SYMPOSIUM II

Fabrication and Characterization Methods for Novel Magnetic Nanostructures

November 27 - 30, 2005

Chairs

Yimei Zhu
Center for Functional Nanomaterials
Brookhaven National Laboratory
Upton, NY 11973
631-344-3057

Kornelius Nielsch
Max-Planck-Institute
Weinberg 2
Halle, 06120 Germany
49-345-5582-902

Mark Freeman
Dept. of Physics
University of Alberta
Edmonton, AB
T6G 2J1 Canada
780-492-4130

Saskia F. Fischer
Dept. of Matls Science & Nanoelectronics
Ruhr University of Bochum
Bldg. IC 2/33
Bochum, D-44780 Germany
49-234-32-25760

Symposium Support

†JEOL USA, Inc.

†2005 Fall Exhibitor

* Invited paper

TUTORIAL

FTII: Novel Characterization Methods for Magnetic Nanostructures
Sunday, November 27, 2005
1:30 PM - 5:00 PM
Room 204 (Hynes)

The tutorial will focus on nanoscale magnetic structure characterization using transmission electron microscopy, magnetic force microscopy, and spin-polarized scanning tunneling microscopy. In the electron scattering area of the tutorial, principles and applications of various qualitative and quantitative magnetic imaging and phase-retrieval methods, including in-situ Lorentz microscopy, off-axis electron holography, and the newly developed electron-optical transport-of-intensity approach will be covered. The separation of electrostatic and magnetostatic potentials to map local magnetization distribution will be discussed. Image simulation will be used to compare experiments with calculations. In the tutorial's scanning probe section, two methods will be introduced. After a short overview of magnetic force microscopy and its history, a detailed discussion on instrumentation as well as magnetic tip preparation will be given. The inversion problem and solutions to quantitative magnetic force microscopy will be presented, and the limits of lateral resolution will be addressed. The tutorial will conclude with the introduction of spin-polarized scanning tunneling microscopy. The advantages and limitations of the three fundamental imaging modes will be discussed. The abilities of this new technique to image ferromagnets and antiferromagnets with atomic resolution will be demonstrated, and the future potential of the method will be highlighted.

A wide range of case studies to demonstrate the merits of the method and the challenges we face will be provided. The tutorial will give attendees a fundamental background on each method, their strengths and drawbacks, as well as their complementarity with other modern tools for characterizing magnetic materials such as neutrons and synchrotron X-rays, the current state of the art, and the future.

Instructors:
Yimei Zhu
Brookhaven National Laboratory

Wulf Wulfhekel
Max-Plank-Institut fuer Mikrostrukturphysik, Germany

SESSION II1: Novel Characterization Techniques for Magnetic Nanostructures (1)
Chairs: Mark Freemann and Yimei Zhu
Monday Morning, November 28, 2005
Room 312 (Hynes)

8:30 AM *II1.1
The application of microscopy to the determination of structure-property relationships in nanoscale magnetic materials. Amanda Petford-Long, Argonne National Laboratory, Argonne, Illinois.

The properties of nanoscale magnetic materials depend critically on their microstructure and composition, with variations on the atomic scale leading to variations in properties. Of particular interest for technological applications in information storage systems are magnetic structures composed of thin layers, such as spin tunnel junctions spin-valves. In such devices the microstructure and chemical profile across the layers are critical in determining the magnetic and transport properties, and therefore need to be critically controlled. In addition, the films currently being developed for device applications are mainly polycrystalline, which makes it more complicated to disentangle the effects of different microstructural parameters than would be the case for single crystal epitaxial films. We have applied high resolution electron microscopy (HREM), transmission electron microscopy (TEM) chemical mapping and three-dimensional atom probe (3DAP) analysis to a range of information storage materials including spin-dependent tunnel junctions, multilayers composed of materials suitable for spin-valves and magnetic nanoparticles and this paper will present some of these results. For example, changes in the TMR ratio and RA product for unpinned tunnel junction structures have been shown by a combination of 3DAP and HREM to be the result of a change in the morphology and composition of the tunnel barrier, with underoxidised and unannealed fully-oxidised barriers being highly non-uniform.

9:00 AM *II1.2
Domain Wall Structure Modification by Gentle Ion Irradiation and Patterning. John N. Chapman, Stephen McVitie, Aurelie Gentils, Damien McGrouther and Yingang Wang; Physics and Astronomy, University of Glasgow, Glasgow, Lanarkshire, United Kingdom.

The structure of domain walls in magnetic thin films and multilayers can be changed by gentle ion irradiation and/or by patterning the films into wires and elements, factors that are exploitable in magnetic devices. Thus highly localised irradiation with Ga ions can be used to determine the location of domain walls in a Ta/CoFe/Ta trilayer or to introduce local regions of in-plane magnetisation in an otherwise perpendicularly magnetised Co/Pt multilayer. We have studied these effects, and their origin, using a combination of magnetic imaging (transmission Lorentz microscopy) and nanoanalytical electron microscopy. Spectrum imaging using electron energy loss spectroscopy shows that, with the ion doses used, no material is removed, rather the effect of the ions is to cause modest elemental mixing in the vicinity of the interfaces. Such effects can be confined to regions <40 nm wide. In the case of the Ta/CoFe/Ta trilayer, periodic reversals of magnetisation on a 100 nm pitch can be achieved, something that is not possible without local property change due to the intrinsic domain wall width and interactions between neighbouring walls in an unmodified film. For Co/Pt multilayers, interfacial mixing is responsible for a local loss of perpendicular anisotropy and here in-plane magnetised lines 50 nm wide can be formed in a variety of geometric patterns. Modest applied fields in the plane of the specimen can be used to control the magnetisation in the lines whilst the perpendicular magnetisation in the surrounding regions remains unaffected. Domain wall structures in sub-micron wide magnetic wires also differ from their counterparts in continuous films, whilst further modification takes place if constrictions are present in the wires. As before the detailed magnetisation distribution has been determined by high-resolution magnetic imaging. Thus reversal of a magnetic wire frequently involves the propagation of a small reversing domain packet along the length of the wire. Such reversing packets can extend over distances greater than the width of the wire and they are frequently asymmetric in form, a consequence of the way reversal was initiated at one end of the wire. Depending on the wire width and thickness, magnetic vortex structures frequently form in the domain packets and strong interactions with the constrictions can be observed. Examples of these and simpler structures in permalloy wires <500 nm wide will be presented.

9:30 AM *II1.3
Induction Mapping of Sub-10-nm Magnetic Nanocrystals Using Off-Axis Electron Holography. Rafal Dunin-Borkowski[1,2], Takeshi Kasama[2,1], Yanna Antypas[1] and Edward Simpson[1]; [1]Department of Materials Science and Metallurgy, University of Cambridge, Cambridge, United Kingdom; [2]RIKEN, Wako, Saitama, Japan.

Off-axis electron holography provides a powerful tool for mapping the magnetic induction inside nanoscale materials and devices. However, the characterization of magnetic fields inside nanoparticles that have dimensions of below 10 nm is highly challenging, firstly because the weak magnetic signal of interest must be separated from the much larger mean inner potential contribution to the phase shift, secondly because the observations approach the spatial resolution of electron microscope lenses that allow samples to be imaged in magnetic-field-free conditions, and thirdly because many sub-10-nm particles are superparamagnetic at room temperature. Here, we demonstrate the successful characterization of the magnetic induction in sub-10-nm crystals of a wide variety of ferromagnetic and ferrimagnetic materials. We compare results obtained from isolated crystals with the more complicated magnetic microstructures seen in one- and two-dimensional arrays of similar nanoparticles. We correlate our results, which are obtained between room temperature and liquid helium temperature, with the three-dimensional morphologies of the same crystals characterized using high-angle annular dark field electron tomography, as well as with micromagnetic simulations. We discuss the spatial and phase resolution that can be achieved in our experiments, and prospects for improving such measurements in the future.

10:30 AM *II1.4
X-Ray Studies of the Dynamic Magnetic Nanoworld. Joachim Stohr, Stanford University, Stanford, California.

In an era where many powerful techniques can provide images of magnetic nanostructures, I will concentrate on the unique capabilities provided by polarized soft x-rays: (i) the short wavelength allows seeing and studying individual nano-objects, (ii) the tunable photon energy provides access to resonance effects that are elemental and chemical state specific and exhibit large cross sections, (iii) the high photon beam brightness provides sensitivity to a small number of atoms, (iv) the x-ray polarization allows the separation of charge and spin phenomena, and (v) the pulsed nature of synchrotron sources allows time-dependent studies with tens of picoseconds resolution. I

will present several examples where x-rays have provided unique information on magnetic nanostructures that cannot be obtained by any other technique. I will also address the important correlation between space and time phenomena - the smaller the faster. I will emphasize that technological advances require exploration of both the ultra-small and ultra-fast domains. This exploration is the real strength of x-rays and the basis for revolutionary developments in the future.

11:00 AM *II1.5
Magnetic Hysteresis Studies of Nano-scale Co Elements Using Electron Holography. Hao Hu[1], Hua Wang[2], Nipun Agarwal[2], David J. Smith[1] and Martha R. McCartney[1]; [1]Department of Physics and Astronomy, Arizona State University, Tempe, Arizona; [2]Department of Chemical and Materials Engineering, Arizona State University, Tempe, Arizona.

Off-axis electron holography has been used to characterize the switching behavior of nano-scale magnetic elements with a wide variety of shapes including squares, rectanges, ellipses, rings and disks. The cobalt elements were fabricated on silicon nitride window membranes using electron beam lithography. The dimensions of the elements were varied, for example circular rings had 400nm outer diameter and inner diameters varying from 250nm to 50nm. The electron holography experiments were performed in-situ in a transmission electron microscope equipped with a Lorentz lens for imaging and using a weakly excited objective lens to provide the external field for the hysteresis studies. Results to be shown will include studies of the dependence of the switching behavior of rings on the ratio of the inner to outer diameters. We will also present results from slotted disks ('Pac-man'), and slotted rings. This latter shape displayed two well-defined domain configurations with a small switching fields range (40 Oe) to convert from one configuration to the other. In addition, small fringing fields outside the elements would allow high-density packing for MRAM applications.

11:30 AM *II1.6
Micromagnetics at the Nanoscale. E. Dan Dahlberg[1], George Skidmore[4], Andrew Kunz[3], Pete Eames[2], Hao Wang[1] and Charles Campbell[1]; [1]Physics, University of Minnesota, Minneapolis, Minnesota; [2]NonVolatile Electronics, Eden Prarie, Minnesota; [3]Physics, Marquette University, Milwaukee, Wisconsin; [4]Zyvex LLC, Richardson, Texas.

There has been a renaissance in magnetism in the last decade or so. In the area of micromagnetics (although in the modern context it should be nanomagnetics), major breakthroughs have resulted from the development of new imaging techniques. The magnetic force microscope (MFM), a variant of the atomic force microscope, has emerged as a powerful tool. One frontier in magnetism being pushed back is our understanding of domain structures and the magnetization reversal in nanometer-sized particles. We have combined high resolution MFM (30 nm) [1] with Landau Lifschitz Gilbert (LLG) simulations to investigate the magnetic domain structures in cylindrical Ni dots with diameters ranging from 40 nm to 1700 nm [2] and various thicknesses up to 200 nm. The Ni as deposited had a perpendicular anisotropy energy minimum, i.e., the easy axis of the dots was collinear with the cylinder axis. In unpatterned films this perpendicular anisotropy induced stripe domains with a period of approximately 200 nm. In the particles, the addition of the perpendicular anisotropy allows for multiple distinct domain states to be observed at remanence. Statistics of the states were determined using the MFM data from over 3000 images of dots. The excellent agreement between the MFM images and the LLG simulations provide confidence in the LLG determined magnetic structure beyond the MFM's resolution. At the end of the presentation I will briefly mention our very recent discovery of vortex-antivortex pair creation and annihilation in the magnetic reversal of stadia shaped particles. [1.] George D. Skidmore, Sheryl Foss, and E. Dan Dahlberg, Appl. Phys. Lett. 71, 3293 (1997). [2.] George D. Skidmore, Andrew Kunz, C. E. Campbell, and E. Dan. Dahlberg, Phys. Rev. B 70, 012410 (2004). Supported by ONR and the University of Minnesota MRSEC.

SESSION II2: Novel Characterization Techniques for Magnetic Nanostructures (2)
Chair: John Chapman
Monday Afternoon, November 28, 2005
Room 312 (Hynes)

1:30 PM II2.1
Broadband ferromagnetic resonance in circulating magnetization states. Xiaobin Zhu[1], Zhigang Liu[1], Vitali Metlushko[2], Peter Grutter[3] and Mark R Freeman[1]; [1]Department of Physics, University of Alberta, Edmonton, Alberta, Canada; [2]Department of Electrical and Computer Engineering, University of Illinois at Chicago, Chicago, Illinois; [3]Physics Department, McGill University, Montreal, Quebec, Canada.

The spin dynamics of the remanent states of circulating magnetization in Permalloy rings and disks is studied by broadband ferromagnetic resonance [1,2]. If a transient pulse field is applied perpendicularly to the disk (ring) plane, the rotationally symmetric modes are preferentially observed. When the pulse field is applied in the plane of the disk (ring) plane, higher-order azimuthal modes are excited, as the initial torque produced by the transient field is angularly antisymmetric. A striking difference between the ring and disk structures is that the degeneracy of the lowest order antisymmetric modes is lifted for the disk, by the presence of the vortex core in the magnetization [3]. Through comparing experimental results with micromagnetic modeling, we find that the gyrotropic motion of the vortex core causes additional splitting of the resonance frequencies of these modes. This has also recently been observed through time-resolved imaging of disk structures [4]. [1] X. Zhu, et al, Phys. Rev. B, 71, 180408 (R) (2005). [2] X. Zhu, et al., Appl. Phys. Lett. 87, 262502 (2005). [3] Ivanov and Zaspel Phys. Rev. Lett., 94,027205 (2005). [4] J. P. Park, and P. A. Crowell, to be published.

1:45 PM II2.2
ESR study of magnetic nanoparticles: between the ferro- and paramagnetism. Natalia Noginova[1], Feng Chen[1], Tracee Harris[1], E. Giannelis[2], A. Bourlinos[2] and V. A. Atsarkin[3]; [1]NSU, Norfolk, Virginia; [2]Cornell University, Ithaca, New York; [3]IRE, Moscow, Russian Federation.

Magnetic nanoparticles of gamma-Fe2O3 coated by organic molecules and suspended in liquid and solid matrices, as well as non-diluted magnetic fluid have been studied by ESR in the dependence on temperature and relative concentration. The ESR spectrum demonstrates an interesting double feature shape, with narrow peak at g=2 growing in intensity with increase in temperature. Angular dependence of the ESR signal in field cooled samples unambigously points to the dominating uniaxial magnetic anisotropy of the nanoparticles, suggesting a strong surface effect. The interpretation based on the FMR equations with account made for thermal fluctuations of the magnetic moment is compared with "paramagnetic" model suggesting a discrete energy spectrum of the lowest high-spin multiplet. Consideration of the superparamagnetic nanoparticles as intermediate between paramagnetic and ferromagnetic entities allows us to explain most of the obtained experimental results and estimate parameters of the magnetization, particle interactions and magnetization dynamics.

2:00 PM II2.3
Atomic Scale Characterization of the Fe3O4/SrTiO3 Interface. Lianfeng Fu[1], Sascha Welz[1], Nigel D. Browning[1,2], Darshan C. Kundaliya[3], Satish B. Ogale[3] and Thirumalai V. Venkatesan[3]; [1]Chemical Engineering and Materials Science, University of California at Davis, Davis, California; [2]National Center for Electron Microscopy, Lawrence Berkeley National Laboratory, Berkeley, California; [3]Center for Superconductivity Research, University of Maryland, College Park, Maryland.

Thin films of Fe3O4 have been extensively studied for their interesting inverse spinel structure and unique magnetic properties. Recently, there is a growing interest in their magnetotransport properties and therefore potential applications in magnetoelectronic devices. In this regard, the structural and chemical qualities of the magnetic/ semiconductor structures play an important role in maintaining the spin character of the electron and its transport across the interfaces. To fully develop the Fe3O4 thin films for magnetic applications, it is therefore necessary to characterize and understand the properties of the heterointerfaces as a function of the growth conditions. In the present study, we have performed structural and chemical characterization of Fe3O4/SrTiO3 heterointerface using high resolution transmission electron microscopy (HRTEM), scanning transmission electron microscopy (STEM) Z-contrast imaging, and electron energy loss spectroscopy (EELS). The experiments have been performed on a 200kV Schottky field-emission gun FEI Tecnai F20 equipped with a high resolution EEL spectrometer and monochromator system. The Fe3O4 films in this study were prepared by pulsed excimer laser deposition using a-Fe2O3 as the target. The films were grown on a <100>-oriented 0.5% Nb-doped SrTiO3 single crystal substrate kept at 350 degrees in a vacuum of better than 1E-6 Torr. Following the deposition, the films were cooled to room temperature at a rate of 10 degrees/min. HRTEM and STEM Z-contrast imaging of the heterointerface shows that a 100-nm Fe3O4 film was epitaxially grown on a SrTiO3 single crystal substrate with the orientation relationship of Fe3O4 (100)// SrTiO3(100). To accommodate the lattice misfit strain between Fe3O4 (a=8.396 angstroms) and SrTiO3 (a=3.905 angstroms), some misfit dislocations occur in the Fe3O4 film near the heterointerface. Line scanning EELS analysis at Ti L2,3-edge, O K-edge, and Fe L2,3-edge near the

interface indicates Ti and Fe atoms inter-diffuse across the interface. The diffusion depths of Ti and Fe atoms are 5+/-1 nm and 3+/-1 nm respectively. Core-loss EELS analysis at Nb L2,3-edge across the interface shows that Nb has depleted at the Fe3O4/ SrTiO3 interface. However, EELS analysis at Sr L2,3-edge indicates that Sr does not diffuse across the interface. These chemical changes across the heterointerface result into the change of electronic structure and magnetic moments, and therefore may affect the electron spin polarization and spin transport performance. This work was performed at the National Center for Electron Microscopy, LBNL. It was supported by the U.S. DOE under Contract No. DE-AC03-76SF00098, and by NSF on Grant No. DMR0205949 and NSF-MRSEC on grant No. DMR-00-80008.

2:15 PM II2.4
Energy barrier to magnetic vortex nucleation. June W Lau[1,2], Jan K Bording[1], Marco Beleggia[1], Gertrude F Neumark[2] and Yimei Zhu[1]; [1]Center for Functional Nanomaterials, Brookhaven National Laboratory, Upton, New York; [2]Applied Physics and Applied Mathematics, Columbia University, New York, New York.

Understanding magnetization reversal dynamics in patterned ferromagnetic thin film systems is an integral part to our information technology today. While micromagnetics simulators can correctly locate the minimum energy state as well as a probable path to reach it, they usually do not calculate the energy barriers associated with such transitions. Well-established bulk techniques for measuring magnetic viscosity have provided valuable insights on the kinetics of a combination of reversal mechanisms.[1] However, since nucleation of the reversed domains and their subsequent propagation occur simultaneously in the bulk, these events are difficult to decouple and analyze in practice. In the present study, we correlate bulk properties with discrete events observed via $in-situ$magnetization relaxation dynamics with Lorentz transmission electron microscopy (TEM).[2] In an array of micron-sized square Permalloy elements, we have attributed a specific type of domain state transformation to a single mechanism: vortex nucleation. This unique exclusion of other switching mechanisms enables us to study magnetic vortex nucleation as a stand-alone phenomenon. We found that nucleations are thermally activated events. Using the Arrhenius-Néel model, we measured the energy barrier to vortex nucleation and a clear dependence on the applied field is observed. 1. S. B. Oseroff, D. Franks, V. M. Tobin, and S. Schultz, "Magnetization Time Decay In Particulate Media," IEEE Trans. Magn. 23 (5), 2871-2873 (1987). 2. J. W. Lau, M. Beleggia, M. A. Schofield, G. F. Neumark, and Y. Zhu, "Direct correlation of reversal rate dynamics to domain configurations in micron-sized permalloy elements," J. Appl. Phys. 97 (10), 10E702 (2005).

SESSION II3: Patterned and Ultrathin Magnetic Films
Chair: Fernando Castano
Monday Afternoon, November 28, 2005
Room 312 (Hynes)

3:30 PM *II3.1
The Grand Challenges in Nanomagnetism. Samuel D. Bader, [1]Materials Science Division, Argonne National Laboratory, Argonne, Illinois; [2]Center for Nanoscale Materials, Argonne National Laboratory, Argonne, Illinois.

