decrease of the coercive field from 36 Oe to 5 Oe. Annealing (2 hours in an 8 kOe applied field at 360 °C) increased the grain size by 14% resulting in a slight increase in H@sub C@ for the boron containing electrode. We find that the interfacial moments for the more amorphous films behave identically to the bulk and may be the source of the increased TMR values. @FootnoteText@ @footnote 1@ S. S. P. Parkin, et al, Nat. Mater. 3, 862 (2004); S. Yuasa, et al., Nat. Mater. 3, 868 (2004).@footnote 2@ D. D. Djayaprawira, et al, Appl. Phys. Lett. 86, 092502 (2005).

4:20pm **MI-WeA8 Tunnel Magnetoresistance Effect in Sputtered MTJs with MgO Barrier and Various Ferromagnetic Electrodes**, ***J. Hayakawa,*** Hitachi Ltd. and Tohoku University, Japan*; S. Ikeda, Y.M. Lee, R. Sasaki, T. Meguro, F. Matsukura,* Tohoku University, Japan*; H. Takahashi,* Hitachi Ltd., Japan and Tohoku University, Japan*; H. Ohno,* Tohoku University, Japan **INVITED**

Magnetic tunnel junctions (MTJs) with a crystalline MgO barrier offer giant tunnel magnetoresistance (TMR) ratio@footnote 1-5@ and current-induced magnetization reversal at low critical current and are of considerable interest in terms of physics involved as well as of application to advanced magnetic memories (MRAMs). Here we report high TMR ratio over 360% at room temperature in (100) oriented CoFeB/MgO/CoFeB MTJ sputtered on Si/SiO wafers. The MTJs consist of Ta (5nm) / NiFe (5nm) / MnIr (10nm) / CoFe (2nm) / Ru (0.8nm) / CoFeB (3nm) / MgO / CoFe(B) / Ta (5nm) / Ru (5nm). The thickness of the MgO barrier was varied from 0.80 to 2.4 nm. We found that the TMR ratio increases with increasing the annealing temperature (Ta), and reaches 361% at RT when the Ta is 400°C (578% at 5 K). These TMR ratios correspond to tunneling spin-polarizations of 0.80 and 0.86 by using Julliere's formula. HRTEM images revealed that the as-deposited CoFeB electrodes were amorphous and the as-deposited MgO barrier had highly (001)-oriented NaCl structure with good uniformity. The images also showed that by annealing at 375°C, full crystallization of the CoFeB ferromagnetic electrodes in body centered cubic structure took place. The observed giant TMR ratio is attributed to the formation of highly (100) oriented crystalline MTJs with an MgO barrier and bcc CoFeB by annealing, which satisfies the conditions for high TMR ratio predicted by the theoretical studies.@footnote 6-8@ We will also show the tunnel magnetoresistance effect in the MTJs with CoFe-B free layers with different Co, Fe, and B (Boron) compositions. This work was supported by the IT-program of Research Revolution 2002 (RR2002): Development of Universal Low-power Spin Memory, Ministry of Education, Culture, Sports, Science and Technology of Japan. @FootnoteText@@footnote 1@S. Yuasa, T. Nagahama, A. Fukushima, Y. Suzuki, and K. Ando, Nat. Mater. 868, 3 (2004). @footnote 2@S. S. Parkin, C. Kaiser, A. Panchula, P. M. Rice, B. Hughes, M. Samant, and S.-H. Yang: Nat. Mater. 3, 862 (2004). @footnote 3@D. D. Djayaprawira, K. Tsunekawa, M. Nagai, H. Maehara, S. Yamagata, N. Watanabe, S. Yuasa, Y. Suziki, and K. Ando, Appl. Phys. Lett. 86, 092502 (2005). @footnote 4@J. Hayakawa, S. Ikeda, Y. M. Lee, R. Sasaki, T. Meguro, F. Matsukura, H. Takahashi, and H. Ohno, Jpn. J. Appl. Phys, 44, L1267 (2005). @footnote 5@S. Ikeda, J. Hayakawa, Y. M. Lee, R. Sasaki, T. Meguro, F. Matsukura, and H. Ohno, Jpn. J. Appl. Phys, 44, L1442 (2005). @footnote 6@W. H. Butler, X.-G. Zhang, T. C. Schulthess and J. M. MacLaren, Phys. Rev. B. 63, 054416 (2001). @footnote 7@J. Mathon and a. Umersky, Phys. Rev. B. 63, 220403R (2005). @footnote 8@X.-G Zhang and W. H. Butler, Phys. Rev. B 70, 172407 (2004).

Magnetic Interfaces and Nanostructures
Room 2006 - Session MI+EM-ThM

Spin Injection
Moderator: A.R. Smith, The Ohio State University

8:00am **MI+EM-ThM1 Spin-Polarized Transport in Ferromagnet-Semiconductor Heterostructures**, ***A.G. Petukhov,*** South Dakota School of Mines and Technology **INVITED**

The early promise of ferromagnet-semiconductor heterostructures (FMSH) and dilute magnetic semiconductors (DMS) as a basis for spintronics has led to serious challenges for both theorists and experimentalists. This talk will focus on three fundamental issues: basic physics of spin injection, multi-scale methodology for spin-dependent transport calculations and band engineering of highly efficient FMSH-based spin injectors and spin detectors. These issues are addressed using a combination of first-principles theory, analytical modeling of the underlying physics, and design and numerical simulation of spintronic devices. We will start from basic definitions of non-equilibrium spin polarizations of the current and electron density and derive some useful relations between these quantities. We will further consider a theory of spin injection within the linear-response approximation and its generalization to a non-linear case. We will formulate a self-consistent multi-scale scheme for spin-dependent transport calculations of FMSH. The scheme combines the large scale drift-diffusion equation approach and the small scale first-principles calculations of the spin-dependent transmission matrix to provide proper microscopic boundary conditions at both sides of the junction. We will demonstrate that spin polarization of electrons in nonmagnetic semiconductors near specially tailored FMSH junctions can achieve 100%. We propose several new devices based on DMS heterostructures that lead to potentially useful effects, including extremely large and tunable tunneling magnetoresistance and high-efficiency spin filtering. These prototype devices include GaMnAs/AlAs/GaMnAs tunnel junctions; double-barrier quantum well heterostructures; and spin-selective resonant interband tunneling devices in the InAs/AlSb/GaMnSb system, using ferromagnetic DMS quantum wells. This work is supported by ONR.

8:40am **MI+EM-ThM3 Epitaxial Growth, Spin Polarization, and Electrical Spin Injection from Fe(1-x)Ga(x) (001) Films on AlGaAs/GaAs(001) LEDs**, ***A.T. Hanbicki***, *O.M.J. van 't Erve, C.H. Li, G. Kioseoglou, M.S. Osofsky, S.-F. Cheng, B.T. Jonker,* Naval Research Laboratory

Electrical spin injection is a prerequisite for a semiconductor spintronics technology. Spin injection into GaAs from ferromagnetic metals such as Fe via Schottky barrier tunnel contacts has been demonstrated. However, the surface emitting geometry employed to facilitate a quantum selection rule based analysis of the polarized electroluminescence (EL) produced by the spin polarized light emitting diode (spin-LED) devices necessitates the use of relatively large external magnetic fields to saturate the Fe magnetization out-of-plane. We have grown epitaxial films of Fe(1-x)Ga(x) (0 < x < 0.75), a material noted for its high magnetostriction, on AlGaAs/GaAs (001) heterostructures, and summarize the structure, magnetization, spin polarization, and results for electrical spin injection into AlGaAs/GaAs. The out-of-plane saturation field and magnetization decrease rapidly with Ga content, but the point contact spin polarization remains near that of Fe for x @<=@ 0.5. Electrical spin injection from an Fe@sub 0.5@Ga@sub 0.5@ contact produces an electron spin polarization of 30% in the GaAs at 20 K, similar to that obtained from Fe contacts, but with out-of-plane saturation fields as low as 0.4 T. This work was supported by ONR. OvE current address: Philips, Eindhoven.