Magnetism is one of the oldest fields in science but it is also at the forefront of the nanotechnology era. This talk provides a modern experimental perspective on recent issues and challenges in the field. Examples to create, explore and understand new nanomagnetic materials and phenomena are provided, including novel assembly routes assisted by soft matter templates and bio-containment, and fundamentals of confined spin states, ultra-fast spin dynamics, and novel spin transport [1] in metallic systems. Work supported by DOE-BES, under contract W-31-109-ENG-38. 1. Spin Injection, Diffusion, and Detection in Lateral Spin-Valves, Y. Ji, A. Hoffmann, J. S. Jiang, and S. D. Bader, Appl. Phys. Lett. 85, 6218 (2004).

4:00 PM II3.2
The Equivalent Ellipsoid for Uniformly Magnetized Bodies. Marco Beleggia[1], Marc De Graef[2] and Yonko Millev[3]; [1]Brookhaven National Laboratory, Upton, New York; [2]Materials Science and Engineering, Carnegie Mellon University, Pittsburgh, Pennsylvania; [3]American Physical Society, Ridge, New York.

There is a general theorem in micromagnetics, according to which, under rather relaxed conditions, a body of arbitrary shape is equivalent to an ellipsoid, both of them uniformly magnetized and with the same volume. The concept of the equivalent ellipsoid is intuitively very satisfactory, but it is not straightforward to actually find the equivalent ellipsoid for non-ellipsoidal shapes. The expectation that some symmetrical ferromagnetic bodies would closely resemble an actual ellipsoid may, in fact, be very misleading. For instance, a right circular cylinder, like an ellipsoid of revolution, exhibits axial symmetry. The shape of such a cylinder is determined solely by the ratio of thickness to diameter, while for an ellipsoid of revolution (a spheroid) the shape is completely specified by the ratio of its axes. It has been often assumed that a cylinder has the same demagnetization factors as an ellipsoid of revolution with equal aspect ratio. It turns out that this leads to large interpretational and quantitative errors in the context of very thin magnetic platelets (disks), or even larger errors for long cylinders (rods). The equivalent ellipsoid for magnetized bodies of arbitrary shape is determined by imposing the equality between the demagnetization factors of the two shapes of equal volume. We will show that the intuitive criteria for mapping the factors between different shapes, for example the equal aspect ratio in the case of disks vs. oblate ellipsoids, often result in large errors. For a generic shape, or for some particular symmetric shapes, such as rectangular rings, intuitive criteria are not available, and a theoretical method is required in order to determine the equivalent ellipsoid. Explicit examples of comparisons between a disk (and a ring) and an oblate or prolate ellipsoid, a cylinder with elliptical cross section and a triaxial ellipsoid, and a generic prism and a triaxial ellipsoid will be presented and discussed. In this contribution, we report on the exact determination of the equivalent ellipsoid for several important shapes. The advance presented in this paper is based on a comparison of the long-known formulas for the ellipsoid demagnetization factors, with the recently obtained results for the factors of a large family of shapes by means of a Fourier-space approach.

4:15 PM *II3.3
Body-Centered-Cubic Ni and Its Magnetic Properties. Xiaofeng Jin, Department of Physics, Fudan University, Shanghai, China.

The body-centered-cubic (bcc) phase of Ni, which does not exist in nature, has been achieved as a thin film on GaAs(001) at 170 K via molecular beam epitaxy. The bcc Ni is ferromagnetic with a Curie temperature of 456 K and possesses a magnetic moment of 0.52 uB/atom. The cubic magnetocrystalline anisotropy of bcc Ni is determined to be +4.0x10 5 ergs cm-3, as opposed to-5.7x10 4 ergs cm-3 for the naturally occurring face-centered-cubic (fcc) Ni. This sharp contrast in the magnetic anisotropy is attributed to the different electronic band structures between bcc Ni and fcc Ni, which are determined using angle-resolved photoemission with synchrotron radiation. [1] PRL 94, 137210 (2005) [2] PRL 94, 027201 (2005) [3] PRL 93, 117205 (2004)

4:45 PM II3.4
Nano-scale Magnetic Domain Structures in Fe/NiO/Fe(100) Trilayers. Andreas K. Schmid[1], N. Rougemaille[1], M. Portalupi[1,2], A. Lanzara[3,1], P. Biagioni[2], A. Brambilla[2], M. Finazzi[2] and L. Duo[2]; [1]Lawrence Berkeley Lab, Berkeley, California; [2]Dipartimento di Fisica, Politecnico di Milano, Milano, Italy; [3]Dept. of Physics, University of California, Berkeley, California.

An interesting type of domain microstructures can be observed when ferromagnetic films interact with antiferromagnets. In the capping layer of Fe/NiO/Fe(100) trilayer structures, we observed extremely delicate magnetic domain patterns by spin-polarized low-energy electron microscopy (SPLEEM). The patterns include many topologically unconnected domains (bubbles) and narrow elongated domains (channels), and the domain wall widths are roughly one order of magnitude smaller than what is observed in Fe layers grown on non-magnetic substrates. The extremely small width of domain walls in the top Fe-layer can be understood as a consequence of exchange coupling between ferromagnetic and antiferromagnetic layers [1]. In pure ferromagnets, domain wall width is often relatively large, because it is governed by the competition between the stronger exchange interaction (favoring greater width) and normally relatively weak anisotropy (favoring smaller width). The situation is different at interfaces with antiferromagnets. Frustrated exchange forces at such interfaces also favor narrow domain walls, and can be far greater than anisotropy forces. This can lead to domain wall widths that are narrower than conventional domain walls by a substantial factor [1]. In light of potential data-storage applications, it is interesting to note that the stability of our observed nanodomains coincides with perfect remanence. Magneto-optic Kerr measurements [3] indicate that remanence of the films can be as large as saturation, which indicates that remanent single-domain states spanning the sample are possible, and one might envision to write individual, stable, bubble-nanodomains into such trilayer structures. [1] A.I. Morosov and A.S. Sigov, Physics of the Solid State 46, 395 (2004) [2] P. Biagioni, A. Brambilla, M. Portalupi, N. Rougemaille, A. K. Schmid, A. Lanzara, P. Vavassori, M. Zani, M. Finazzi, L. Duo, F. Ciccacci, J. Magn. Magn. Mat. 290-291, 153 (2005)

SESSION II4: Magnetic Semiconductors (1)
Chairs: Ramesh Chandra Budhani and Saskia Fischer
Tuesday Morning, November 29, 2005
Room 312 (Hynes)

8:30 AM *II4.1
High Tc Wide Band-Gap TM-Doped Oxides: How Are They Ferromagnetic? Kannan M. Krishnan[1], K. A. Griffin[1], A. B. Pakhomov[1], M. Varela[2] and S. J. Pennycook[2]; [1]Department of Materials Science, University of Washington, Seattle, Washington; [2]Solid State Division, Oak Ridge National Laboratory, Oak Ridge, Tennessee.

For effective spin injection in spin-electronics devices and to overcome the related problem of impedance mismatch a number of new materials are being developed. Mn-doped, III-arsenides are proven ferromagnetic semiconductors where the ferromagnetism is known to be carrier-mediated and can be controlled by doping or injection of free carriers. The Curie temperature of such dilute magnetic semiconductors (DMS) is well below room temperature and this has prompted the investigation of alternative TM-doped, wide band-gap oxides and nitrides exhibiting room-temperature ferromagnetism. However, the mechanism of ferromagnetism in the latter materials is very poorly understood. In this talk we will present our recent results on Co-TiO2 [1] and Cr- ZnO [2], showing that the observed room temperature ferromagnetism is not carrier mediated, but co-exists with the dielectric state, and suggest that these materials are better referred to as dilute magnetic dielectrics (DMD). The films were grown epitaxially on appropriate, lattice-matched substrates and subsequently characterized by x-ray diffraction, high-resolution transmission electron microscopy, Rutherford back scattering and near-edge x-ray absorption fine structure measurements. As grown, the films are highly insulating ferromagnets, with a spontaneous magnetic moment that increases substantially on vacuum annealing to a value greater than 1 Bohr magneton per TM-ion at room temperature. Recent results, combining atomic resolution electron energy-loss spectroscopy and z-contrast imaging using angstrom-size probes, show that the spatial distribution of cobalt in anatase is critically dependent on the overall crystal quality and the annealing history. This is also reflected in the magnitude of the magnetic moment per cobalt ion. The important role of oxygen vacancies, that occur naturally to compensate the charge of Co 2 when it substitutes for Ti 4 in the anatase lattice (in Cr:ZnO oxygen vacancy concentration was controlled by sputtering conditions), and their subsequent trapping on heat treatment, similar to mixed valance in doped-manganites may provide a plausible explanation for the ferromagnetism in these DMD materials [3]. [1] K.A. Griffin, A.B. Pakhomov, C.M. Wang, S.M. Heald and Kannan M. Krishnan, Phys. Rev. Lett., 94, 157204 (2005). [2]2. B. K. Roberts, A.B. Pakhomov and Kannan M. Krishnan, J. Appl. Phys, 97, 10D310 (2005). [3] This work is supported by NSF/ECS#0224138 and by the Campbell Endowment at UW. KAG is also partially supported by a UW-PNNL-JIN fellowship.

9:00 AM II4.2
Carrier Controlled Ferromagnetism in Anatase Co Doped TiO_2. Taro Hitosugi[1,2], Go Kinoda[2], Yukio Yamamoto[2], Yasushi Hirose[2], Yutaka Furubayashi[2], Kazuhisa Inaba[2,3], Toshihiro Shimada[1,2] and Tetsuya Hasegawa[1,2]; [1]Dept. of Chemistry, University of Tokyo, Bunkyo, Tokyo, Japan; [2]KAST, Kawasaki, Japan; [3]Materials and Structures Laboratory, Tokyo Inst. Tech, Yokohama, Japan.

The magnetic moment and coercive force of ferromagnetic anatase Co:TiO_2 epitaxial thin film are enhanced and controlled by carrier doping. The carrier density can be varied independent of the Co concentration by Nb doping, from 1.0×10^{20} cm^{-3} to 2.6×10^{21} cm^{-3}. The $Ti_{0.95-x}Co_{0.05}Nb_xO_2$ (x = 0 - 0.2) films show ferromagnetism at room temperature, and Hall measurement revealed that these materials are degenerate semiconductor. The film with Nb content x = 0.06 showed Faraday rotation angle of 1.5×10^4 deg/cm at wavelength of 400 nm under magnetic field of 0.5 T. Anomalous Hall effect is observed in magnetotransport measurements, showing that the charge carriers are spin polarized, revealing the magnetic interaction between itinerant electrons and localized Co spins. The carrier dependent ferromagnetic properties of the synthesized films will be argued in comparison with those of carrier controlled anatase Fe:TiO_2.

9:15 AM II4.3
Observation of Spin Polarisation in a Diluted System: Co-Doped $La_{0.5}Sr_{0.5}TiO_3$ Magnetic Oxide. Gervasi Herranz[1], Rocio Ranchal[2], E. Tafra[3], Mario Basletic[3], Karim Bouzehouane[1], Manuel Bibes[4], Sabrina Guyard[1], Amir Hamzic[3], C. Pascanut[5], P. Berthet[5], N. Dragoe[5], Eric Jacquet[1], Jean Luc Maurice[1], Agnes Barthelemy[1], Jean-Pierre Contour[1] and Albert Fert[1]; [1]UMP CNRS/Thales, Palaiseau, France; [2]Depto. Fisica de Materiales (UCM), Madrid, Spain; [3]Dep. of Physics, Fac. of Science (U. of Zagreb), Zagreb, Croatia; [4]IEF, Univ. Paris-Sud, Orsay, France; [5]Lab. de Physico-Chimie de l Etat Solide, Univ. Paris-Sud, Orsay, France.

Spintronics applications require the use of highly spin-polarized current sources. With this purpose in mind, half-metallic ferromagnets, such as various magnetic oxides, have been integrated in devices and high magnetoresistance values have been recorded. However, the Curie temperatures of the involved materials are too close to room temperature for technological applications. New approaches to achieve high spin-polarized sources at high temperatures involve doping host materials with magnetic ions, as in diluted magnetic semiconductors (DMS). We have followed this approach by doping metallic non-magnetic $La_{0.5}Sr_{0.5}TiO_3$ with Co (LSTO(Co)) in the range 0 - 3 %. The samples were grown by pulsed laser deposition with a frequency-tripled Nd:YAG laser (λ = 355 nm) on $SrTiO_3$ (STO) (001) and $LaAlO_3$ (LAO) (001) substrates. X-ray diffraction structural characterization shows that films are epitaxial and without parasitic phases. RHEED and AFM measurements show that the growth is 3D for samples grown on LAO, while it is 2D on STO substrates, with very low roughness values [1]. No Co-clusters are observed neither by means of high-resolution transmission electron microscopy (HRTEM), electron energy-loss spectroscopy (EELS) or Auger spectroscopy. The dependence of the resistivity and the magnetization on growth parameters such as oxygen growth pressure, film thickness and Co-content have been carefully analyzed. The films show magnetic hysteresis cycles at room temperature and the observed magnetic anisotropy supports an intrinsic origin for ferromagnetism. The largest ferromagnetic signals are measured in films grown at low oxygen pressures ($< 10^{-5}$ mtorr). The main result of the present work is the determination of a spin polarization in a diluted magnetic system. LSTO(Co 1,5%)/STO/Co and LSTO(Co 1,5%)/LAO/Co junctions have been fabricated either by optical lithography or by real-time resistance-controlled nanoindentation with a conductive AFM tip. Tunnel magnetoresistance values (TMR = (Rp-Rap)/Rap, Rp and Rap are the resistances in parallel and anti-parallel configurations, respectively) up to 20% are measured at low temperature. Applying Jullière's model, this implies a spin polarization of at least $P_{LSTO(Co)} \approx$ 50 % calculated from the highest TMR value. The analysis of the temperature dependence of the TMR reveals a fast decrease with temperature and the TMR becomes vanishingly small at T > 200 K. The origin of this TMR suppression remains to be clarified. The bias dependence of the TMR will be discussed. The present work represents an important step towards the understanding and application of the DMS approach to spintronic devices using complex oxide materials. The present work represents an important step towards the understanding and application of the DMS approach to spintronic devices using complex oxide materials. [1] R. Ranchal et al., to be published in J. of App. Phys.

9:30 AM II4.4
ZnO based dilute magnetic semiconductors: Origin of room temperature ferromagnetism. Shivaraman Ramachandran[1], Ashutosh Tiwari[1], John Prater[2,1] and Jagdish Narayan[1]; [1]NCSU, Raleigh, North Carolina; [2]Army Research Office, Raleigh, North Carolina.

The exciting possibility of combining the charge and spin of an electron to realize novel spintronic devices has attracted widespread attention recently. Transition metal doped ZnO has already proved to be a potential candidate as a diluted magnetic semiconductor to achieve this end[1]. Oxide based semiconductors, particularly, Zinc Oxide have been found to show a varied range of properties depending on the processing conditions and whether the material is in the bulk or thin film form. In this work, we will present detailed characterization of Zn (M) O [M = Mn, V, Co] thin films grown on sapphire single crystal substrates by pulsed laser deposition technique. An analysis of the properties of these materials from both points of view viz, carrier induced and F-center mediated exchange mechanism will be discussed. We have employed both insitu and ex-situ steps to vary the conductivity, from insulating to semiconducting and this gives a direct handle to correlate the magnetic properties with presence / absence of F-centers. Magnetic measurements including magnetization as a function of applied magnetic field and magnetization as a function of temperature (field cooled and zero field cooled) have been performed in a superconducting quantum interference device (SQUID) magnetometer. Elaborate atomic scale characterization has been done using transmission electron microscopy (TEM), including high-resolution TEM, Scanning TEM Z-contrast and Electron energy Loss Spectroscopy (EELS). These studies coupled with optical characterization using absorption spectroscopy yield interesting insight into the local environment of the dopant in the crystal field of the host. We will also discuss spin polarized injection into ZnO for potential spintronic device applications. [1]$Zn_{0.9}Co_{0.1}O$-based diluted magnetic semiconducting thin films, S. Ramachandran, Ashutosh Tiwari, and J. Narayan App.Phys.Lett. 84, pp. 5255-5257

9:45 AM II4.5
Ferromagnetic semiconductors Sb2-xVxTe3 with high TC.
Zhenhua Zhou, Yi-Jiunn Chien and Ctirad Uher; Physics, University of Michigan, Ann Arbor, Michigan.

Thin film ferromagnetic semiconductors Sb2-xVxTe3 ($0 \leq x \leq 0.35$) with the Curie temperature as high as 177 K were prepared on sapphire (0001) substrates by molecular-beam epitaxy. Out-of-plane ferromagnetic ordering was found in films of Sb2-xVxTe3 with the Curie temperature that increases with increasing concentration of vanadium in the structure. The ferromagnetic order is manifested by hysteresis loops observed in magnetization, magnetoresistivity and the anomalous Hall effect. Transport characterizations indicate decrease of the electrical resistivity by an order of magnitude when V is substituted on the Sb sublattice as a result of the increase of the concentration of holes when the content of vanadium increases. Reference: (1)Y.-J. Chien, Z. Zhou and C. Uher, J. Cryst. Growth, accepted. (2)Z. Zhou, Y.-J. Chien and C. Uher, Appl. Phys. Lett., submitted.

10:30 AM *II4.6
Spin Dephasing and Dynamical Nuclear Polarization in Semiconductors.
Bernd Beschoten, II. Physikalisches Institut, RWTH Aachen, Aachen, Germany.

Nuclear spins are a candidate for solid-state implementation of a quantum computer, since they are localized and exhibit spin relaxation times in the order of seconds. Electron spins can be used to address and control nuclear spins by the hyperfine interaction. Therefore we investigated dynamic nuclear polarization in bulk n-GaAs in small magnetic fields using all-optical NMR. Electron spins are coherently pumped by a circularly polarized laser pulse. Their orientation is probed by time-resolved Faraday rotation. Two-color pump probe experiments in n-type GaAs yield the energy dependence of the coherency of electron spins near the Fermi level or of hot electron spins with excess kinetic energy. The resonant excitation of localized donor-like electron spin states was found to rive rise to large nuclear fields influencing the precession frequency of the spins in an external magnetic field. The origin of this dynamical nuclear polarization is assigned to the relaxation of the localized donor-like spin states. In contrast, delocalized electron spins with long spin life-times couple only weakly to the nuclear system. Those states can thus be used for fast readout of the nuclear fields by the Overhauser shift using resonant spin amplification. The dynamical nuclear polarization upon resonantly exciting electron spins yields the basis for an all optical NMR technique and open a link to alternative, NMR-based routes to quantum information processing. Work done in collaboration with L. Schreiber, K. Schmalbuch, M. Heidkamp, and G. Güntherodt. Supported by by the Bundesministerium für Bildung und Forschung of the Federal Republic of Germany.

11:00 AM II4.7
Magneto-Optical and Structural Studies on Mn Ion States in MOCVD-grown Ga(1-x)Mn(x)N.
Nola Li[1], William E. Fenwick[1], Matthew Kane[1,2], Martin Strassburg[1,3], Ali Asghar[1], Nikolaus Dietz[3] and Ian T. Ferguson[1,2]; [1]Electrical and Computer Engineering, Georgia Institute of Technology, Atlanta, Georgia; [2]School of Materials Science and Engineering, Georgia Institute of Technology, Atlanta, Georgia; [3]Department of Physics and Astronomy, Georgia State University, Atlanta, Georgia.

The ability to control both the flow of electrons and spin in semiconductor material has been a focus of ferromagnetics research over the past decade. Dilute magnetic semiconductors, in particular wide bandgap materials such as transition metal (TM) doped GaN and ZnO have been studied for use in spintronic devices because of their unique properties at room temperature. In order to control the ferromagnetic behavior and to reveal the mechanisms providing the spin alignment in such structures, a better understanding of their magneto-optical properties is crucial. The study of Mn doped GaN focuses on the influence of TM doping on the lattice dynamics and to investigate the position of spin-split states in the bandgap are necessary for ferromagnetic interactions. This study investigates high quality undoped GaN and Ga1-xMnxN layers grown by MOCVD. High-resolution x-ray diffractometry showed no precipitates and/or second phase formation for Mn concentration as high as 1.5%. Also, no statistically significant deviation in the a- or c-axis lattice parameters was observed in the as-grown samples. A more detailed study of the local and long-range lattice properties was performed by Raman spectroscopy. However, the intensity of Mn-related disorder-induced modes or LVMs is two orders of magnetitude below the intensities of the dominant Raman modes of the GaN host lattice. In particular, three sets of Raman modes appeared to be more sensitive to Mn incorporation. The intensities of a broad band around 300cm-1 and sharper modes near 669cm-1 increase with increasing Mn concentration. The rise of the former is attributed to a decrease in long-range lattice ordering for higher Mn concentration. The second mode is due to nitrogen vacancy-related LVMs of the GaN host lattice. The slight excess of metal components in the growth process of Ga1-xMnxN compared to undoped GaN growth and the incorporation of Mn deep acceptor levels favor the formation of nitrogen vacancies relative to undoped GaN. Additional experiments on Si co-doped Ga1-xMnxN revealed that shallow donor states in GaN suppress the formation of nitrogen vacancies by compensating the p-type deep level defects introduced by substitutional Mn. A third group of Raman modes was also related to the Mn incorporation. The slight blue shift in the E1(TO) mode and a shoulder on the high energy side of the E2(high) mode provide further evidence of the Mn-related influences on the lattice dynamics. The manipulation of spin by polarization dependent optical excitation enables the detection of spin split bands and how the spin mediates through the semiconductor. The formation of a Mn3+ midgap impurity band is suggested for the spin mediation by some theoretical work. An absorption band due to transitions in such a band was revealed in Ga1-xMnxN for x>0.8%, but not for Si co-doped samples. Kerr rotation and magnetic circular dichroism spectroscopy are performed to study the spin sensitivity of this band.

11:15 AM II4.8
Structural Stability and the Formation of Mn-rich Inclusions in Magnetic Semiconductors: (Ga,Mn)As, (Zn,Mn)Te, and (Cd,Mn)Te.
Pawel Jakubas[1], Nevill Gonzalez Szwacki[1,3], Piotr Boguslawski[1,2] and Jerry Bernholc[2]; [1]Institute of Physics PAS, Warsaw, Poland; [2]Center for High Performance Simulation and Department of Physics, North Carolina State University, Raleigh, North Carolina; [3]Rice University, Houston, Texas.

(Ga,Mn)As is one of the most investigated magnetic semiconductors due to its relatively high Curie temperature and compatibility with the GaAs technology. In particular, it was established that while annealing at about 200 C results in an improvement of its magnetic properties [1], annealing at higher temperatures leads to the formation of nanoclusters. Depending on the annealing conditions, inclusions consist of smaller Mn-rich (Ga,Mn)As nanoclusters with the zinc-blende structure of the host GaAs, or larger clusters of MnAs in the NiAs phase [2]. We generalize the definition of the mixing enthalpy to the case of alloys with a varying crystalline structure and investigate structural stability of (Ga,Mn)As through density functional theory calculations. We find that the stability of the zinc-blende phase persists up to about 75% of Mn, while for higher Mn content the equilibrium structure is the NiAs phase. Furthermore, cubic (Ga,Mn)As is intrinsically unstable with respect to segregation into the pure end compounds. This suggests that the formation of MnAs inclusions occurs in two steps: First, the instability towards segregation results in fluctuations of the alloy composition, i.e., the formation of Mn-rich clusters. In the second step, the clusters undergo a structural transformation from the metastable zinc-blende phase to the stable NiAs structure. Since the formation of inclusions with a secondary phase is observed in many other alloys, we assess the generality of our results and extend the analysis to (Zn,Mn)Te and (Cd,Mn)Te. In agreement with experiment we find that the phase diagrams of both alloys are similar to that of (Ga,Mn)As, exhibiting a transition from the cubic to the NiAs phase with increasing Mn content. For all systems considered above we discuss the magnetic ordering (which is ferromagnetic for (Ga,Mn)As, and antiferromagnetic for (Cd,Mn)Te and (Zn,Mn)Te), and its contribution to the structural stability. This work has been supported by grant PBZ-KBN-044/P03/2001 and U.S. DOE. [1] K. Edmonds et al., Phys. Rev. Lett. 92, 37201 (2004). [2] M. Moreno et al, Phys. Rev. B 67, 235206 (2003); Sh. U. Yuldashev et al., Appl. Phys. Lett. 90, 3004 (2001).

11:30 AM II4.9
Half-metallic ferromagnetism in zinc-blende type MnAs: effects of exchange-correlation functionals.
Jincheng Zheng, Yimei Zhu, James W. Davenport and Wei Ku; Brookhaven National Lab, Upton, New York.

Zinc-blende type MnAs has been investigated by first principles full potential calculations using linearized argumented plane wave method. The magnetic properties of MnAs have been examined by employing several different exchange-correlation functionals including local density approximation (LDA), general gradient approximation (GGA), X-alpha, and meta-GGA, as well as strongly correlated effects (Coulomb on-site correction, namely, LDA+U). We found that the lattice constant and ferromagnetism in MnAs are very sensitive to exchange-correlation functionals. LDA and some types of GGA predict MnAs as a nearly half-metallic ferromagnet, while the LDA+U and X-alpha functionals predict MnAs as a full half-metallic ferromagnet (i.e., the major spin is metallic, and minor spin is semiconducting). The validation of functionals in magnetic calculations of MnAs is discussed.

11:45 AM II4.10
Dopant Assisted Mn Substitution in Ge and Si.

Wenguang Zhu[1], Zhenyu Zhang[2,3,1] and Efthimios Kaxiras[1]; [1]Department of Physics, Harvard University, Cambridge, Massachusetts; [2]Condensed Matter Sciences Division, Oak Ridge National Laboratory, Oak Ridge, Tennessee; [3]Department of Physics and Astronomy, University of Tennessee, Knoxville, Tennessee.

Dilute magnetic semiconductors (DMS) have attracted attention as promising materials for spintronic devices. Initially, III-V semiconductors doped with Mn were studied and found to exhibit ferromagnetic ordering. Recently, ferromagnetic ordering has also been observed in Mn doped Ge-based materials, offering a better opportunity for integrating magnetism with existing silicon technology. Previous studies showed that the magnetic ordering temperature, TC, may depend sensitively on relative populations of interstitial and substitutional magetic dopants. Based on first-principles total energy calculations, we invetigate the influence of a p-type or n-type dopant on Mn impurities in both Ge and Si bulk systems. For Ge, the Mn impurities can be incorporated easier into substitutional sites when a nearby n-type dopant is present, such as P. Mn impurities also change character in bulk Si, from interstitial to substitutional sites, in the presence of nearby n-type dopants, such as P.

SESSION II5: Magnetic Semiconductors (2)
Chair: Kannan Krishnan
Tuesday Afternoon, November 29, 2005
Room 312 (Hynes)

1:30 PM II5.1
Mn clustering and magnetic ordering in Mn-doped Ge ferromagnetic semiconductor. An-Ping Li[1], K. von Benthem[1], M. F. Chisholm[1], K. Varga[1], Jian Shen[1], N. Rao[2], S..K. Dixit[2], L. C. Feldman[2,1] and Hanno Weitering[3,1]; [1]Oak Ridge National Laboratory, Oak Ridge, Tennessee; [2]Vanderbilt University, Nashville, Tennessee; [3]The University of Tennessee, Knoxville, Tennessee.

We present a combined experimental and theoretical study of the spatial distribution of Mn dopant atoms in germanium, grown with molecular-beam epitaxy. Cross-sectional transmission electron microscopy reveals the Mn-doped Ge film contains a high density of columnar features 2nm in diameter. Electron energy loss spectroscopy and ion-channeling analysis indicate that these columns contain 80% of the total Mn in the film. The Mn clustering behavior suggests the existence of a long-range attraction between the dopants, which is confirmed by our Monte Carlo simulations based on many-body Coulomb effect. Ferromagnetism in Mn-doped Ge (with doping concentration up to 9%) is characterized by two ordering temperatures. A critical temperature TC* (112 K for x 0.05) is obtained as ferromagnetic spin clusters form, and a second transition occurs at much lower temperature Tc (12 K for x 0.05) at the onset of global ferromagnetic ordering. The Mn enriched columns provide seeds of magnetic spin clusters, these spin clusters expand in size with lowering temperature and percolate eventually to form infinite magnetic clusters at low temperature, which is consistent with a magnetic polaron percolation theory.

1:45 PM II5.2
Low-Temperature Molecular Beam Epitaxy of Fe_3Si/Si(111). Taizoh Sadoh, Hisashi Takeuchi, Ryo Kizuka, Koji Ueda, Hiroshi Kanno, Atsushi Kenjo and Masanobu Miyao; Electronics, Kyushu University, Fukuoka, Fukuoka, Japan.

The ferromagnetic silicide Fe_3Si (Tc=840K) is attractive for Si-based spintronic applications. Three phases (A2, B2, DO3) exist for Fe_3Si. From a theoretical calculation, it is shown that the DO3 phase is half-metallic. Moreover, since the lattice mismatch between Fe_3Si and Si is as small as 4%, epitaxial growth of Fe_3Si on Si is expected to be possible. In the present study, we have examined the possibility of epitaxial growth of Fe_3Si layers on Si (100) and Si (111) substrates by using the molecular beam epitaxy (MBE) technique. In the experiment, Fe and Si were co-evaporated on the Si (100) and (111) substrates at 60-400°C by using the solid-source MBE system (base pressure: $5x10^{-11}$Torr, deposition rate: 1.2 (Fe) and 0.4Å/s (Si)), total thickness: 50-100nm). The grown layers were evaluated by using Auger electron spectroscopy (AES), x-ray diffraction (XRD), and transmission electron microscopy (TEM). For samples deposited on Si (100) substrates at 60-300°C, XRD peaks due to Fe_3Si were observed by both the 2θ and θ-2θ configurations, suggesting formation of poly-Fe_3Si with random orientations. In the XRD spectra of samples deposited on Si (111) substrates at 60-300°C, the peaks due to Fe_3Si (222) were observed for the samples only in the θ-2θ configuration, which suggests that Fe_3Si (111) layers were epitaxially grown on Si (111) substrates. When the substrate temperature was increased up to 400°C, XRD peaks due to FeSi were observed for both the samples deposited on Si (100) and (111) substrates. AES results confirmed the concentration ratio of Fe:Si=1:1 for these samples, which was due to the Si supply from the substrate at 400°C. In order to confirm the epitaxial growth of Fe_3Si layers on Si (111) substrates, the cross sectional TEM measurements were performed. The electron diffraction patterns obtained from the different regions of the Fe_3Si layer deposited at 300°C showed a similar symmetrical structure to that of Si substrates. These results demonstrated that Fe_3Si layers were epitaxially grown on Si (111) substrates. Although the lattice mismatch was same for Si (100) and (111) substrates, the epitaxial growth of Fe_3Si was achieved only for Si (111) substrates. The reason for this is now under investigation. To identify the phase of epitaxially grown Fe_3Si, XRD measurements (ϕ scan) were performed. The peaks (Fe_3Si (331)) peculiar to the DO3 phase were observed for the sample deposited at 300°C, while the peaks were not observed for the sample deposited at 60°C, which suggested that the DO3 phase could be obtained by deposition at a temperature above 200°C. This technique for epitaxial growth of Fe_3Si on Si (111) substrates will open a new era of the Si-based spintronics devices. A part of this work was supported by CREST of Japan Science and Technology Corporation.

2:00 PM II5.3
Room-temperature ferrimagnetic semiconductor thin films based on the ilmenite-hematite solid solution. Hajime Hojo, Koji Fujita, Katsuhisa Tanaka and Kazuyuki Hirao; Material Chemistry, Kyoto University, Kyoto, Japan.

Magnetic semiconductors with Curie temperature (T_C) beyond room temperature have attracted considerable attention since they are expected to be promising candidates for spin electronics applications where the degrees of freedom in both charge and spin are efficiently utilized. One approach toward the development of magnetic oxide semiconductors is to explore semiconducting materials that are known to show ferromagnetism or ferrimagnetism above room temperature. An example of such materials is solid solutions of ilmenite, $FeTiO_3$, and hematite, α-Fe_2O_3. It is known that although both $FeTiO_3$ and α-Fe_2O_3 are antiferromagnetic insulators, their solid solutions with intermediate compositions exhibit both semiconducting and ferrimagnetic properties. α-Fe_2O_3 belongs to the family of corundum structure (space group: R-3c) and is composed of an hcp closed packing of O ions. Fe ions occupy two-thirds of the available octahedral interstices, forming an alternate stack of Fe and O layers along the c-axis. The crystalline structure of $FeTiO_3$ is a derivative of corundum α-Fe_2O_3; Fe layers stacked along the c-axis in α-Fe_2O_3 are alternatively replaced by Ti layers. Due to the replacement, the space group changes from R-3c to R-3. Consequently, the solid solutions consisting of $FeTiO_3$ and α-Fe_2O_3 undergo the order-disorder transition between R-3c and R-3 symmetry. Strong ferrimagnetic properties are observed when the crystalline structure is the ordered phase with R-3 symmetry, while the disordered phase with R-3c symmetry shows antiferromagnetic properties or rather weak magnetization. The uniqueness of this system lies in the fact that the conduction type can be controlled as either p or n type by simply changing the composition. Furthermore, recent theoretical predictions suggested the possibility of spin-polarized carriers and high T_C in the solid solutions. In spite of such interesting electrical and magnetic properties, only a few studies have been reported on the solid solution with the form of thin film. Especially, it has never been demonstrated that semiconducting and ferrimagnetic thin films having the T_C above room temperature could be obtained in the solid solutions, to our knowledge. In this study, epitaxial thin films composed of $0.7FeTiO_3$-$0.3Fe_2O_3$ solid solution have been prepared on α-Al_2O_3 (0001) substrates by the pulsed laser deposition method, and their electrical and magnetic properties have been examined. The crystalline structure of as-deposited thin films depends strongly on the oxygen partial pressure and substrate temperature during the deposition. A single phase of the ordered phase (R-3 symmetry) can be obtained under the limited deposition conditions. The as-deposited thin film with the ordered phase is a p-type semiconductor and ferrimagnetic below room temperature. Subsequent annealing treatment in vacuum enhances the T_C up to temperature above room temperature, without changing the conduction type.

2:15 PM II5.4
Fabrication and Properties of Nanoscale Magnetic Tunnel Junctions. Land Belenky[1], Xianglin Ke[2], Dmitry Ruzmetov[3], Yongho Seo[3], Haiping Sun[4], Chang-Beom Eom[1,2], Mark Rzchowski[2], Venkat Chandrasekhar[3] and Xiaoqing Pan[4]; [1]Department of Materials Science and Engineering, University of Wisconsin, Madison, Wisconsin; [2]Department of Physics, University of Wisconsin, Madison, Wisconsin; [3]Department of Physics and Astronomy, Northwestern University, Evanston, Illinois; [4]Department of Materials Science and Engineering, University of Michigan, Ann Arbor, Michigan.

Magnetic tunnel junctions show a very strong magnetoresistance useful for hard drive read heads, MRAMs or other magnetic sensing devices. Spin-dependent tunneling is strongly influenced by the properties of the interfaces. As the size of the device is reduced to that relevant to future electronic applications, the role of grains,

domain walls and defects becomes more significant. Magnetic oxide materials such as La(0.66)Sr(0.33)MnO(3) (LSMO) are ideal choices for nanoscale tunnel junctions because they can be grown epitaxially on lattice-matched substrates, exhibit magnetic anisotropy and sharp, interfaces. We reported the fabrication of epitaxial nanodots with atomically sharp interfaces. Here, we report the fabrication of nanoscale spin-dependent tunneling devices with barriers of a few atomic layers. Using pulsed laser deposition with high pressure, in situ RHEED, we have grown trilayer structures with sharp interfaces. The top and bottom electrodes are LSMO and the barriers are La(0.7)Sr(0.3)Al(0.7)Ta(0.3)O(6) (LSAT). An array of independently addressable nanoscale pillars has been fabricated using electron beam lithography. The pillar diameter is on the order of 100nm. We will discuss point-contact magnetoresistance and MFM measurements of magnetic nanostructure in addition to structural measurements by x-ray and cross-section TEM.

SESSION II6: Magnetoelectronics and Spintronics
Chair: Bernd Beschoten
Tuesday Afternoon, November 29, 2005
Room 312 (Hynes)

3:30 PM *II6.1
Current-Induced-Magnetization-Switching (Spin Transfer) in Novel Magnetic Tunnel Junctions. Jian-Ping Wang, Electrical and Computer Engineering, University of Minnesota, Minneapolis, Minnesota.

Current-induced-magnetization-switching (CIMS) (or named spin transfer or spin torque) predicted by Slonczewski and Berger has attracted a great deal of attention in recent years. Experimental findings have proved this phenomenon in current-perpendicular-to-plane (CPP) spin-valves and magnetic tunnel junctions (MTJs). CIMS provides a very useful writing approach for high-density magnetic random access memory (MRAM) and other spintronic devices. Currently, MRAM element is operated by magnetic field generated from current lines, which causes lots of problems, such as scaling issue, cross talk, heat diffusion and poor reliability. CIMS, on the other hand, could potentially solve the above problems and simplify the circuit design for MRAM. However, the high critical current density (Jc 10e7 A/cm2) blocks its applications in MRAM. For MTJ structure, a high current density will cause a high voltage, which will destroy the device. In this talk, we will review our recent progress on CIMS with emphasis on the CIMS in several novel low RA MTJ structures with lateral dimensions around 100 nm: 1) MTJ structure with a novel nano-current-channel (NCC) layer; 2) MTJ structure combined with a current-perpendicular-to-plane spin valve; With these new MTJ structures, the total current density required to switch the magnetization of the free layer was found tremendously down to 10e6 A/cm2. Then CIMS in a novel perpendicular magnetized MTJ structure will be discussed. Finally a scheme for a thermally stable MTJ cell with sub 100 nm dimension for Gbit/in2 MRAM will be presented.

4:00 PM II6.2
Mechanical strain induced switching of magnetostrictive TMR elements. Maik Thomas Bootsmann, Stefani Dokupil, Eckhard Quandt and Markus Loehndorf; Micro- and Nanostructures, Research Center caesar, Bonn, Germany.

For further miniaturization of magnetostrictive tunnel magneto resistive (TMR) devices [1] for sensor applications such as pressure sensing a detailed understanding of the switching properties of the magnetostrictive thin films is important. We have combined MEMS fabrication processes and thin film technology in order to fabricate highly magnetostrictive micro-dot arrays and TMR elements on membrane structures with different diameters (150 to 500 micrometer). Applying mechanical strain to the membrane leads to a change in the magnetization direction, due to the inverse magnetostrictive effect or Villari effect. Compressive or tensile mechanical strain is introduced by applying different air pressure (0.1 bar to 4 bar) to the sealed membrane cavity. We have applied magnetic force microscopy (MFM) [2] and magneto-optic kerr effect (MOKE) in order to obtain the magnetization switching and to resolve the domain structure of amorphous FeCoBSi micro-dot arrays on Si3N4 membranes and FeCo free-layers of TMR junctions on Si membranes. Additionally, the local strain distribution of the various membrane structures have been obtained by finite-element simulations and compared to the experimental results for different positions on the membrane. [1] M. Loehndorf et al, Appl. Phys. Lett. 81(2), 313 (2002). [2] M.-T. Bootsmann et al., IEEE Trans. Mag., in-press (2005).

4:15 PM II6.3
On-chip Planar Solenoid Inductors using Magnetite (Fe3O4) Nanorod Cores for High Frequency Applications. Jinsook Kim[1], Weiping Ni[1], Ian D. Hosein[2], Yanning Song[2], Chekesha Liddell[2] and Edwin C. Kan[1]; [1]School of Electrical and Computer Engineering, Cornell University, Ithaca, New York; [2]School of Material Science and Engineering, Cornell University, Ithaca, New York.

The on-chip passive inductor is a key microwave integrated circuit element. Despite of numerous efforts to incorporate ferromagnetic (FM) materials to improve the performance and area efficiency, inductors with FM materials have relatively poor performance at high frequency due to the Eddy current loss (ECL) and ferromagnetic resonance (FMR) in the FM material. To decrease these losses, patterning the FM film into small segments has been common [1], but lithography limit and fabrication complexity hinder its wide applicability. Considering ECL, resistive loss, and easy/hard axis orientation in FMR, we adopt magnetite (Fe3O4) nanorods for magnetic cores of on-chip inductors. The nanorods have a mono-dispersed size of 0.5 μm diameter and 2 μm length with high resistivity [2]. The silica coating on the outer nanorod surface provides electrical isolation that further reduces ECL at high frequencies. Various core patterns, including pie, vertical bars, multi-ring, and cylinders are additionally defined for the solenoid cores. External magnetic fields are applied during nanorod deposition to form different easy/hard axis orientations to investigate the range for FMR, which are also independently characterized by a vibrating sample magnetometer. We use analytical calculations and electromagnetic simulation [3] in the design phase to estimate the inductor performance. The fabrication starts from a normal Si substrate with both top and bottom 500nm-thick nitride layers for final membrane structures. A PECVD oxide of 5mm is deposited, followed by the electroplating of 30nm Cr and 1mm Au layers for the signal lines. Magnetite nanorods are deposited from its water mixture. The drying process is accompanied with applied magnetic field to align nanorods to a specific direction. A 100nm SiO2 layer is evaporated to fix the nanorods on the PECVD oxide. The core patterns are then completed by a lift-off process. With the S-parameter measurements and the open-short-through de-embedding procedure [4] between 400MHz and 40GHz, the quality factor (Q-factor), inductance and resistance as a function of frequency are obtained. We have found improvement in both inductance and the Q-factor up to 15GHz with magnetite nanorod cores. In comparison, typical integrated solenoid inductors using FM thin films cannot achieve performance enhancement for frequencies over 3GHz. References: [1] Y. Zhuang, M. Vroubel, B. Rejaei, and J.N. Burghartz, IEDM02, 475 (2002) [2] T. Sugimoto, M. M. Khan, A. Muramatsu, Colloids Surf. 1993, A70, 167. [3] HFSS Electromagnetic Simulation Tools, Ansoft, Release 9.0, 2003. [4] C. Chen, and M. J. Deen, Trans. on MTT, vol. 49, No.5, May 2001, pp.1004-1005. Jinsook Kim, Cornell University, School of Electrical and Computer Engineering, 323 Phillips Hall, Ithaca, NY, 14853, USA, Tel: 607-254-8842, FAX: 607-254-3508, jk368@cornell.edu

4:30 PM *II6.4
Growth and Characterisation of Hybrid Magnetic/Semiconductor Spintronic Structures. Yongbing Xu, Jill Claydon, Yongxiong Lu, Ehsan Ahmad, Iain Will and Ya Zhai; The University of York, York, United Kingdom.