9:00am **MI+EM-ThM4 Remanent Electrical Spin Injection from Fe into GaAs Edge-Emitting Spin-LEDs**, ***G. Kioseoglou,*** Naval Research Laboratory*; O.M.J. van 't Erve,* Philips Research Laboratories*; A.T. Hanbicki, C.H. Li, B.T. Jonker,* Naval Research Laboratory

Electron spin polarizations (P@sub spin@) of 40-70% have been obtained in GaAs due to electrical injection from Fe or FeCo contacts using surface-emitting spin-LEDs. In such LEDs, a narrow (100 Å) QW is typically used, and the heavy hole (HH) angular momentum is constrained to lie along the surface normal due to quantum confinement, requiring a similar orientation for the spin of the injected electrons. Since Fe has its magnetization easy axis in the substrate plane, a large magnetic field (>2.2 tesla) along the surface normal is required to saturate the magnetization out-of-plane. To take advantage of the small coercive fields and large remanent in plane magnetizations of Fe, the edge emitting geometry should be developed to facilitate transduction of the spin state variable between the electron spin and optical polarization. Here we demonstrate electrical spin injection from Fe into edge-emitting LEDs with relatively wide QWs (500 and 1000 Å) and compare surface and edge emission spin injection efficiencies. The edge-emitted optical polarization for the 100Å QW spin LED is zero, as expected due to hole spin orientation. For the wider QWs, the confinement energy diminishes and the magnetic field rather than the confinement defines the quantization axis. In this case the HH angular momentum can in principle lie in-plane, co-linear with the electron spin and light propagation direction, enabling a determination of P@sub spin@ via the same selection rules. We find similar spin injection efficiencies for electron spins (contact magnetization) oriented in-plane and normal to the surface. The magnitude of the edge emitted optical polarization is limited at low magnetic fields by the orientation of the HH angular momentum, which is constrained to lie partially out-of-plane due to the reduced symmetry accompanying weak localization at the QW interfaces. This work was supported by ONR.

9:20am **MI+EM-ThM5 Towards Electrical Spin Injection into a Single InAs/GaAs Quantum Dot**, ***C.H. Li,*** *G. Kioseoglou, A.T. Hanbicki,* Naval Research Laboratory*; O.M.J. van 't Erve,* Philips Research Laboratories Eindhoven*; B.T. Jonker,* Naval Research Laboratory

We have demonstrated electrical injection of spin-polarized electrons from an Fe Schottky contact into an ensemble of InAs/GaAs self assembled quantum dots (QDs) in a spin-LED.@footnote 1@ We observed a 5% electron spin polarization from 80-300K, consistent with the suppression of DP spin scattering expected for QDs. The electroluminescence we observed is a convolution of emission from an ensemble of dots with a considerable variation in size, hence it exhibits a broad FWHM of ~50 meV. It is highly desirable to isolate emission from a single QD to further elucidate the details of electrical spin injection and consequent spin polarization in quantum dots as a function of dot size and charge state. To this end, we have developed MBE growth methods to reduce the density of dots by more than an order of magnitude (in the order of 10@super 9@/cm@super 2@ as shown by atomic force microscopy of uncapped samples), and narrowed the aperture sizes of the surface-emitting LEDs to the order of a hundred nanometers using ebeam lithography. As the density and aperture size decrease, the initially broad emission spectrum of the dot ensemble breaks into distinct narrow features attributed to single dot emission. Emission spectra exhibiting a few well-separated peaks are observed with linewidths that are spectrometer resolution-limited. With increasing bias, the number of peaks increases drastically, indicating emission from an increasing number of dots, while the linewidth of these narrow emission peaks broadens, suggesting contributions from various charge states of the dot. Progress towards electrical spin injection into a single QD, and details of the electroluminescence spectra from these single-dot spin-LEDs as a function of bias and magnetic field will be discussed at the meeting. Supported by ONR and DARPA. @FootnoteText@ @footnote 1@C. H. Li et al. APL 86, 132503 (2005).

9:40am **MI+EM-ThM6 Organic-based Materials in Spintronics**, *S. Liu, P. Jeppson, J. Sandstrom, B. Anderson, D.B. Chrisey, D.L. Schulz,* ***A.N. Caruso***, North Dakota State University

Magnetic and non-magnetic organic-based solids provide physical, magnetic and electronic flexibility with regard to multilayer device fabrication. This flexibility manifests itself in the form of organic synthesis whereby molecular orbital localization and hybridization can be finely tuned. The use of low Z materials in environments where spin coherence is vital will be discussed relative to spin orbit coupling and hyperfine interaction as well as a comparison between organic and inorganic density of states and their type of existence at the Fermi level for conductors. Organic based magnets provide optimal conditions, from their pi-pi* splittings, to allow for photomagnetic and other novel phenomena not observed easily with inorganic materials. Results from our work on the room temperature Mn(II)chalcogenocarboxylate system will be discussed and indicate promise toward an organic based spin-injector. Overall, it has been shown that organics do and will play a large role in standard electronics, such that the addition of the spin degree of freedom from magnetic organic-based materials is inevitable.