Hybrid ferromagnetic/semiconductor (FM/SC) devices where ferromagnetic materials are used in conjugated with semiconductor materials emerges as a significant area of research known as Spintronics with the aim to develop next generation non-volatile and fast devices. In this talk, we will report our experimental study of Fe and Fe3O4 nanostructures on GaAs (100) surfaces and hybrid spintronic devices. The element specific x-ray magnetic circular dichroism (XMCD) measurement showed directly that the Fe atoms on GaAs (100) are ferromagnetic down to 0.25ML [1]. The spin moment is close to the bulk and the orbital moment is enhanced by 300%. The ultrathin films exhibited strong uniaxial anisotropy, of the order of 6.0x105erg/cm3 as shown by the FMR measurements. We have demonstrated for the first time the epitaxial growth of single-crystal half metallic Fe3O4 ultrathin films on GaAs(100) substrate by post growth annealing of ultrathin epitaxial Fe films in an oxygen partial pressure [2]. The Fe3O4 /GaAs(100) is one of the most the most promising spintronic materials as the Fe3O4 has high Tc and high spin polarisation. The formation of the ferrimagnetic Fe3O4 rather than Fe2O3 or other ion oxides has been further confirmed by RHEED, XPS, and XMCD. The Fe3O4/GaAs(100) system shows an interesting epitaxial relationship with the unit cell of the Fe3O4 rotated by 45 degree to match that of GaAs(100) substrate. The films show a uniaxial magnetic anisotropy, unexpected from the crystal symmetry. We have fabricated a novel vertical Co/GaAs/FeNi spintronic device with a GaAs membrane. This device exhibited rectifying current-voltage (I-V) characteristic, with biasing current dependent MR characteristics [3]. A maximum change of 12% in the MR is observed which indicate a large room temperature spin injection and detection. [1] J. S. Claydon, Y.B. Xu, M. Tselepi, J.A.C. Bland, G. van der Laan, Phys. Rev. Lett., 93 (3) JUL 16 2004. [2] Y. X. Lu, J. S. Claydon, Y. B. Xu, D. M. Schofield, S. M. Thompson, G.

van der Laan, Phys. Rev. B, 70 (23): art. no. 233304 DEC 2004 [3] E. Ahmad, A. Valavanis J. S. Claydon, Y.l X. Lu and Y. B. Xu, IEEE Transactions on Magnetics, in press, 2005

SESSION II7: Poster Session: Magnetics Materials
Chairs: Saskia Fischer and Kornelius Nielsch
Tuesday Evening, November 29, 2005
8:00 PM
Exhibition Hall D (Hynes)

II7.1
Switching in square ring based MRAM design: Effects due to shape and applied fields. Anand Subra Mani, Dwarakanath Geerpuram, Vidhya Shankar Baskaran, Gaudalaupe Rodriguez and Vitali Metlushko; Electrical and Computer Engineering, University of Illinois at Chicago, Chicago, Illinois.

Magnetic memory devices like MRAMs have achieved significant progress in the field of data storage. This is due to its characteristics of being fast and dense. One of the most important features of this device is its non-volatility, which enables data to be written forever. These devices have also been tested against extreme conditions like high heat and radiation and have been found to be very stable. The efficiency of any memory device is measured by the reading and writing times of the data in the devices. In MRAMs, faster selective writing and data access are obtained by controlling the formation of two stable data storing states and the switching between these two states. We propose a square ring, which is the simplest structure with defined boundaries. The square ring also has a well-defined pinning corner, and this helps in restricting the domain wall movement due to stray fields. The proposed square ring is made asymmetric by making one arm of the ring thicker than the other three. This is done to account for the asymmetric defects, which occur due to fabrication. The advantage of this design is that the amount of asymmetry introduced can be precisely controlled. The stable states in the square are the "onion states" and the intermediate state is determined by the direction of magnetization, with a "vortex" forming for a diagonal magnetization and two intermediate states called the "horse-shoe " and the "90^oonion state" for magnetization along the sides. Micro-magnetic simulations were performed using the OOMMF code with exact experimental parameters for different variations in sample shape, asymmetry and applied external field. Hysteresis loops for all the cases were plotted during the simulations. It was observed that the thicker arm of the ring switched at a much lower field compared to the thinner arm of the ring. This was due to the formation of localized vortices on the thicker arm of the ring. The formation of these localized vortices and their movement along the thicker arm occurred at a much lower field than required for the movement of the domain wall along the arm. The formation of these localized vortices was enhanced with the increasing thickness of the asymmetric arm. It has been thus observed in our design that the formation of the stable states and the switching between the stable states were controlled by the shape of the ring and the direction of applied field. This provides us with a very good predictability of the switching process in these rings. Also, we found a good correspondence between the simulations and experimental MFM data and, as a result, further optimization of the nano-rings' critical dimensions and amount of asymmetry needed could be determined based on simulations. Acknowledgements: OOMMF code is provided by the National Institute of Standards and Technology. This work is supported by the U.S National Science Foundation, grants ECS-0202780 and DMR-0210519.

II7.2
Magnetisation reversal in elliptical Cobalt (Co) nanorings. Prabeer Barpanda, Ceramic and Materials Engineering, Rutgers University, Piscataway, New Jersey.

The ever increasing need of newer and better ferromagnetic structures for advanced MRAM and other device applications has led to extensive research in magnetic nanostructures like nanorods, nanopillars, nanowires and nanodots. Of them, nanodots are very promising for MRAM applications. Recently, nanorings (hollow dots) have been reported to possess more stable switching behaviour by Klaui et al. The challenge here is to get a stable and reproducible remanence/ switching behaviour. In this context, the introduction of ellipsity in the nanorings can yield distinct reversal behaviour due to its anisotropy. Though spherical ring has been widely studied, the effect of ellipsity in the nanorings is yet to be scrutinized. In the current work, elliptical Co nanoring (of fixed thickness 10 nm) has been investigated by changing its ellipsity (minor axis/major axis) from 0.25 (elliptical) to 1 (spherical) and by varying the major diameter from 50 to 500 nm and width from 10 to 30 nm. As magnetization reversal is highly dependent on the dimension of the magnetic elements, a thorough study on various magnetization reversal mechanisms was computed using micromagnetic modeling based on Landau-Lifshitz-Gilbert (LLG) equations. Depending upon the dimension of nanorings, various quasi-static magnetic states like onion structures, uniform/ twisted vortex and single domain were observed and were mapped into a magnetization reversal phase diagram. Upon reversal, the saturated state initially gets converted to an onion like structure forming two sharp domain boundaries. Further reversal is essentially based on different types and extent of movement of these domain boundaries. These reversal trends were tapped by a series of simulated holographs during hysteresis cycle. In addition, the effect of size and ellipsity of Co nanoring on the switching field and reversal time was plotted. It is marked that with increase in ellipsity, the switching field and reversal time gradually increased owing to increase in the magnetocrystalline anisotropy. The variation in magnetostatic energy during hysteresis was correlated to the corresponding coercivity of different nanorings. The whole study on micromagnetism of elliptical Co nanorings evaluates the possibility of their usages in memory applications and proposes some direction for future experiments.

II7.3
Synthesis of CoPt and FePt Magnetic Nanoparticles From Single Source Precursors. Matthew Wellons, Chemistry, Vanderbilt University, Nashville, Tennessee.

Metal nanoparticles which exhibit ferromagnetism, particularly high corecivity $L1_0$ materials, are of great interest as promising materials for magnetic recording applications and for the investigation of magnetic-size effects. Typical preparations involve reduction and/or thermal treatment of multiple precursors in solution-phase syntheses. Preparation of such bimetallic magnetic nanoparticles can be problematic due to possible compositional heterogeneity of individual particles and particle sintering during thermal annealing. A synthesis strategy for preparing FePt and CoPt nanoparticles using single-source molecular precursors dispersed on the surface of water-soluble solid supports will be presented. $L1_0$FePt and CoPt nanoparticles are formed by reductive decomposition of the single-source molecular precursors, $FePt(CO)_4$dppmBr_2 and $CoPt(CO)_4$dppeMe, respectively. Nanoparticles of both magnetic alloys are reliably produced in the size ranges of 5-40 nm and both show strong ferromagnetism. Precursors are deposited on Na_2CO_3 powder, which serves as a solid support for subsequent metal-ion reduction and thermal annealing. Temperatures between 550 °C and 650 °C are required to achieve complete formation of the ordered $L1_0$ fct phase. Treating the final annealed composite with a 1% wt Ctab aqueous solution simultaneously dissolves the solid support and passivates the formed metal nanoparticles. The fct metal alloy nanoparticles have been characterized using TEM, EDS, and XRD. Magnetic characterization will be provided, as available.

II7.4
ac Magnetization Measurements on NiO Nanoparticles. S. D. Tiwari and K. P. Rajeev; Dept. of Physics, IIT-Kanpur, Kanpur, UP, India.

Work on small particles, few nanometers in size, has become of increasing interest due to new properties that materials show when crystal size is reduced. Nanoparticles of magnetic materials are of more interest because of its useful applications [1]. Magnetic nanoparticles show superparamagnetism and the blocking temperature is proportional to the volume of the particle [2]. In 1961 Néel suggested that small particles of an antiferromagnetic material should exhibit magnetic properties such as superparamagnetism and weak ferromagnetism [3]. Among antiferromagnetic transition metal monoxide nanoparticles, nanoparticles of NiO has been rather well studied [4-7] and has been reported to show some anomalous magnetic properties. In this paper we present ac magnetization measurements on sol-gel prepared NiO nanoparticles of different sizes. Samples are prepared as described elsewhere [4-7], and characterized by X-ray diffraction and transmission electron microscopy. We perform ac magnetization measurements at different frequencies for different sized particles as a function of temperature and field. We find peak in susceptibility vs. temperature curve. The peak temperature (Tp) increases with increasing frequency such that (ΔTp/Tp) per decade of frequency, equals to 0.02. This shift is smaller than expected for superparamagnets [8]. The peak temperature Tp is found to decrease with increasing particle size which is also against what is expected for superparamagnetic particles. We perform ac magnetization measurements as a function of temperature in the presence of different dc fields and show that the system follows the de Almeida-Thouless (AT) line [9], which is a characteristic of spin-glasses. We propose that the system shows spin-glass behavior. Possible origins of spin-glass phase and dynamic scaling [10] are also discussed. References: 1. R. W. Chantrell and K. O'Grady, in Applied Magnetism, edited by R. Gerber et al. (Kluwer Academic Publishers, The Netherlands, 1994), p.113. 2. T. Bitoh, K. Ohba, M. Takamatsu, T. Shirane, and S. Chikazawa, J. Phys. Soc. Jpn. 64, 1305 (1995). 3. L. Neel, in Low Temp. Phys., edited by C. Dewitt et al. (Gordon and Beach, New York, 1962), p.413. 4. J. T. Richardson and W. O. Milligan, Phys.

Rev. 102, 1289 (1956). 5. J. T. Richardson, D. I. Yiagas, B. Turk, K. Foster, and M. V. Twigg, J. Appl. Phys. 70, 6977 (1991). 6. R. H. Kodama, S. A. Makhlouf, and A. E. Berkowitz, Phys. Rev. Lett. 79, 1393 (1997). 7. S. A. Makhlouf, F. T. Parker, F. E. Spada, and A. E. Berkowitz, J. Appl. Phys. 81, 5561 (1997). 8. J. A. Mydosh, Spin Glass (Taylor & Francis, 1993), p.65-67. 9. J. R. L. de Almeida and D. J. Thouless, J. Phys. A 11, 983 (1978). 10. S. Geschwind, D. A. Huse, and G. E. Devlin, Phys. Rev. B 41, 4854 (1990).

II7.5

Synthesis, Crystalline Structure and Magnetic Properties of Ni Colloidal Nanoparticles. Herbert Winnischofer[1], Carlos M. Espinoza[1,2], Leandro M. Socolowsky[2], Wallace C. Nunes[2], Marcelo Knobel[2] and Daniela Zanchet[1]; [1]LNLS, Campinas, Brazil; [2]UNICAMP, Campinas, Brazil.

Magnetic nanoparticles (NPs) have been object of increase interest because of the fundamental and technological aspects involved. In this aspect, the synthesis of NPs by predictable, controllable and reproducible way become of great interest. In this work, we have focused on the synthesis of Ni NPs in the 4 to 16 nm range and how the synthesis parameters affect NP size, surface and crystalline structure and as a consequence, their magnetic behavior. A detail characterization by high resolution transmission electron microscopy (HRTEM), small angle X ray scattering (SAXS) and X ray photoelectron spectroscopy (XPS) have been done and correlated with magnetization data. Ni NPs have been produce by adapting a general procedure described in the literature (C.B.Murray et al, MRS Bull., Dec.2001,985). Briefly, a Ni salt precursor (acetate or acetylacetonate) is mixed with a 10-fold excess of dry 1,2-dodecanodiol in the presence of stabilizing agents under N_2 atmosphere. After 15-20 min the reaction is cooled at room temperature and ethanol is slowly added to selective precipitate the Ni NPs in the 4 - 16 nm range, depending on the synthesis condition. SAXS curves have exhibited well-defined oscillations, typical of monodisperse systems (σ = 5-8 %). Ni NPs of 4.8 nm have been obtained by using $Ni(ac)_2$/trioctylamine in a 1:4 molar ratio, while 7 nm NPs have been formed using a 1:2 molar ratio. Replacing the trioctyl- with tributylamine has produced larger NPs (10 nm). On the other hand, the substitution of trialkylamine with oleylamine has led to larger NPs, in spite of the C18 chain. We have found that the salt precursor plays a special role not only in the average NP size but also in crystallinity. Replacing $Ni(ac)_2$ with $Ni(acac)_2$ reduces the nucleation temperature, producing larger (16 nm) but polycrystalline and defective Ni NPs. HRTEM has shown that NPs produced from $Ni(ac)_2$ mainly presented the expected fcc structure; however, decahedral and twinned particles could also be found. Some particles have also shown poorly ordered surface layers, possibly in the oxide form. The chemical nature of the NP surface is under investigation by XPS. It is well known that the crystalline structure can deeply affect the magnetic behavior of materials but it is still little addressed in colloidal systems. In our system, the zero-field-cooled and field-cooled magnetization curves (ZFC/FC) have suggested the presence of two contributions to the magnetization, a magnetically ordered core and a disordered shell that exhibits a non-saturating component. A ZFC/FC curve of a highly polycrystalline sample that exhibits a high non-saturating component supports our hypothesis. On the other hand, the signal assigned to the magnetically ordered core presented the expected behavior as a function of particle size. Efforts to completely correlate the synthesis conditions of Ni NPs to the crystalline structure and magnetic behavior are ongoing.Acknow.:LNLS,FAPESP, CNPq.

II7.6

Synthesis and Dipolar Interactions in Fe-Fe Oxide Colloidal Nanoparticles. Jose M. Vargas[1,2,3], Wallace C. Nunes[3], Leandro M. Socolowsky[3], Marcelo Knobel[3] and Daniela Zanchet[1]; [1]LNLS, Campinas, Brazil; [2]Centro Atomico Bariloche, San Carlos de Bariloche, Argentina; [3]UNICAMP, Campinas, Brazil.

One crucial topic in the study of magnetic nanoparticles (NPs) is the role played by magnetic interactions. This subject has been extensively studied but until now there is not a clear picture of how the dipole-dipole interactions would affect the macroscopic magnetic behavior. An important point to be tackled is the production of *model* systems, with narrow size distribution and detailed morphological characterization. We have produced size-controlled Fe-Fe oxide samples by colloidal methods[1] and explored them in the study of dipolar interactions[2,3]. Both, synthesis aspects and magnetic behavior have been addressed. The as-synthesized NPs present narrow size distribution and average sizes in the range of 6−12 nm[1,2]. From the structural point of view, these NPs are amorphous as-synthesized and a polycrystalline oxide phase is formed with time[1]. The dependence of magnetic properties with NP size has been evaluated in powder samples by measuring zero field-cooled and field-cooled magnetization curves and magnetization loops[2]. The evolution of dipolar interaction with inter-particle distances has been evaluated by embedding the NPs in a matrix in different concentrations[3]. Different models have been applied, such as the so-called superferromagnetic model, proposed by Hansen & Morup[4], and the T* model recently proposed by Allia[5], and compared to independent morphological characterization. The very good agreement between morphological analysis and magnetic measurements for each case (powder and diluted samples) has allowed us to quantify some relevant physical parameters in this system, which will be presented. It is important to point out, however, that a drawback of choosing the Fe-Fe oxide system for this study was the poorly crystalline structure of the NPs and their evolution to a complex oxide phase. To overcome this issue, we have tested different procedures aiming to crystallize the NPs but keeping their size distribution and solubility. We have found that a thermal treatment in excess of ligand at 300^o C for a few minutes led to the formation of a new population of larger NPs (30 nm) that presents a well crystalline oxide phase (magnetite); this population showed a narrow size distribution and increased for longer thermal treatments. This process was favored in the presence of oxygen, suggesting that an Ostwald ripening mechanism takes place and favors the formation of a crystalline oxide phase. One important point is that the final product was still soluble in organic solvents, and could be explored to further address the role of dipole interactions in this system. Acknowledgements: LNLS-SAXS and XAFS beamlines, TEM/LME; financial support: FAPESP, CAPES and CNPq. [1] J.M. Vargas et al, IEEE Trans. Magn., 39 (2003) 2681. [2] J.M. Vargas et al, Nanotech.,16 (2005) S285. [3] M.F. Hansen et al, Phys. Rev. B, 62 (2000) 1124. [4] P. Allia et al, Phys. Rev. B, 64 (2001) 14420. [5] J.M. Vargas et al, Phys. Rev. B, submitted.

II7.7

A Facile Route to High-temperature Ferromagnetic Nanocrystals in the Co-Zn-O System. Xuefeng Wang[1], Jianbin Xu[1], Huogen Yu[2], Hua Tang[2], Juan Wang[3], Bei Zhang[4], Jiaguo Yu[2], Quan Li[3], Xixiang Zhang[4] and Rong Zhang[5]; [1]Department of Electronic Engineering and Materials Science and Technology Research Center, The Chinese University of Hong Kong, Shatin, New Territories, Hong Kong; [2]State Key Laboratory of Advanced Technology for Materials Synthesis and Processing, Wuhan University of Technology, Wuhan 430070, China; [3]Department of Physics, The Chinese University of Hong Kong, Shatin, New Territories; [4]Department of Physics, The Hong Kong University of Science and Technology, Clear Water Bay, Kowloon, Hong Kong; [5]Department of Physics, Nanjing University, Nanjing 210093, China.

Impurity doping is an effective and magic method for manipulating the physical properties of semiconductors. Doping 3d-paramagnetic transition-metal ions into wide-band-gap semiconductors can generate the optically transparent ferromagnetic diluted magnetic semiconductors (DMSs) that are applicable to novel spintronic devices with lower power consumption and faster operating speed than those of the charge-based counterparts. Zinc oxide (ZnO) is a wide-band-gap semiconductor with a high excitonic binding energy which has attracted considerable attention in the last few years and been identified as one of the most promising host materials for spintronics. The Curie temperature (Tc) of ZnO-based DMSs has been theoretically predicted to be above room temperature, and subsequently been verified experimentally in thin films, bulk samples, as well as various nanostructures very recently. However, the origin and quality of the ferromagnetism in doped ZnO by transitional metals still remains controversial. In this presentation, we report on the preparation of n-type wurtzite DMS of single-crystalline Co-doped ZnO nanocrystals (around 50 nm) using an ethanol-assisted solvothermal method that allows high pressure and the extreme conditions in the phase diagram but low-temperature processing without any catalysts. The magnetic properties are characterized by vibrating sample magnetometer and superconducting quantum interference device magnetometer. High-temperature ferromagnetism is observed with Tc much higher than room temperature (> 350 K) and the saturated magnetization at 300 K is about 0.86 μB/Co atom. Structural and spectroscopic characterizations have been performed, namely, x-ray diffraction, micro-Raman spectroscopy, cathodoluminescence, high-resolution x-ray photoelectron spectroscopy, high-resolution transmission electron microscopy, electron energy loss elemental mapping, and electron energy loss spectroscopy. All results indicate that Co ions (+2 valence state) are substituted for the Zn sites in ZnO and thus forming the magnetic defects. No secondary phases such as (Zn,Co)Co2O4, CoO, and cobalt-metal impurity are detected. Ferromagnetism is undoubtedly established to be intrinsic in our samples. Our results demonstrate that high-temperature DMSs in ZnO nanocrystals can be fabricated simply via a facile solvothermal route.

II7.8

Synthesis of the Magnetic Nanocomposites "MgFe2O4 Nanoparticles - Nonmagnetic Glass Matrix" by Oxidation of the Basaltic Glasses. Alexander V Knotko[1], Irina B. Davydova[1], Alexey V. Garshev[2,1] and Valery I. Putlayev[1]; [1]Dept of Chemistry, Moscow State Univ, Moscow, Russian Federation; [2]Dept of Material

Sciences, Moscow State University, Moscow, Russian Federation.

The processes in solid solutions, which lead to creation of the concentration inhomogeneties (compositional fluctuations) or to precipitation of new phases, are the perspective method of the modification of properties of the inorganic materials. Depending on the mechanism and degree of the passing, such transformations induce the appearance of specific micro- and nanostructures, which often improves the functional properties of the materials. The maximal homogeneity of the precipitates distribution in the matrix phase (which is important for many practical applications) may be arrived at the homogeneous nucleation or at homogeneous (i.e. accompanied by small the atomic rebuilding in large volume of the material) solid state process. For the substances which have not (according the phase diagram) the possibility of transformations without the changes in the chemical composition to the metastable state, in which the homogeneous transformations are possible, such transformation in some cases may be performed because of the diffusion in this compound of the component with very larger diffusion coefficient in comparison with other components (mechanism of the internal solid state reaction). The most easily realized at that are the reaction of internal oxidation (or reduction), in which one reagent (or reaction product) is in the gas phase. In the present work the nanocomposites "MgFe2O4 nanoparticles - nonmagnetic glass matrix" were obtained by oxidation of Fe2+ to Fe3+ in air at the temperatures 700 - 900C in the various commercial basaltic glasses (with different chemical composition). Also the basaltic glasses after (aqueous HCl, pH=2) hydrolysis were oxidized at the same conditions. The composites were tested by XRD, TEM, magnetization measurements. The MgFe2O4 nanoparticles (> 20 nm according TEM) formed at the first stage of thermomodification of non chemically modified glasses. The second stage consisted in the crystallization of plagioclases. In the CaO - rich glasses the crystallization of plagioclases was observed at the first transformation stage. This work was partially supported by Russian Foundation for Basic Researches (grant 05-03-32693a).

II7.9

Magnetization and Coercivity of Magnetite Nanoparticulates: Synthesis, Measurement and Model. Silvia Liong[1], Alexa W. Harter[2] and Rick L. Moore[2]; [1]School of Materials Science and Engineering, Georgia Institute of Technology, Atlanta, Georgia; [2]Signature Technology Laboratory, Georgia Tech Research Institute, Atlanta, Georgia.

It is well known that the saturation magnetization and coercivity of ferro and ferri magnetic nanoparticles (diameter less than 100 nm) deviate from bulk properties. In this work, the authors report on the fabrication and characterization of spherical magnetite (Fe_3O_4) nanoparticles in the size range of 5-12 nm. The nanoparticles were synthesized by chemical coprecipitation, a method that allowed for the production of relatively large quantities (on the order of grams). Ferric and ferrous salts, such as $FeCl_3$ and $FeCl_2$ respectively, were placed under basic conditions, where they hydrolyzed and precipitated as iron oxide particles. We report on how variations in pH, temperature, iron salt concentration, and ionic strength were used to control the size and morphology of the particles. Vibrating sample magnetometry was used to measure the room-temperature magnetization and coercivity of the particulates. Low temperature magnetic properties were obtained from SQUID and Mossbauer spectroscopy. These measurements were supported by XRD and TEM characterization. The saturation magnetization and coercivity both decrease with particle size. The coercivity decreases more or less linearly with particle size, indicating that the particles are superparamagnetic. The measured magnetization data is well fit by a model that calculates the magnetization as a volumetric average of a spherical core with magnetization near the bulk value and a passive outer shell. This analysis is supported by measurements on other iron-oxide nanoparticle systems found in the literature. The thickness of the shell calculated from the magnetization data (0.84 nm) is approximately equal to the lattice constant of the nanoparticles (0.8397 nm) calculated from XRD data. Such empirical observations, that fit magnetization and coercivity to simple algebraic forms, can be leveraged in application. The radio frequency (RF) resonant frequency of spherical particulates should be proportional to the coercivity. That resonant frequency could be used as an identifier of particulate size and thus trace molecular or biological species to which the particle is attached. The accompanying RF absorption can be applied in biotherapy. The particle's change in magnetization could be used to identify materials tagged with various sized magnetite particles

II7.10

Ferromagnetic Behavior of Carbon Nanospheres Encapsulating Silver Nanoparticles. Roman Caudillo[1,2], Xiaoxia Gao[1,2], Roberto Escudero[4] and Miguel Jose-Yacaman[3,2]; [1]Materials Science and Engineering, University of Texas at Austin, Austin, Texas; [2]Texas Materials Institute, University of Texas at Austin, Austin, Texas; [3]Chemical Engineering, University of Texas at Austin, Austin, Texas; [4]Instituto de Investigaciones en Materiales, Universidad Nacional Autonoma de Mexico, Mexico City, D.F., Mexico.

We report on the structure and magnetic properties of a silver and carbon nanocomposite produced by a silver electrode pulsed power plasma arc discharge process in an inert gas and hydrocarbon atmosphere. Structural characterization reveals that the nanocomposite consists of Ag nanoparticles encapsulated in carbon nanospheres that are interconnected and form flexible necklace-like structures. We show that the Ag nanoparticles can be physically removed from the carbon nanospheres with electron irradiation, clearly revealing them to be interconnected spherical closed carbon cages of 10 nm average diameter. The Ag nanoparticles can also be removed chemically, in which case the carbon nanospheres agglomerate and form a carbon nanofoam resembling Schwarzite. Trace metal analysis using ICP-MS indicates that there are no magnetic contaminants in the sample, yet magnetic measurements of the Ag and C nanocomposite show ferromagnetic behavior up to room temperature, with a coercive field of 400 Oe at 2 K and 100 Oe at 300 K, from which we estimate the presence of ferromagnetic behavior up to 425 K. We also measure a pronounced peak in the magnetization measurements between 50 and 90 K that is completely suppressed when measurements are made in the cooling direction. We attribute the magnetic behavior to the carbon nanospheres and propose a model for the observed magnetism: curvature in the carbon nanospheres introduces sp^3 character to sp^2 carbon sheets, thus localizing p_π spins which interact antiferromagnetically and, due to the curvature in the material, gives a canted spin, weak ferromagnetic component of the antiferromagnetically coupled p_π localized spins. In addition, frustrated interparticle coupling between the nanospheres gives a spin glass with a T_g that is suppressed to 10 K in the cooling direction, thus suppressing the observed peak in the magnetization.

II7.11

Fabrication of permanent magnet mixing $Nd_2Fe_{14}B$ (hard) and α-Fe (soft) by self-assembly. Young Soo Kang[1], Young Hwan Kim[1], Hyun Gil Cha[1], Hae Woong Kwon[2] and in Chul Jeong[2]; [1]Chemistry, Pukyong National Univ., Pusan, South Korea; [2]Materials Science and Engineering, Pukyong National Univ., Pusan, South Korea.

The magnetic α-Fe nanoparticles were prepared by wet-milling route in methanol with cationic surfactant and the milled for 20 hrs magnetic $Nd_{15}Fe_{77}B_8$ nanoparticles in methanol with anionic surfactant used in this study. $Nd_2Fe_{14}B$ and α-Fe nanoparticles on behalf of building up an exchange-coupled magnetic nanocomposite were mixed via self-assembly. So the mixture annealed in a vacuum furnace under vacuum (10-5 Torr) at 550 °C for 30 min. The mixture of $Nd_2Fe_{14}B/\alpha$-Fe of nanoparticle was confirmed by Transmission Electron Microscopy (TEM). The crystal structure of the nanocomposite was corroborated by using X-ray powder diffraction (XRD). The magnetization curve was measured with vibrating sample magnetometer (VSM). Thermogravimetry using a microbalance with magnetic field gradient positioned below the sample was used for the measurement of a thermomagnetic analysis (TMA) curve showing the downward magnetic force versus temperature.

II7.12

Ultra High Frequency Permeability of Magnetic Nano-Cermats. Jeremy Alan Lieberman, Cheong Yang Koh and Robert Bruce van Dover; Material Science, Cornell University, Ithaca, New York.

Thin films with high permeability, low magnetic coercivity and high resistance are desirable for many modern electromagnetic amplifying devices such as high frequency read-write heads for magnetic storage devices. These properties allow for devices to operate at a high frequency of electrical field oscillation, which directly determines how quickly data can be written to and read from a magnetic storage device. To make a material with these desirable properties we control the nano-structure of a Fe-M-O sample (M = Hf, Al, etc). Our films consist of metallic grains only a few nanometers in size in an oxide matrix. We are experimenting with both the composition and size of the grains in order to optimize the properties of the resulting cermets. A combinatorial co-deposition sputtering chamber that we have built allows us to rapidly explore wide swaths of the composition space. Film nanostructure, including the incorporation of Fe entirely in the nano-grains rather than in oxide form, is controlled by varying both the deposition conditions and post-deposition annealing schedules. We characterize our samples' resistivity, magnetization and the permeability at ultrahigh frequency. We explore the relation between the materials properties and its composition and structure. We also are able to explore multiple systems using our method for rapid sample production. We have observed that the relationship between the substrate used and the nano-structure of the film grown upon it influences the materials magnetic properties. We have successfully generated nano-structured grains and have seen the effects of the

structure on various properties.

II7.13
Magnetization and Curie Temperature Tuning in $Mn_xZn_{1-x}Fe_{2-y}R_yO_4$ (R = Gd, Eu) Ferrite Nanocrystals for Magnetocaloric Applications. Oscar Perales-Perez[1], Eric Calderon[2], Carmen Melendez[3], Gustavo Gutierrez[4] and Maharaj Tomar[5]; [1]General Engineering, University of Puerto Rico, Mayaguez, Puerto Rico; [2]Chemical Engineering, University of Puerto Rico, Mayaguez, Puerto Rico; [3]Industrial Engineering, University of Puerto Rico, Mayaguez, Puerto Rico; [4]Mechanical Engineering, University of Puerto Rico, Mayaguez, Puerto Rico; [5]Physics, University of Puerto Rico, Mayaguez, Puerto Rico.

The reasonably high saturation magnetization at room temperature and a Curie temperature, T_c, around 373K exhibited by nanocrystaline $Mn_xZn_{1-x}Fe_2O_4$ ferrite enable this material to be considered as a potential candidate for magnetocaloric pumping applications. The magnetocaloric pump needs to operate close to the T_c where temperature changes can produce significant demagnetization and, therefore, a significant pressure gradient to provoke the movement of the fluid bearing the ferrite nanocrystals. Acordingly, a suitable control of saturation magnetization and T_c in those ferrites becomes indispensable. In the present work, we investigated the dependence of magnetic properties with composition and crystal size in nanocrystalline Mn-Zn ferrites. The ferrite crystals were synthesized by a modified aqueous coprecipitation route where nucleation and crystal growth conditions were controlled during the reaction of 0.011M Fe(III) with 0.055M [Zn(II) + Mn(II)] solutions under alkaline conditions. When doping, suitable amounts of Gd(III) or Eu(III) salts were added to the Fe(III) ions in starting aqueous solutions. XRD, FT-IR and Raman spectroscopy analyses verified the formation of the Mn-Zn ferrite structure. An average crystallite size varying from 8 to 12nm in the evaluated composition range was estimated by using Scherrer's equation. SQUID analyses suggested that ferrite nanocrystals were superparamagnetic at room temperature. The maximum magnetization values, under an external field of 50 kOe, were strongly dependent on the composition of the Mn-Zn ferrite. Maximum magnetization values varied from 15 emu/g up to 41 emu/g for Mn atomic fractions of 0.0 and 0.7, respectively. The enhancement in magnetization with a raising fraction of Mn was attributed to the incorporation of magnetic Mn(II) for non-magnetic Zn(II) ions and their redistribution between the A- and B-sites in the ferrite structure. For a selected composition, the saturation magnetization was enhanced even further through a precise control on nucleation and crystal growth conditions. This type of control was achieved by adjusting the feeding rate of reactants in presence of pre-existent ferrite nuclei (seeds) in reacting solutions. The variation in magnetization with temperature for ferrites, in powdered form and as stable suspensions in aqueous and non-aqueous solvents, was also investigated. A T_c of 357K was determined from the magnetization-temperature data corresponding to an aqueous-based fluid bearing $Mn_{0.5}Zn_{0.5}Fe_2O_4$ nanocrystals. The variation in saturation magnetization and T_c for various concentrations of Gd(III) and Eu(III) species in the Mn-Zn ferrites, will also be presented and discussed.

II7.14
Synthesis of KY(WO4)2 and Doped Nanocomposites by Complex Sol-Gel Process. Andrzej Deptula[1], M. T. Borowiec[2], W. Lada[1], T. Olczak[1], D. Wawszczak[1], T. Zayarniuk[2], V. Domukhovski[2], P. Aleshkevych[1] and H. Szymczak[2]; [1]Institute of Nuclear Chemistry and Technology, Warsaw, Poland; [2]Institute of Physics, Polish Academy of Sciences, Warsaw, Poland.

A complex sol-gel process and use of ascorbic acid as a chelating agent were applied to preparation of KY(WO4)2 and nanocomposites of KY(WO4)2 doped with 1% additive. The rare-earth double tungstate compounds ARe(WO4)2, where A = K,Rb and Re = Dy, Er, Ho, Nd, Yb, are attractive materials as laser hosts [1] and of special interest in regard to magnetic and structural phase transitions [2]. Saturated tungsten sols (0.15 M) were prepared by dissolving (NH)10H2(W2O7)6 in an aqueous ascorbic acid solution. Y and Y + Yb nitrates were added to this solution. Sols were then gelled under reduced pressure and thermally treated. Thermogravimetric and differential thermal analyses coupled with X-ray diffraction measurements indicated that the final nanocomposites formed at the relatively low temperature of approximately 420C. Carbon-free products were obtained by firing at 550C for 10 h or at 650C for various times. To avoid these drying procedures, self-ignition was induced at temperatures of 250-450C. Only gels with high specific surface areas could be ignited. The decarbonization temperatures of tungstates were reduced from 650C through use of chemical treatment with concentrated nitric acid and hydrogen peroxide. Heat treatment of the resulting slips at 550C for 2 h yielded carbonate-free tungstates. X-ray diffraction (XRD) and electron paramagnetic resonance spectra were studied. The expected monoclinic phase C2/c of the KYW nanocomposites was confirmed by XRD. The unit cell parameters and the sizes of particles were determined. Electron spin resonance studies in the X-band were performed on the KYW and KYW:Yb nanocomposites, and on the KYW single crystals. Additional lines observed for the doped KYW were attributed to the presence of Yb ions. [1] J.A. Caird and S.A.Payne, Handbook of lasers ccience and technology, ed. M.J.Weber (1991); A.A. Kaminskii, Today and tomorrow of laser crystal physics, Phys. Stat. Sol. A 148 (1) 1995. [2] M.T. Borowiec, The phase transitions in double tungstates - in extremely low-dimensional and low-symmetry compounds with cooperative Jahn-Teller effect, Proc.SPIE 4412 (2001) 196. *This work was supported in part by the EU project DT-CRYS and by the Polish State Committee on Science (KBN; Project No. 72/E-67/SPB/6.PR/DIE 430/2004-2006).

II7.15
Abstract Withdrawn

II7.16
Magnetic Properties of Permalloy Nanoparticle Films Generated by Laser Ablation of Microparticle Aerosols (LAMA). Chong Huang[1], Eui Jung Yun[2], Ewerton Ickowzcy[1], Desiderio Kovar[1], John W. Keto[1] and Michael F. Becker[1]; [1]Texas Materials Institute, University of Texas at Austin, Austin, Texas; [2]Department of Electrical, Infomation and Communication Engineering, Hoseo University, Asan, Chungnam, South Korea.

Recently, it has been shown that nano-processing can provide an improved permalloy (Ni81Fe19; at%) films for future MHz to GHz micromagnetic devices (such as thin film inductors and transformers), recording heads, and spintronic devices (such as magnetic random access memory (MRAM)) with enhanced properties such as coercivity, electrical resistivity, hardness, corrosion behavior, and wear characteristics with minimal reduction in the saturation magnetization. There is, however, at present relatively little detailed information in the literature on the magnetic properties of permalloy nanoparticle (NP) films. In this study, therefore, we investigate the particle size dependence of magnetic properties in permalloy NP films prepared by laser ablation of micropaeticle aerosols (LAMA). Using the LAMA process, a KrF excimer laser with wavelength of 248 nm and pulse-width of 12 ns was focused onto a permalloy microparticle (Ni 81 at%: Fe 19 at%, Goodfellow NJ016010) aerosol stream which was constrained by a coaxial buffer gas. Two different gases (He and Ar) with different gas pressures (1 2 atm) were used to modify the produced nanoparticles (NPs) size, jet velocity, and thus the impaction energy of the NPs. The resulting NPs were deposited by a supersonic jet onto silicon substrates at ambient temperatures to form films. An in-plane bias magnetic field was applied during the deposition of some of the NP films. The use of a charge separation device to size-select the particles was also explored. Transmission electron microscopy (TEM) micrographs of the NPs formed under different conditions were compared. The magnetization-magnetic field loops of the magnetic NP films were obtained using a superconducting quantum interference device (SQUID) magnetometer over the temperature range 5 300 K. The electrical conductivity of the films was measured using a four-point probe technique. It was observed from experimental results that the particle diameter of permalloy NPs, density of the resulting films, and thus the magnetic and electrical properties of NP films can be modified by varying the processing parameters.

II7.17
Enhanced Chemical Ordering and Coercivity in FePt Alloy Nanoparticles by Sb-doping. Qingyu Yan, Taegyun Kim, Arup Purkayastha, Mutsuhiro Shima and Ganapathiraman Ramanath; Materials Science and Engineering, Rensselaer Polytechnic Institute, Troy, New York.

Obtaining the ordered tetragonal $L1_0$ phase at low temperatures is crucial to achieving high magnetic coercivity in FePt nanoparticles for ultra-high-density applications. We demonstrate for the first time that Sb doping stabilizes the chemically ordered tetragonal $L1_0$ structure in FePt alloy nanoparticles, yielding higher magnetic coercivity at lower annealing temperatures, than previously reported. Even the as-synthesized 8-nm-diameter nanoparticle assemblies with atomic fractions X_{Sb}=0.23 and X_{Sb}=0.14 are ferromagnetic at room temperature with coercivity H_c 120 mT and 10 mT, respectively. Upon annealing to 300 °C, nanoparticles with $X_{Sb} \geq$ 0.14 show H_c >500 mT, which is more than 10-times greater than that previously reported for FePt nanoparticles of similar sizes annealed to the same temperature. Transmission electron microscopy of the annealed assemblies shows no observable nanoparticle coalescence at 300 °C. SQUID measurements reveal an intrinsic coercivity[1] H_0 1200 mT and a thermal stability factor K_uV/k_BT 60 at room temperature. This implies an anisotropic constant K_u 3.5 MJ/m^3. The high H_c resulting from enhanced low-temperature chemical ordering is suggested to be due to increased Fe and Pt mobility facilitated by segregation of

high-activity and low-surface energy Sb. 1. S. H. Sun, E. E. Fullerton, D. Weller, and C. B. Murray, "Compositionally controlled FePt nanoparticle materials," IEEE T Magn 37 (4), 1239-1243 (2001).