10:00am **MI+EM-ThM7 Characterization of Ferromagnetic Metal/Organic Semiconductor Interfaces in Organic Spin Valves**, ***G.J. Szulczewski***, *J. Tang, W. Xu, L. Navar, R. Schad, A. Gupta,* University of Alabama

In the past several years there has been a growing interest in combining ferromagnetic and molecular materials to create organic-based spintronic devices, such as light-emitting diodes and spin-valves. In a vertical device

structure one of the processing steps is deposition of a ferromagnetic thin film onto an organic layer. In order to understand the electronic and magnetic nature of these interfaces we have vapor deposited thin films of Co, Fe, and Ni onto 100 nm films of pi-conjugated organic molecules. The molecules studied were aluminum tris(quinolate), tetraphenylporphyrin, phthalocyanine, and perylenetetracarboxylic dianhydride. Using magnetometry techniques the temperature dependent saturation magnetization and coercivity was measured as a function of ferromagnetic metal film thickness. In general several trends were observed. First, in thin ferromagnetic layers less than 3 nm the films did not exhibit a magnetic moment. Second, the Co, Fe and Ni films exhibit ferromagnetic behavior above 3 nm with a coercivity much larger than would be observed for sputter films on Si wafers. Third, the coercivity of Ni and Co films depends on the roughness and functional groups in the molecules more than Fe films, which is attributed to the higher chemical reactivity of Fe atoms. Based on these observations we choose Co films as the top electrode in the fabrication of organic-spin valves because it less reactive than Fe and has a higher coercivity than Ni. Spin-valves were made by depositing Co films onto porphyrin and phthalocyanine organic layers which were first deposited onto La@sub0.67@Sr@sub0.33@MnO@sub3@ substrates. At 80 K the magnetoresistance was measured to be about 20%. The magnetoresistance was found to decrease rapidly with both increasing temperature and voltage bias. The role of the ferromagnetic/organic interfaces on spin-valve performance will be discussed.

10:20am **MI+EM-ThM8 Interface Magnetization Precession and Switching in Fe/AlGaAs (001)*, G. Luepke,*** College of William and Mary **INVITED**

Efficient spin-polarized electron injection is a prerequisite for the development of semiconductor-based spintronic devices. Several recent experimental studies have reported successful electrical spin injection from ferromagnetic metals into III-V semiconductor light emitting diodes (LEDs) using a variety of tunnel barriers. However, further improvement requires a detailed understanding of interface magnetic properties.@footnote 1@ In this study, we have measured the reversal process of the Fe interface layer magnetization in Fe/AlGaAs heterostructures using magnetization-induced second harmonic generation (MSHG), and compared it with the bulk magnetization as obtained from magneto-optic Kerr effect (MOKE).@footnote 2@ The switching characteristics are distinctly different - single step switching occurs at the interface layer, while two-jump switching occurs in the bulk Fe for the magnetic field orientations employed. The different switching processes lead to a deviation angle of 40-85o between interface and bulk magnetization. This behavior may result from reduced exchange interaction in the direction normal to the interface and different magnetic anisotropies at the heterojunction. To study the magnetization dynamics at the interface, we use time-resolved MSHG to investigate the coherent magnetization precession. The results are directly compared with the bulk spin precession as obtained from time-resolved MOKE.@footnoe 3@ The different switching characteristics are further revealed in the precession dynamics at low fields. The field dependence of precession frequency provides a quantitative analysis of magnetic anisotropy and magnetostatic energy of the interface layer. @FootnoteText@ @footnote 1@J. M. D. Teresa et al., Science 286, 507 (1999); B. T. Jonker, Proc. IEEE 91, 727 (2003). @footnote 2@H.B. Zhao et al., Phys. Rev. Lett. 95, 137202 (2005). @footnote 3@H.B. Zhao et al., Appl. Phys. Lett. 86, 152512 (2005).

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