II7.18
Surfactant-Confined Growth of Face-Centered-Cubic (fcc) FePt Nanoparticles and Subsequent Thermal Transformation to Face-Centered-Tetragonal (FCT) FePt Nanoparticles.
William H. Morris and Charles M. Lukehart; Chemistry, Vanderbilt University, Nashville, Tennessee.

The magnetic recording industry considers ferromagnetic face-centered-tetragonal (fct) FePt nanoparticles to be a promising material for the next generation of media storage. The evolution of face-centered-cubic (fcc) FePt nanoparticles (average size 104 nm) by reduction of iron (III) chloride and potassium tetrachloroplatinate within size-confining surfactant vesicles in aqueous media and subsequent thermal annealing to transform the obtained fcc FePt nanoparticles to fct FePt nanoparticles is reported. High concentrations of surfactants, such as hexadecyltrimethylammonium bromide (CTAB) and sodium octyl sulfate (SOS), restrict the growth of fcc FePt nanoparticles. Extensive nanoparticle coalescence during the annealing process is avoided by immobilizing fcc FePt nanoparticles on a silica surface prior to thermal annealing using 3-aminopropyldimethylethoxysilane as a linker molecule. Annealing is necessary for phase transformation of fcc FePt nanoparticles to fct FePt nanoparticles. Transmission electron microscopy (TEM), energy dispersive spectroscopy (EDS), and powder x-ray diffraction (XRD) data confirm the structure, size, and composition of the resulting alloy nanoparticles. Magnetic property data will be presented, as available.

II7.19
The Mechanism of (001) Texture Evolution in FePt Thin Film during Post-annealing. Jaesong Kim[1], Lee Byeong-Joo[1], Lee Seong-Rae[2] and Koo Yang-Mo[1]; [1]Materials Science and Engineering, Pohang University of Scinece and Technology, POHANG, GYUNGBUK, South Korea; [2]Materials Science and Engineering, Korea University, Seoul, South Korea.

Strain and surface energies of FePt L10 alloy were calculated in order to find the origin of FePt thin film (001) texture evolution during post-annealing, where the modified embedded atom method (MEAM) was used for it. Calculations show that the (111) surface plane had the lowest energy among crystal planes like other fcc crystals, as confirmed by atomic force microscopy (AFM). Corresponding to simple biaxial strain, the (100) orientation (crystals having (100) crystallographic orientation relative to the surface of the film) had the lowest or similar energy to the (001) orientation. Transformation strain with free normal stress and biaxial strain conditions caused the (001) orientation to have the very lowest energy when compared to other crystals. Since FePt L10 alloys have a large transformation strain according to the (001) axis, a (001) orientation which has no stress to the (001) direction can consume the large strain. This result indicates that the origin of the (001) texture evolution is not surface or simple biaxial strain, but a transformation strain under free normal stress conditions.

II7.20
Texture Analysis of Sputter-deposited Co_3Pt on NiFeMo/Ru Buffer. Duhyun Lee[1], T. W. Lim[1], S. Y. Yoon[2] and S. J. Suh[1]; [1]Dept. of Advanced Materials Eng., Sungkyunkwan University, Suwon, Kyonggi-do, South Korea; [2]Storage Lab., Samsung Advanced Institute of Technology, Yongin, Kyonggi-do, South Korea.

For high-density magnetic recording media, chemically ordered binary alloy such as Co_3Pt, CoPt, and FePt are studied extensively because of their high magnetic anisotropy (K_U). In most cases, these films are grown with MBE (molecular beam epitaxy). But for mass production, the sputtering is more favorable than the MBE. Previous MBE studies showed that not only the long-range-ordered (LRO) Co_3Pt, but also the short-range-ordered (SRO) one could have high K_U comparable to the former. And this fact elucidated the possibility of sputtering to get high K_U Co_3Pt. Thus, in this study, Co_3Pt film was grown with sputtering. For highly textured Co_3Pt, and finally high perpendicular magnetic anisotropy, the bilayer buffer of NiFeMo/Ru was used instead of Ru single-layer buffer. The NiFeMo has the composition of Ni 79 - Fe 16 - Mo 5 wt. % and shows advantageous properties such as low misfit with Ru and Co_3Pt, good (111) texture, and highly soft ferromagetics. The multilayer of Ta 5nm/ NiFeMo x nm/ Ru 30nm/ Co_3Pt 50nm was sputter-deposited on the Si substrate that had native oxide on its surface. Changing the NiFeMo thickness from 0 to 20 nm the texture evolution of Ru and Co_3Pt was observed with XRD and TEM. A sputter-deposited Ru typically has hcp (0002) texture perpendicular to the plane. And Co_3Pt was expected to grow with same texture with Ru. For the multilayer without NiFeMo, however, the XRD 2theta-theta scan revealed no preferred orientation of Ru and Co_3Pt. Perpendicular magnetic anisotropy was not observed also. Whereas, in case of NiFeMo/Ru buffer, highly (0002) textured Ru was produced and the FWHM from the rocking curve of Ru (0002) was about 4.5°. The close-packed plane of Co_3Pt also grew perpendicular to the plan. And as a result, enhanced perpendicular magnetic anisotropy was obtained. Only the 5 nm of NiFeMo was good enough to induce the texture to above layers. Thick NiFeMo instead increased the rocking-curve FWHM of above layers. For the optimum sample with 10 nm NiFeMo, the VSM result from out-of-plane direction showed the coercivity and the squarness about 2.15 kOe and 0.57 respectively. K_U measured with torque magnetometer was about 1.5×10^6 erg/cm^3. The ordered Co_3Pt has hcp m-$D0_{19}$ structure and the disordered has fcc. From XRD, it was difficult to distinguish the presence of hcp, because the hcp (0002) and fcc (111) has a same diffraction angle, and no superlattice peak - the evidence of LRO - was observed. Instead, cross-sectional TEM observation revealed the co-existence of hcp and fcc in Co_3Pt layer. The selected area diffraction pattern indicated the presence of not only fcc but also hcp, distorted hcp, and mosaic structures. Nearly continuous columnar growth between Ru and Co_3Pt with average diameter of 11 nm was observed from TEM images. In conclusion, the enhanced perpendicular anisotropy can be attributed to the enhanced texture and the existence of hcp in the Co_3Pt layer.

II7.21
Abstract Withdrawn

II7.22
Orientation and Magnetic Property of FePt Films Grown on MgO(001) and (110) Substrates by Electron-Beam Coevaporation. Minghui Yu[1,2,3], H. Ohguchi[2], I. Takeuchi[2], J. P. Liu[3], D. Josell[4] and L. A. Bendersky[4]; [1]Advanced Materials Research Institute, University of New Orleans, New Orleans, Louisiana; [2]Materials Science and Engineering, University of Maryland, College Park, Maryland; [3]Department of Physics, University of Texas at Arlington, Arlington, Texas; [4]Materials Science and Engineering Laboratory, National Institute of Standard and Technology, Gaithersburg, Maryland.

The growth of epitaxial FePt films is of great interest since FexPt1-x films (with x 0.5) can form the $L1_0$ tetragonal, chemically ordered (CuAu I) phase which has high saturation magnetization and magnetocrystalline anisotropy. The good hard magnetic property of FePt $L1_0$ film makes it suitable choice for studying the exchange coupled nanocomposite magnets. The ideal model system for studying the soft/hard exchange coupling is epitaxial magnetic bilayer, which is especially important for understanding the influence of interface orientation and condition to the exchange coupling. In this work, we studied the orientation and magnetic property of the FePt films grown on MgO(001) and (110) single-crystal substrates by electron-beam coevaporation. The substrates were heated to 600 oC for the deposition, and the deposition rates of Fe and Pt were fixed at 0.4 Å/S and 0.5 Å/S, respectively. For the FePt film grown on MgO(110), a 10 Å thick Pt buffer layer was first deposited at 700 oC with the deposition rate of 0.1 Å/S. The epitaxial growth of the FePt films was proved by XRD measurements. Two orientations (00l) and (h00) were observed in the FePt film grown on MgO(001) substrate, and three orientations (hh0), (h0h) and (00l) in the film grown on Pt buffered MgO(110) substrate. High magnetic anisotropy was observed in these two FePt films, and the relation between the orientation and the magnetic anisotropy will be discussed in detail.

II7.23
Spin-polarized Current Induced Magnetization Switching for Ferrimagnetic Thin Films. Alberto Canizo-Cabrera[1], Valentin Garcia-Vazquez[2] and Te-ho Wu[1]; [1]Taiwan SPIN Research Center, National Yunlin University of Science & Technology, Touliu, Yunlin, Taiwan; [2]Instituto de Fisica Luis Rivera Terrazas, Universidad Autonoma de Puebla, Puebla, Puebla, Mexico.

The magnetization dynamic (driven magnetic precession and magnetic reversal) study by the current-induced spin transfer was first shown by Slonczeswki and Berger [1,2]. The dynamics of the magnetization of the magnetic free layer in the presence of a spin transfer torque is described by the modified Laundau-Lifshitz-Gilbert (LLG) equation that includes spin transfer torque. Most of the works related to this phenomenon have used in-the-plane magnetization materials as the source material [3,4,5]. In this work we present a theoretical study of magnetization dynamics by spin-transfer torque using perpendicular anisotropic magnetic thin films which contain two strongly coupled antiparallel magnetic subnetworks. We have developed the modified LLG equation to be used in this kind of material and demonstrated the final equation governing the dynamics of net magnetization as well as results of the time evolution of net magnetization under the influence of a spin-current. Furthermore, the estimation of critical current for the application of MRAM writing has been also developed. 1. J. C. Slonczewski, J. Magn. Magn. Matter. 159, L1 (1996). 2. L. Berger, Phys. Rev. B 54, 9353 (1996). 3. J. Z. Sun , Phys. Rev. B 62,

570 (2000). 4. Z. Li and S. Zhang, Phys. Rev. B 68, 024404 (2003). 5. Y. Jian, T. Nozaki, S. Abe, T. Ochiai, A. Hirohata, N. Tezuda and K. Inomata, Nature Materials, 3, 361 (2004).

II7.24

Multiple Magnetic Reorientation Transition in Ultrathin Co Films on Ru(0001). Farid El Gabaly[1,6], Silvia Gallego[2], Carmen Munoz[2], Laszlo Szunyogh[3], Peter Weinberger[3], Christof Klein[5], Kevin F. McCarty[4], Andreas K. Schmid[5] and Juan de la Figuera[1,6]; [1]Fisica de la Materia Condensada, Universidad Autonoma de Madrid, Madrid, Spain; [2]Instituto de Ciencia de Materiales de Madrid, CSIC, Madrid, Spain; [3]Center for Computational Materials Science, Technische Universitat Wien, Vienna, Austria; [4]Sandia National Laboratories, Livermore, California; [5]Lawrence Berkeley National Laboratories, Berkeley, California; [6]Centro de Microanalisis de Materiales, Universidad Autonoma de Madrid, Madrid, Spain.

The existence of magnetic anisotropy in ultrathin films has been one of the most important discoveries in low dimensional magnetism, with direct application in the improvement of the storage density of magnetic memory devices. We have studied the structure and magnetism of ultrathin Co films on Ru(0001) by means of conventional and spin polarized low energy electron diffraction (LEEM and SPLEEM). We find that Co/Ru presents two spin-reorientation transitions (SRT) as the Co thickness increases from 1 to >3 layers. The first monolayer of Co is magnetized in-plane with a Curie temperature of 170K, while films two monolayers thick are magnetized out-of-plane (with a Curie temperature close to 500K). For more than three layers the magnetization is found to be in-plane again. We correlate these magnetic properties with the structure of each film: while the first Co layer grows pseudomorphically, there exists a lateral relaxation beginning with the second layer. Ab-initio calculations of the magnetic anisotropy energy (MAE) within the Screened Korringa-Kohn-Rostoker (SKKR) method evidence the fundamental role in the multiple SRT of the structural evolution as the Co thickness enlarges. While the MAE of films above 2 Co layers is governed by the magnetic dipole-dipole interaction, which favours an in-plane magnetization, a delicate interplay of structural parameters determines the MAE of the thinnest films. Its ultimate origin can be understood regarding the balance between surface and interface layerwise contributions to the MAE.

II7.25

Investigation of Size Effects in Nanostructured Magnetic Elements in Thin Film Matrices. Jeremiah T Abiade[1] and Dhananjay Kumar[1,2]; [1]Mechanical Engineering, North Carolina A&T State University, Greensboro, North Carolina; [2]Condensed Matter Science Division, Oak Ridge National Laboratory, Oak Ridge, Tennessee.

Magnetic nanostructures and composites containing magnetic elements embedded in nonmagnetic materials have received considerable interest. To realize the potential benefits of truly nanostructured magnetic components, we have used pulsed laser deposition (PLD) to embed Ni and Fe nanoparticles in various thin film matrices such as TiN and Al_2O_3. The size of Ni and Fe inclusions was controlled by varying the deposition time. To investigate the effect of size and magnetic coupling, single and multiple layers of Ni and Fe (2-100 nm) were sandwiched between thin films of TiN and Al_2O_3 (25 nm) by sequential ablation of the appropriate target. In this talk, we will discuss the field and temperature dependence of the magnetization measured using a superconducting quantum interference device magnetometer. Structural characterization was carried out using x-ray diffraction (XRD), x-ray reflectometry (XRR), and transmission electron microscopy (TEM). The XRD, XRR, TEM, and magnetic measurements demonstrate that PLD provides a reproducible method for self-assembly of nanomagnetic particles with precise dimensional and stoichiometric control.

II7.26

Switching Between Continuous and Discontinuous Spin-Reorientation Transition in Ultra-Thin Ni/Cu(100) Films. Christof Klein[1], Robert Ramchal[3], Andreas K. Schmid[1] and Michael Farle[2]; [1]Materials Sciences Division, Lawrence Berkeley National Laboratory, Berkeley, California; [2]Institut fuer Physik, Universitaet Duisburg-Essen, Duisburg, Germany; [3]Technische Natuurwetenschappen, Universiteit Twente, Twente, Netherlands.

The inverse reorientation of the magnetization from in-plane to out-of-plane in ultra-thin Ni films grown on Cu(100) has attracted a great deal of attention in the last decade due to its anomalous thickness dependence. Surprisingly, the order of this transition is still not completely clear. In the present work, we used spin-polarized low-energy electron microscopy (SPLEEM) to study whether this thickness-dependent spin-reorientation transition (SRT) is continuous or discontinuous. Using SPLEEM it is possible to simultaneously measure the direction of magnetization as well as shape and size of magnetic micro-domains during in-situ film growth. This allows us to unambiguously determine the order of the SRT. We found that both transition kinetics are possible and that surface topography of the Cu substrate determines the order of the SRT. By suitable preparation of the Cu substrate we were able to switch back and forth between continuous and discontinuous SRT on the same sample. For Cu crystals, which show no step bunching, a continuous, second order SRT was observed, i.e. spiral-like movement of the magnetization vector from in-plane and parallel to the steps to out-of-plane and perpendicular to the steps. However, when step-bunching was considerably enhanced, a first order SRT was found to take place, i.e. sample magnetization switches discontinuously from in-plane to out-of-plane. Consequently, we can reconcile the discrepancies found in the literature by attributing them to different crystal morphology.

II7.27

Electrochemical manipulation of the magnetic properties of iron oxide thin films. Vikram Sivakumar[1], Caroline A Ross[1], Sundeep Kumar[2] and Yang Shao-Horn[2]; [1]Materials Science and Engineering, Massachusetts Institute of Technology, Cambridge, Massachusetts; [2]Mechanical Engineering, Massachusetts Institute of Technology, Cambridge, Massachusetts.

Thin films of maghemite (γ-Fe_2O_3) and Iron Manganese Oxide $(Mn_{1-x}Fe_x)_2O_3$ were grown by pulsed laser deposition from pressed oxide targets on single crystal Si, MgO and polycrystalline Cu substrates. The iron oxide films were grown with laser energies of 300-500 mJ/pulse, laser repetition rates between 25 and 50 Hz, temperatures between 300-500^{0}C and at pressures in the range 10^{-4} to 10^{-5} Pa. The iron-manganese oxide films were grown at similar energies at 20-25 Hz, 500-700 ^{0}C in vacuum (10^{-5} torr) and under oxygen pressure (10-60 mtorr). The films were characterized for magnetic properties by Vibrating Sample Magnetometry (VSM) and thickness by profilometry. Structural characterization was done by (θ-2θ and Glancing Angle) X-ray diffraction and Wavelength Dispersive Spectroscopy. Iron oxide films grown on copper were lithiated electrochemically. Lithium metal was used as anode and 1M $LiPF_6$ in EC:DMC (1:1 volume) was used as electrolyte. Coin cells of the form Li—1M $LiPF_6$ (EC:DMC)—Iron oxide was assembled inside an Argon filled glove box (oxygen level less than 1ppm and moisture level less than 5ppm). Such coincells were discharged galvanostatically at rates of C/50 to C/200 to voltage cutoffs in the range 1.2V to 0.8V. These films were analyzed for structure and magnetic properties post-lithiation. The iron oxide films grow in the inverse spinel structure, and this structure is observed to persist upon lithiation. The films on copper show a (111) texture, and X-ray diffraction measurements show that the intensity of the (311), (220) and (440) peaks decrease upon lithium insertion. The magnetic moment of the films is observed to decrease upon electrochemical discharge. The change in saturation moment can be as high as 18% due to lithium insertion. The decrease in magnetization can be used as a diagnostic tool for determining the positions into which the various ions go. This can be used as a canonical system for probing thin films of other magnetic oxides where a bigger change could be effected in the magnetic properties, in particular the saturation magnetization, by insertion of Li ions into the host structure.

II7.28

Magnetic and Electrical Properties of Room-Temperature Spin-Polarized Mn-Doped Fe_3O_4 Ultrathin Films Grown on Various Insulating Substrates. Issei Satoh[1], Mizue Ishikawa[1], Luca Pellegrino[1,2], Hidekazu Tanaka[1] and Tomoji Kawai[1]; [1]ISIR, Osaka University, Osaka, Japan; [2]LAMIA, INFM-University of Genova, Genova, Italy.

Magnetite (Fe_3O_4) has become a matter of interest for spintronics due to its high Curie temperature (860 K) and fully spin-polarized halfmetallic properties which can allow for spin-dependent tunneling magnetoresistance (TMR) devices with quite high efficiency. We have reported on pulsed-laser deposition (PLD) growth of Mn-doped Fe_3O_4 and achievements of low carrier concentration without losing carrier-spin polarization [1]. It is quite important to know about the electronic structures close-by interfaces between ferromagnet electrodes and barrier insulators for fabricating TMR junctions. In order to investigate the electronic transport properties close-by the interfaces, $Fe_{2.5}Mn_{0.5}O_4$ (FMO) ultrathin films (5, 10 nm) are grown by PLD technique (ArF excimer laser, 193 nm) on various insulating substrate materials, MgO (100), $SrTiO_3$ (STO) (100) and Al_2O_3 (0001), under growth conditions of substrate temperature 300 °C, O_2 gas ambient pressure 10^{-4} Pa. Various techniques such as x-ray diffraction, SQUID magnetometry, atomic force microscopy and x-ray photoelectron spectroscopy are used. The orientation of films grown on MgO (100) and STO (100) substrates is (100) direction while that on Al_2O_3 (0001) is (111). The saturated magnetizations of films at room temperature are around $\sim 1.0\times10^2$ emu/cm^3 for on MgO (100) and on STO (100), $\sim 1.5\times10^2$ emu/cm^3 for on Al_2O_3 (0001), respectively. The magnetization and resistivity of FMO ultrathin films

grown on MgO (100) substrates are close to those of thicker films (∼100 nm). The temperature dependence of resistivity is semiconducting for all films, and the resistivity of the films on Al_2O_3 (0001) at room temperature is lower than those on MgO (100) and STO (100). The substrate dependence of resistivity-temperature data exhibit interesting features, which are analyzed in terms of the its (111) film orientation on Al_2O_3 (0001) substrates and/or large lattice mismatch between FMO and Al_2O_3. [1] M. Ishikawa, H. Tanaka, T. Kawai, Appl. Phys. Lett. 86, 222504 (2005).

II7.29
Preparation of Highly Conductive Mn-Doped Fe_3O_4 Thin Films with Spin Polarization at Room Temperature using Pulsed Laser Deposition Technique. Hidekazu Tanaka, Mizue Ishikawa and Tomoji Kawai; ISIR-Sanken, Osaka University, 8-1 Mihogaoka, Osaka, Japan.

We report preparation of $Mn_xFe_{3-x}O_4$ (x=0, 0.1, 0.5) films using pulsed laser deposition technique, and their modified film formation condition and electrical/magnetic properties toward application to room temperature spin electronics devices. Third elements such as Co- and Ni-doped ferrite are one of modification method on electrical/magnetic properties in spinel type- ferrite, but they are usually insulators, and are not applicable to electronics. In order to generate possible carrier conduction and modulation while preserving the transport mechanism via the B site network with half-metallicity, the third elements need to be selectively substituted into the A sites, and not the B sites. The $Mn_xFe_{3-x}O_4$ film with x=0.1 could be fabricated at the higher substrate temperature of 600C than Fe_3O_4 thin film without Mn doping. The resistivity of the doped films exhibited low resistivity of about $7.0x10^{-3}$(x=0.1) $9.0x10^{-2}$(x=0.5)Ωcm at room temperature. Moreover, a spin polarization of carrier of $Mn_xFe_{3-x}O_4$ (x=0, 0.1, 0.5) films was confirmed at room temperature by anomalous Hall coefficient measurements. As manganese contents increase from x=0 to x=0.5, carrier mobility kept constant value of $10^{-1}cm^{-2}$/Vsec while carrier concentration decreased from $8.2x10^{21}/cm^3$ to $7.3x10^{20}/cm^3$. Judging from the constant mobility, it is considered that low resistivity of Mn doped Fe_3O_4 is realized by substitution of Mn ion in A site without disturbing conduction path of Fe ion network in B site. Therefore it?fs considered that Mn doped Fe_3O_4 thin films could be fabricated as the spinel structure even under the higher oxidizing film formation condition without any impurity phase. The fabrication of $(Fe,Mn)_3O_4$ even under higher oxygen pressure and temperature will facilitate the construction of novel functional heterostructures such as magnetite based FET **.** [Ref.] M. Ishikawa et al. Appl. Phys. Lett. 86 (2005) 222504

II7.30
Influence of the C-Axis Conductivity of the Cuprate on Interlayer Magnetic Coupling in Manganite-Cuprate-Manganite Trilayers. K. Senapati, S. Mandal, S. K. Bose and R. C. Budhani; Department of Physics, Indian Institute of Technology Kanpur, Kanpur, India.

The magnetic interlayer exchange coupling (IEC) between two ferromagnetic layers separated by a non-magnetic spacer has remarkable technological consequences and offers rich physics. Surprisingly however, while the literature on IEC through various metallic and insulating spacer materials is extensive, the case of a superconducting spacer has attracted little attention. Superconductors as spacers are interesting due to the fact that below the superconducting transition temperature (T_c), the pair condensation drastically changes the Fermi surface by opening an energy gap. Since IEC is established as a Fermi surface phenomenon, it is interesting to study its behavior across the T_c of the spacer material. The absence of quasiparticle states near the Fermi surface of an s-wave superconducting spacer forbids magnetic correlation below T_c. However, high T_c superconducting spacers are expected to be much more permeable to IEC due to the anisotropic (d-wave) nature of the energy gap. We have studied the temperature dependent magnetic exchange coupling between two ferromagnetic $La_{0.67}Sr_{0.33}MnO_3$ layers through a c-axis oriented $YBa_2Cu_3O_7$ spacer of thickness in the range of 50 Å to 300 Å, in a trilayer geometry [1, 2]. In all cases, dc-magnetization measurements reveal an antiferromagnetic ground state of the system. Interestingly, the long range antiferromagnetic correlation was also clearly observable in the superconducting state of the $YBa_2Cu_3O_7$. In order to investigate the origin of this predominantly antiferromagnetic coupling, we replaced the intermediate $YBa_2Cu_3O_7$ layer with an isostructural insulator $PrBa_2Cu_3O_7$ whose c-axis resistivity is a few orders of magnitude higher than the resistivity of $YBa_2Cu_3O_7$. No signature of any magnetic coupling between the ferromagnetic boundaries was observed in this case. This result shows a strong dependence of the magnetic coupling phenomenon on the c-axis conductivity of the cuprate. The evolution of interlayer exchange coupling as the c-axis resistivity of the cuprate is decreased in a controlled manner will be addressed in the paper. Acknowledgement: This research has been supported by a grant from the Defense Research and Development Organization, Govt. of India. [1] K. Senapati and R. C. Budhani, Phys. Rev. B 70, 174506 (2004). [2] K. Senapati and R. C. Budhani, Phys. Rev. B (2005) in press; cond-mat/0504237.

II7.31
Thin Films of Metallic Antiferromagnet $La_{0.45}Sr_{0.55}MnO_3$ for Exchange Biasing of Spin Valves. P. K. Muduli, S. K. Bose and R. C. Budhani; Department of Physics, Indian Institute of Technology Kanpur, Kanpur, India.

Spin dependent tunneling in magnetic tunneling junctions (MTJs) is currently an active field of research. One of the most important properties of MTJs is that the tunneling current depends on the relative orientation of magnetization of the two ferromagnetic layers across the tunneling barrier. Generally, the magnetization of one of the layers is pinned by an antiferromagnetic material, while the moment of the other layer follows the external magnetic field. One of the promising ferromagnet for MTJs is the half metallic $La_{0.67}Sr_{0.33}MnO_3$ (LSMO). A good choice of biasing antiferromagnet in this case is $La_{0.45}Sr_{0.55}MnO_3$. This compound is an A-type antiferromagnet (AF) with lattice parameter same as that of $La_{0.67}Sr_{0.33}MnO_3$, and is free from charge ordering phenomena. In spite of these important characteristics of AF-LSMO for MTJs, very little attention has been given to thin film of this compound. Here we report a systematic study of the structure, magnetic ordering and electrical resistivity of AF-LSMO films deposited on two substrates, $NdGaO_3$ (110) (NGO) and $SrTiO_3$ (100) (STO) by pulsed laser ablation. Magnetization measurements on films deposited on NGO and STO showed a Nèel temperature T_N of 220 K. The onset of antiferromagnetic ordering in films deposited on NGO also reflects itself as a sharp cusp in resistivity ρ(T). The ρ(T) below the T_N is metallic, although its absolute value is quite large (400 $\mu\Omega$cm). This metallic behavior persists down to 50 K and then the resistivity starts increasing on lowering the temperature. The absolute value of resistivity at any temperature has a striking dependence on film thickness. The resistivity is minimum for 400Å thick films. It increases up to 1000 Å and then drops on further increase in thickness. This unusual behavior of resistivity can be understood from the fact that as the thickness is lowered there is continuous increase in strain which presumably affects the perfect antiferromagnetic alignment of Mn-core spins of the neighboring MnO_2 planes and facilitate hopping along the c-direction. However, when film thickness becomes smaller (< 400 Å), thin film size effects also contribute to the resistivity and the decreasing trend is reversed. This interpretation for the variation of resistivity is consistent with the results of lattice parameter measurement. The absolute values of the resistivity of the films deposited on (100) STO is higher as compared to the film of the same thickness on NGO. Details of these results along with the nature of magnetic coupling between ferromagnetic LSMO and AF-LSMO bilayers will be presented. Acknowledgement: This research has been supported by a grant from the Defense Research & Development Organization (DRDO) of India.

II7.32
Investigation on ferromagnetism in $La_{1-x}Ce_xMnO_3$ thin films using soft x-ray absorption magnetic circular dichroism. Takeshi Yanagida[1], Hidekazu Tanaka[1], Tomoji Kawai[1], Yuji Saitoh[2], Yukiharu Takeda[2] and Atsushi Fujimori[3]; [1]ISIR-Sanken, Osaka University, Osaka, Japan; [2]JAERI/SPring-8, Hyogo, Japan; [3]Department of Complexity Science and Engineering, University of Tokyo, Chiba, Japan.

The perovskite type manganese oxides have attracted much attention of many researchers due to their fascinating physical properties. The major interest of research in this field has been directed at hole-doped systems with doping a divalent cation (e.g. Ca, Sr and Ba), while it has been recently reported that electron-doped manganese oxide systems would be also feasible by doping a tetravalent cation including Ce. If such electron-doped systems were available, the p-n homo-junctions of both hole and electron-doped manganese oxides would be possible and promising for spintronics applications in the future. Among them, $(La,Ce)MnO_3$ (LCeMO) system has been reported to exhibit the metal-insulator transition and ferromagnetic transition. The presence of Mn^{2+} by doping Ce was also shown by spectroscopy measurement. However, the contribution of Mn^{2+} to ferromagnetism is not clear and such information would be crucial to clarify the physical origin of ferromagnetism within LCeMO. Thus this study investigates ferromagnetism of LCeMO thin films using x-ray absorption spectroscopy (XAS) and the magnetic circular dichroism (X-MCD). LCeMO thin films were fabricated by PLD technique as reported elsewhere. XAS and X-MCD measurements were performed at the BL23SU (JAERI BL) beamline in SPring-8. For comparison, LCeMO films whose transition temperatures were ranged from 150-260K were used with post-annealing. On the XAS data, the presence of Mn^{2+} within LCeMO films was found for all

films. The intensity of Mn^{2+} peak however decreased with increasing the transition temperature. This clearly contradicts with general scenario based on a double exchange interaction, since the transition temperature scales with the carrier density. More crucially the X-MCD data of LCeMO films was found to be consistent with that of hole-doped manganites. These results highlight that the contribution of Mn^{2+} to ferromagnetism in LCeMO is negligible and the origin of ferromagnetism is mainly due to a double exchange interaction between Mn^{3+} and Mn^{4+} with cation vacancies and/or over-oxidization even in the presence of Mn^{2+}.

II7.33

Structural, magnetic properties and x-ray absorption spectroscopy of $Nd_{1-x}Ce_xMnO_3$ thin films. Takeshi Yanagida[1], Hidekazu Tanaka[1], Tomoji Kawai[1], Yuji Saitoh[2], Yukiharu Takeda[2] and Atsushi Fujimori[3]; [1]ISIR-Sanken, Osaka University, Osaka, Japan; [2]JAERI/SPring-8, Hyogo, Japan; [3]Department of Complexity Science and Engineering, University of Tokyo, Chiba, Japan.

Tetravalent cation-doped manganites have recently attracted much attention due to their scientific importance as well as potential application in the p-n homo-junctions of both hole and electron doped manganese oxides. Among them, (La,Ce)MnO_3 (LCeMO) systems, which exhibited metal-insulator transition, ferromagnetic transition and colossal magnetoresistance effect, have been considered to be promising as electron-doped manganites. Recent investigation however revealed that the origin of ferromagnetism in LCeMO is related to self-hole doping effects due to cation vacancies, over-oxidization and Ce-rich nanosized impurities. Since the ionic radius of cation in manganites affects significantly the physical properties as seen in hole doped systems, it would be interesting to investigate such effects by changing A site cation. $Nd_{1-x}Ce_xMnO_3$ (NCeMO) thin films were fabricated by PLD technique as reported elsewhere. Note that the single phase of these bulk materials were found to be not feasible by solid state reaction method due to CeO_2 segregation phases. XRD measurements of these films showed the single phase of these films and did not show any impurity peaks of CeO_2 segregation phases. More importantly, HRTEM-EDS analysis demonstrated the absence of Ce-rich impurities within NCeMO films, which essentially differs from trends of LCeMO films. Thus the ionic radius of A-site cation plays an important role on the microstructure of tetravalent cation-doped manganites. NCeMO films deposited under reduction atmosphere only exhibited weak ferromagnetic behavior with the Curie temperature around 65K. In order to clarify the origin of ferromagnetic-like behavior within NCeMO films, soft x-ray absorption spectroscopy measurement is performed at SPring-8. Possible scenarios for the ferromagnetic-like behavior of NCeMO films will be discussed in the presentation.

II7.34

Colossal Magnetoresistance and Negative Thermal Expansion in the Ruthenocuprate RuSr2Nd1.1-xYxCe0.9Cu2O10. Abbie Christina Mclaughlin[1], Falak Sher[2] and John Paul Attfield[2]; [1]Chemistry, Aberdeen University, Aberdeen, United Kingdom; [2]Centre for Science at Extreme Conditions and School of Chemistry, University of Edinburgh, Edinburgh, United Kingdom.

Coexistence of weak ferromagnetism and superconductivity was recently discovered in the 1222 and 1212 ruthenocuprate systems RuSr2RECeCu2O10 and RuSr2RECu2O8 [1-3] (RE = Sm, Eu, Gd). Novel ruthenocuprates RuSr2Nd1.1-xYxCe0.9Cu2O10 (x = 0.1, 0.2) have recently been synthesised in air by conventional solid-state methods; these materials are fascinating. The compounds are semiconductors and two magnetic transitions are observed from neutron diffraction and magnetic susceptibility data. Antiferromagnetic order of the Cu spins is observed below TN = 50 K and weak ferromagnetic order of the Ru spins is observed below TM = 140 K. Surprisingly, bulk negative magnetoresistance (MR) is also observed below this temperature and increases rapidly below the second magnetic transition at 50 K. Bulk negative MR values up to 34% for RuSr2Nd1.0Y0.1Ce0.9Cu2O10 have been observed at 4 K in a 7 T field. Large bulk MR effects have not been previously reported in cuprate ceramics, and these results show that a very strong spin-charge coupling can occur in the normal state. Even more interestingly, results from neutron diffraction recorded on beamline D2B at the ILL show that negative thermal expansion (NTE) is observed in RuSr2Nd0.9Y0.2Ce0.9Cu2O10 below TM = 140 K. The unit cell edges and volume show a normal thermal contraction on cooling from room temperature to 140 K, but then expand on cooling from 140 K to 4 K with an average volume coefficient of $\alpha V = d(\ln V)/dT$= -1.43 x 10 -6 K-1. The NTE arises from an anomalous increase in the separation of the CuO2 planes below TM. This is intriguing, as volume NTE is not found in any other layered cuprates or ruthenocuprates. Variable temperature and field neutron diffraction studies, magnetic and magnetotransport measurements of this new material will be presented. References 1. I. Felner, U. Asaf, Y. Lavi and O. Milio, Phys. Rev. B, 1997, 55, 3374. 2. A. C. Mclaughlin, W. Zhou, J. P. Attfield, A. N. Fitch and J. L. Tallon, Phys. Rev. B 1999, 60, 7512. 3. J. W. Lynn, B. Keimer, C. Ulrich, C. Bernhard and J. L. Tallon, Phys. Rev. B., 2000, 61, 14964.

II7.35

Effect of Yttria Dopant Concentration on the Microwace Coupling On-Set Temperature in Zirconia. Gary E. Del Regno, College of Engineering, Alfred University, Alfred, New York.

Yttria doped Zirconia was sintered in a 2.45 GHz Microwave Cavity. Commercially available chemically synthesized Yttria doped Zirconia nano-grain materials were used at molar concentration of 0, 3, 8, and 10 mol-% Yttria and a metal-alkyoxide based chemical process was used to obtain the higher molar concentrations of 25 and 40 mol-% Yttria. Microstructures developed in the sintered samples as well as the effects of varying molar concentrations of Yttria in Zirconia on the electrical conductivity and the microwave coupling on-set temperatures were observed. Preliminary results will be presented indicating a decrease in microwave coupling on-set temperatures and an increase in electrical conductivity at higher Yttria concentrations. Typical microwave sintering profiles will be discussed as compared with conventional sintering profiles in the context of increased ionic conduction and dielectric relaxation mechanisms. Obvious differences in microstuctures between microwave and conventionally sintered samples may be shown to be related to the microwave coupling on-set temperatures.

II7.36

X-ray Absorption Edge Fine Structure Study of the Metal Insulator Transition in Cr Doped V2O3. Anatoly I. Frenkel[2], Douglas M. Pease[1], Poorani Shanthakumar[1], Ting Huang[1], Nathalie Abitbol[2], Louisette Soussan[2] and Joseph I. Budnick[1]; [1]Physics, University of Connecticut, Storrs, Connecticut, Connecticut; [2]Physics, Yeshiva University, New York City, New York.

We have applied the x-ray absorption edge fine structure (XAFS) method to study the series V2O3(1-x)Cr2O3x , where x ranges from 0 to .052. At room temperature, the metal - insulator transition (MIT) between paramagnetic metal 1 (PM-1) and paramagnetic insulator (PI) phases occurs near x = .01. We have obtained V K edges for this series and the Cr K edge for the x = .052 sample. Studies have also been conducted as a function of increasing temperature, from 130 K to 673 K, for which these systems cross AFI-PM1-PM2 boundaries (for x = 0, 0.00365) or AFI-PI-PM2 boundaries (for x=0.0523). X-ray diffraction (XRD) and temperature dependent x-ray absorption results will be discussed in terms of the possible percolative nature of the MIT system. X-ray absorption near edge structure (XANES)show systematic changes across the MIT boundary, both temperature and dopant driven. The near edge peaks in the region corresponding to 1s to 3d transitions are sharper in the insulating phase in both pure and Cr doped V2O3.

II7.37

Transition metal-doped ZnO: a comparison of optical, magnetic, and structural behavior of bulk and thin films. M. H. Kane[1,2], W. E. Fenwick[1], R. Varatharajan[3], M. Strassburg[1], B. Nemeth[3], D. J. Keeble[4], H. El-Mkami[5], G. M. Smith[5], J. Nause[3], C. J. Summers[2] and I. T. Ferguson[1,2]; [1]Electrical and Computer Engineering, Georgia Institute of Technology, Atlanta, Georgia; [2]School of Materials Science and Engineering, Georgia Institute of Technology, Atlanta, Georgia; [3]Cermet Inc., Atlanta, Georgia; [4]Carnegie Laboratory of Physics, University of Dundee, Dundee, United Kingdom; [5]School of Physics and Astronomy, University of St. Andrews, St. Andrews, United Kingdom.

Following theoretical predictions of room temperature (RT) ferromagnetism in transition-metal (TM)-doped zinc oxide, extensive experimental studies have attempted to produce ferromagnetic behavior in Zn(1-x)Mn(x)O and Zn(1-x)Co(x)O. The nature of ferromagnetism in all cases continues to remains an object of discussion and crystalline defects may play a significant role. This work reports on the optical and magnetic properties of Co- and Mn-doped ZnO grown by a modified melt-growth technique and metalorganic chemical vapor deposition (MOCVD), and the effects of annealing and co-doping on the magnetic behavior. Good crystalline quality was confirmed by X-ray diffraction (XRD), which revealed that the as-grown crystals are pure single crystals with no second phases. Mn doping up to 5% results in an increase in c-axis lattice parameter (5.207 A to 5.211 A), and in X-ray linewidths (78 arcsec to 252 arcsec). Structural properties were also investigated with Raman spectroscopy. The standard Raman active modes were visible in the Raman spectra, suggesting good crystalline quality. An additional Raman mode observed at 522cm-1 has been attributed to Mn incorporation in the crystal, though the dominant feature with transition metal doping is the activation of 'silent' Raman modes within the wurtzite lattice due to a loss of translational symmetry with Mn-doping. Optical transmission shows distinct absorption

spectra related to the color of the Zn(1-x)TM(x)O sample resulting from interatomic transitions within the divalent transition metal ion in a tetrahedral crystal field. Electronic paramagnetic resonance studies confirm the divalent nature of the substitutional transition metal atoms. Magnetization measurements reveal a paramagnetic behavior at all temperatures for both Mn- and Co-doped ZnO with the dominant exchange mechanism in both the Mn- and Co-doped ZnO single crystals as antiferromagnetic (AFM) superexchange. In order to examine binding energies of the dopants and defect centers and to investigate the incorporation and possible formation of spin-split electronic states leading to ferromagnetic behavior, the results will be compared with temperature-dependent optical and magneto-optical studies. The influence of annealing and codoping in both bulk and thin film samples within the framework of relevant current theories of ferromagnetism will also be discussed.

II7.38

Formation and Properties of Wurtzite w-MnN and of w-MnN Inclusions in (Ga,Mn)N. Piotr Boguslawski[1,2] and Jerry Bernholc[2]; [1]Institute of Physics PAS, Warsaw, Poland; [2]Center for High Performance Simulation and Department of Physics, North Carolina State University, Raleigh, North Carolina.

A considerable effort is currently devoted to the search of semiconductors with ferromagnetism (FM) controlled by band carriers for spintronic applications. (Ga,Mn)N attracts a particular attention because the predicted Curie temperatures exceed the room temperature. Extensive experimental studies of (Ga,Mn)N include optical absorption and Franck-Condon energies, photoconductivity, EPR, EXAFS measurements of Mn-N bond lengths, and dependencies of these features on the Fermi level. These data, together with the results of our density functional theory calculations, provide a consistent picture of the electronic structure of (Ga,Mn)N. On the other hand, a consistent picture of the magnetic properties of (Ga,Mn)N is lacking. The reported coupling is either antiferromagnetic (AFM) or FM, and a co-existence of FM and paramagnetism is also observed. We analyzed the Mn-Mn magnetic coupling as a function of the Fermi energy, but the calculated values are too low and of too-short range to explain the experiment. A possible explanation of the observed room temperature FM is the presence of inclusions of magnetic phases of the GaMnN ternary system. In particular, w-MnN inclusions with the wurtzite structure should be more difficult to identify experimentally than the observed GaMn3N4 inclusions with the perovskite structure. Consequently, we investigated the properties of w-MnN. First, we find that (Ga,Mn)N is unstable with respect to segregation of Mn. This induces fluctuations of the alloy composition, and may result in formation of w-MnN inclusions. Further, we find that w-MnN both at its theoretical lattice constant (a=3.13 A) and at that of GaN (a=3.21 A) is AFM, while the energy of the FM phase is higher by about 50 meV/Mn. Thus, both small inclusions stretched to fit the lattice constant of the host GaN and large inclusions with the lattice constant of w-MnN are AFM, and the formation of w-MnN does not explain the high-temperature FM observed in (Ga,Mn)N. Finally, we predict that w-MnN inclusions in both AlN and InN are AFM as well. This work has been supported by grant PBZ-KBN-044/P03/2001 and U.S. DOE.

II7.39

Development and characterization of epitaxial [ferromagnetic metal/semiconductor] hybrid nano-materials. Akifumi Matsuda[1], Shusaku Akiba[1], Takashi Okada[1], Masashi Kitamura[1], Masayasu Kasahara[1], Takahiro Watanabe[1], Osami Sakata[2], Kouji Koyoma[3], Atsuko Takeuchi[3], Yoshitaka Kitamoto[4] and Mamoru Yoshimoto[1,4]; [1]Materials and Structures Laboratory, Tokyo Institute of Technology, Yokohama, Kanagawa, Japan; [2]SPring-8, JASRI, Sayo-gun, Hyogo, Japan; [3]CG Laboratory, Namiki Precision Jewel Co., Ltd., Adachi-ku, Tokyo, Japan; [4]Interdisciplinary Graduate School of Sci. and Eng., Tokyo Institute of Technology, Yokohama, Kanagawa, Japan.

Compared with the polycrystal materials, the epitaxially (single crystal like) grown various metal films, can induce unique electronic, optical, and magnetic properties and also enhance their advantages which are undoubtedly important for the development of many expected applications such as ultra-high density magnetic recording devices and magnetic sensing devices. Epitaxial metal films are mostly grown by thermal evaporation and magnetron sputtering using metal sources, which methods need high temperatures at least around 700°C. Here we report a newly developed method to prepare epitaxial ferromagnetic-metal/semiconductor hybrid nano-materials at low temperatures by way of hydrogen reduction of the transition metal oxide multilayers. We used the ultrasmooth sapphire (0001) substrates which have atomic steps of 0.2 nm in height and atomically flat terraces of 50-100 nm in width. In experimentals, [NiO(111)/ZnO(0001)/NiO(111)/sapphire] films were grown at room temperature full-epitaxially using pulsed laser deposition (PLD) method. NiO epitaxial nanowires and nanogrooves were also prepared by way of self-assembly. Characterizations were made by X-ray diffraction (XRD), reflection high-energy electron diffraction (RHEED) and atomic force microscopy (AFM) for the epitaxy and surface morphologiies of nano-materials, respectively. The specimens were then annealed for an hour in hydrogen gas ambient, to reduce whole antiferromagnetic NiO into ferromagnetic Ni metal. We have also applied the same experimental procedure to the NiO (111) epitaxial film, and found that the epitaxy remains after the complete reduction into Ni(111); we named this novel epitaxy technology Metal Oxide-Reduction-Epitaxy, the "MORE" method. By utilization of MORE method to [NiO(111)/ZnO(0001)/NiO(111)/sapphire] films, watching contrasts of stabilities between oxide and metal phases for each materials, [Ni(111)/ZnO(0001)/Ni(111)/sapphire] films of epitaxial [ferromagnetic metal/semiconductor] hybrid structure were achieved successfully. When this technique was applied to self-assmbled oxide nano-materials, nano-structured ferromagnetic Ni(111) remaining their morphologies were obtained certainly. Further experimentals are conducted for crystallographic and structural analyses, and magneto-electronic characterizations for above mentioned ferromagnetic-metal/semiconductor hybrid nano-materials.

II7.40

A-site Ordered Colossal Magnetoresistant Manganite Films. Vasily Moshnyaga[1], Oleg I. Lebedev[2], Sudheendra Lakshman[1], Kai Gehrke[1], Oleg Shapoval[3], Alexandr Belenchuk[3], Sigrun A. Koester[1], Bernd Damaschke[1], Gustaf van Tendeloo[2] and Konrad Samwer[1]; [1]I. Physikalisches Institut, Universitaet Goettingen, Goettingen, Germany; [2]EMAT, University of Antwerp, Antwerpen, Belgium; [3]Institute of Applied Physics, Academy of Sciences, Chisinau, Moldova.

We report on the cation ordered colossal magnetoresistant epitaxial La-Ca-Mn-O (LCMO) thin films with doping level x=0.3, grown by layer-by-layer (LL) mechanism. They show unusual pseudo cubic structure, accompanied by the formation of a new perovskite superstructure due to La/Ca ordering. Extremely sharp insulator-metal (IM) and para-ferromagnetic (PM-FM) phase transitions as well as electronically homogeneous metallic behaviour for $T < T_c$, revealed by STM/STS techniques, were observed for LL-films. This is in sharp contrast with orthorhombic La/Ca disordered LCMO films, which show mesoscopic coexistence of metallic and insulating regions for $T <¡ T_c$ as well as broadened IM and PM-FM phase transitions. We provide a direct evidence that phase separation phenomenon is caused by the local cationic disorder within the orthorhombic structure.

II7.41

Understanding the Anomalous Hall Effect: Measurements on Tunable Magnetic Systems. Peter Khalifah[1,2], Brian Sales[2], Hans Christen[2], Isao Ohkubo[2], David Mandrus[2] and John Cerne[3]; [1]Dept. of Chemistry, University of Massachusetts - Amherst, Amherst, Massachusetts; [2]Condensed Matter Sciences Division, Oak Ridge National Laboratory, Oak Ridge, Tennessee; [3]Dept. of Physics, University at Buffalo, Buffalo, New York.

While the anomalous Hall effect (AHE) has the potential to discriminate between intrinsic and extrinsic magnetic semiconductors and to shed light on the magnetic interactions within solids, application of AHE measurements is hindered by a scarcity of measurements on well-characterized magnetic materials and by the theoretical challenges of accurately calculating the anomalous Hall coefficient R_s. Recent theoretical advances involving Berry's phase calculations show the potential for accurately determining R_s from band structure calculations. Experimental AHE data on one tunable ferromagnetic system which has been the subject of such calculations ($Ca_xSr_{1-x}RuO_3$) will be presented, and the frequency dependence of measurements on this system will be discussed. The behavior of the $Ca_xSr_{1-x}RuO_3$ will be compared to our results on an intrinsic dilute magnetic semiconductor system currently under investigation.

II7.42

Double-exchange driven metal-insulating transition in Mn-doped Cu. Alessio Filippetti and Vincenzo Fiorentini; SLACS and Physics Dept., University of Cagliari, Monserrato (Ca), Italy.

Doping antiferromagnetic CuO with Mn causes a uncommon metal-insulating transition where the low-temperature (T < Tc=80 K) phase is ferromagnetic, with a large but metallic-like resistivity, while the high-temperature phase is paramagnetic and insulating, but with a resistivity typical of Mott insulators in the variable-range hopping regime. Applying a first-principles, self-interaction corrected local spin density approach, we are able to understand and rationalize this puzzling behavior: each doping Mn in CuO acts as a single donor, inducing a double-exchange driven metallic regime and a Mn-Mn ferromagnetic alignment. Nicely, here double-exchange can also work at rather low Mn concentrations since carriers can freely flow within the CuO (x,y) planes and only need the Mn assistance to move

through the c axis. In the antiferromagnetic phase the system is insulating, but a polaron hopping conductivity through a few meV-wide Coulomb gap is envisaged. This scenario depicts the intriguing possibility of designing double-exchange driven ferromagnetic cuprates.

II7.43
Metal Hybridization and Electronic Structure of Tris(8-hydroxyquinolato)Aluminum (Alq3). Anthony Caruso, D. L. Shulz, S. B. Choi, J. Thomas, D. G. Grier and P. Boudjouk; Center for Nanoscale Science and Engineering, North Dakota State University, Fargo, North Dakota.

The metal-organic complex Tris(8-hydroxyquinolato)aluminum (Alq3) is a widely utilized component in organic electroluminescent devices and has recently shown promise as a thin non-magnetic layer in a giant magnetoresistive device [1]. The future of other organic or metal-organic materials in spintronic devices needs to be addressed from both the electronic and spin-polarized point of view for various device heterostructures. We present an electronic structure study of Alq3 adsorbed on both cobalt and gold with the intention of understanding how interfacial bonding may ultimately affect spin polarized transport. The electronic studies include energy and light polarization dependent photoemission as well as resonant photoemission to identify the molecular orbitals involved in metal chelation. When adsorbed on cobalt and gold surfaces, marked differences in the Alq3 metal-to-ligand bonds were observed, with intramolecular aluminum-to-ligand bonding through the oxygen heteroatom when Alq3 is adsorbed on gold, but through the nitrogen heteroatom when on cobalt. These results indicate that substrate interfacial complex formation plays an important role in the Alq3 molecular configuration and intramolecular bonding. The following question arises: Does this formation of an interfacial complex between a cobalt surface atom and an uncompensated oxygen from the quinolinate ligand (i.e., a Co-O interface bond) negatively perturb the spin polarized transport, such that a sensitive magnetic tunnel junction may not be realized for this hybrid organic/inorganic system? If this is the case, the Alq3/Co system might only be applicable to hot electron GMR devices (e.g., a spin LED as previously reported [1]). In this paper, the details of the aforementioned Alq3 study will be discussed. In addition, new results from electronic structure characterization of other metal-organic materials for spintronic applications will be presented. This work was supported by the Defense Micro Electronics Activity under DARPA. [1] Z.H. Xiong, Di Wu, Z. Valy Vardeny and Jing Shi, Nature 427 (2004) 821

II7.44
Structural Properties of Ferromagnetic Mn-implanted Si. Chaffra A. Awo-Affouda, M. Bolduc, M. B. Huang, F. Ramos, K. Dunn, B. Thiel and V. P. LaBella; College of NanoScale Science and Engineering, University at Albany-SUNY, Albany, New York.

We investigated the possibility of fabricating Mn_xSi_{1-x} as potential ferromagnetic semiconductor for spintronic applications. Making a semiconductor such as silicon ferromagnetic will aid in fabricating future spintronic devices. We recently demonstrated that ferromagnetism can be achieved via Mn-ion implantation of n-type and p-type Si wafers. A Curie temperature greater than 400K was observed for the p-type samples. The structure of the implanted material was investigated in order to identify the source of the ferromagnetism. SIMS depth profiling of the as-implanted samples showed a typical Gaussian shape profile of Mn atoms in the silicon lattice, which peaks at 250 nm. Post-implant annealing was performed to heal the damage from the implantation process and resulted in a strong redistribution of the Mn atoms. Furthermore diffraction contrast TEM of the annealed samples revealed nanometer size precipitates distributed throughout the implanted region, along with a large band of dislocation and stacking faults. Selected area diffraction pattern gives strong evidence that these phases are $MnSi_{1.7}$ crystallites. We will discuss the role of these precipitates on the observed ferromagnetism.

SESSION II8: Magnetic Nanowires and Nanotubes
Chair: Samuel Bader
Wednesday Morning, November 30, 2005
Room 312 (Hynes)

8:30 AM II8.1
Diluted Magnetic Semiconductor Mn:AlGaN Nanotubes. Heon-Jin Choi[1], Han-Kyu Seong[1,2], Yun-Ki Byeun[2], Kyeong-Sop Han[2], Jae-Gwan Park[2], Youngh Lee[3] and Won-Seon Seo[3]; [1]School of Advanced Materials Science and Engineering, Yonsei University, Seoul, South Korea; [2]Materials Science and Technology Division, Korea Institute of Science and Technology, Seoul, South Korea; [3]Reliability Assessment and Materials Evaluation Center, Korea Institute of Ceramic Engineering and Technology, Seoul, South Korea.

Diluted magnetic semiconductors (DMSs) represent the most promising candidates for simultaneously manipulating both charge and spin in a single semiconductor medium that leads to the exciting area of spintronics. Theoretical studies indicate that transition metal doped GaN possesses ferromagnetic transition temperature higher than room temperature by hole mediated ferromagnetism that would be advantageous for many of the proposed spintronic applications. Many experiments have already been carried out to demonstrate such hypothesis, however, significant controversy exists over the possible magnetic impurity phase separation for many of these thin-film studies. Moreover, nonequilibrium molecular beam epitaxial growth process of thin-film results many defects that act as a hurdle to realize the hole mediated ferromagnetism. We have already reported single crystalline DMS GaN:Mn nanowires possessed Curie point above room temperature, magnetoresistance near room temperature, spin-dependent transport and, importantly, p-type character, which has not been shown in thin film studies. It proves that the DMS nanowire is unique building blocks toward development of spintronics as well as understanding the fundamental aspects of ferromagnetism in DMSs. Herein we report the other novel class of one dimensional nanostructures, single crystalline AlGaN:Mn nanotubes with inner diameters of 30-200 nm and wall thicknesses of 5-50 nm. Our observation indicates that the etching out of metal catalysts during the growth of one dimensional AlGaN nanostructures resulted in such a DMS nanotubes. The nanotubes have hexagonal shapes with uniform diameters of $<$ 200 nm and wall thickness of 20 nm, corresponding to the [0001] growth direction. 2.5 at % Mn dopants are homogeneously distributed within the AlGaN nanotube lattice without any phase separation. The nanotubes showed clear hysteresis loop with coercive fields of approximately 210 and 170 Oe for 5 and 300 K, respectively. Importantly, the DMS nanotubes showed consistent ferromagnetism up to room temperature. Based on the experimental results including structural-, magnetic- and electrical properties, the possible application as building blocks for spintronic devices as well as fundamental aspect of DMS nanotubes will be discussed.

8:45 AM II8.2
Self-Assembled (Mn:Ge) Nanowires: Coaxial Ferromagnetic-Semiconductor Core-Shell Heterojunctions. Humberto R. Gutierrez[1], Awnish Gupta[1], Yoji Kobayashi[3] and Peter C. Eklund[1,2]; [1]Department of Physics, The Pennsylvania State University, University Park, Pennsylvania; [2]Department of Materials Science, The Pennsylvania State University, University Park, Pennsylvania; [3]Department of Chemistry, The Pennsylvania State University, University Park, Pennsylvania.

Mn:Ge compounds have emerged as a very promising system in order to obtain efficient spin injection. Recently, Mn_5Ge_3 (Tc 300K) thin films epitaxially grown on Ge substrates and highly Mn-doped Ge bulk single crystals with Tc = 285 K have been reported. This system is very interesting candidate for device applications due to the long-range magnetic ordering at temperatures Tc 300K. Furthermore, their structural and chemical compatibilities with Ge reduce the losses of the carrier's spin-orientation at the interface. In this work, we report on self-assembled Mn:Ge nanostructures obtained in a CVD reactor. Separated Ge and Mn powder sources were used in an Ar flow. For temperatures between 800-870^{o}C, freestanding Mn-Ge nanowires were obtained at the surface of Mn crystals. Conventional x-rays diffraction showed the presence of different Mn_xGe_y phases, including Mn_5Ge_3. HRTEM, STEM (ADF), EDS and selective area electron diffraction were used to spatially localize these phases within particular nanostructures. Interesting coaxial heterostructures in which a Ge-core is surrounded by an Mn_5Ge_3-shell were also obtained. The detection of a Ge-rich core suggests a self-catalytic Vapor-Liquid-Solid mechanism for nanowire's formation, which can be expected from the phase diagram of Mn-Ge binary compound with Ge content higher than 53%. The growth of the Ge-core is very fast and the Mn_5Ge_3-shell forms later due to the co-deposition of Ge and Mn atoms at the nanowire surface. This ferromagnetic-semiconductor core-shell heterojunction may find application in spin-injection devices; in this case a spin-polarized current could be radially injected into the semiconductor core at room temperature. To our knowledge, this is the first report on self-assembled freestanding nanostructures in this system (Mn:Ge).

9:00 AM II8.3
Synthesis of pure and doped ZnO nanowires on unseeded substrates by electrodeposition. Jingbiao Cui and Ursula Gibson; Dartmouth College, Hanover, New Hampshire.

Pure and transition metal doped ZnO nanowire arrays were synthesized at 90 C by an electrochemical process. Structural, optical, magnetic, and field emission properties of the nanowires were investigated with various techniques, including X-ray diffraction,

SEM, TEM, EDX, XPS, VSM, cathodoluminescence, and Raman scattering. In comparison with the conventional hydrothermal process, nucleation density on unseeded substrate is enhanced by 4 orders of magnetfude and the growth rate was found to increase by 30 times in this new approach. In addition, the applied potential improves the incorporation of metallic dopants in the nanowires. Both Co and Ni-doped ZnO nanowires exhibit room temperature ferromagnetism, which makes the nanowires potentially useful as building components for spintronics.

9:15 AM II8.4
Electrochemically-Deposited Magnetic Nanotubes with Square or Circular Cross-Section. Woo Lee, Kornelius Nielsch, Ran Ji and Ulrich Goesele; Max Planck Institute of Microstructure Physics, Halle, Germany.

In the present work we report on the electrochemical synthesis of ferromagnetic nanotubes based on alumina membranes. By combining interference and imprint lithography for the pre-patterning of the alumina substrates prior to the anodisation process, we have obtained alumina pore arrays with hexagonal or square arrangement and pore channels with a circular or square cross-section, respectively. Our novel approach for the fabrication of magnetic nanotubes is based on the preferential electrodeposition of magnetic and non-magnetic materials along the pore walls of aluminum oxide membranes in the presence of metallic nanoparticles on the nanochannel surfaces. Initially, Ag nanoparticles were deposited by means of electroless-plating on the membrane walls. After placing a gold electrode on one membrane side we successfully electrodeposited a thin metallic film along the pore walls. For the first time multi-segmented magnetic nanotubes with bi-metallic stacking configuration along the tube axis have been fabricated. Additionally, we will report on the magnetic properties of continuous and multi-segmented Ni and Co nanotubes with circular or square cross-section. The diameter of the nanotubes can be adjusted between 150 to 300 nm and the thickness of the tube wall is in the range of 30 to 45 nm. We will compare the magnetic properties of our electrodeposited nanotubes with previous results on ultra-thin Co/Polymer multilayer nanotubes (Nielsch et al., *AdvancedEngineeringMaterials* **7**, 217 (2005)), where we have measured strong exchange bias effects. Financial support from the German Federal Ministry for Education and Research (BMBF, Project No. 03N8701) is gratefully acknowledged.

9:30 AM II8.5
Magnetism in Palladium Nanowires. Derek Stewart, Cornell Nanoscale Science and Technology Facility, Ithaca, New York.

In this study, we examine ultrathin (1 nm) palladium nanowires in an effort to resolve their magnetic properties. While bulk fcc palladium is paramagnetic, analysis of the density of states based on the Stoner criterion indicates that the material is on the verge of becoming magnetic. Previous studies of palladium surfaces and clusters have shown that slight modifications of the palladium bond lengths can induce ferromagnetic behavior. In this study, the electronic structure of ultrathin fcc and hcp palladium nanowires is calculated using both plane-wave and linear muffin tin ab-initio approaches. We find that atoms in hcp Pd nanowires exhibit an average magnetic moment of 0.31 μ_B/atom directed along the axial direction, while fcc Pd nanowires are only weakly ferromagnetic ($<$ 0.01 μ_B/atom). However, a 5% expansion of the fcc lattice constant results in a significant magnetic moment (0.26 μ_B/atom). Total energy calculations show that fcc Pd nanowires are more stable than their hcp counterparts. This study indicates that fabrication of Pd nanowires on slightly lattice-mismatched surfaces could lead to the formation of magnetic nanowires. The influence of nanowire radius on magnetism is also considered for the hcp configuration.

9:45 AM II8.6
Fabrication of Mn-doped Fe_3O_4 nanochannel structures and application to nano FET devices by AFM Lithography. Hidekazu Tanaka[1], Luca Pellegrino[1,2], Yoshihiko Yanagisawa[1], Mizue Ishikawa[1], Takuya Matsumoto[1] and Tomoji Kawai[1]; [1]ISIR-Sanken, Osaka University, Ibaraki, Osaka, Japan; [2]Universita di Genova, INFM-Lamia, Via Dodecaneso, Genova, Italy.

Recently, prototypes of Magnetoresistive Random Access Memories (MRAM) have been introduced into the market. Oxide ferro(ferri)magnets with Curie temperature above 300 K are currently under intensive investigation for their employments as spin injection elements in Magnetic Tunnel Junction (MTJ) devices. Magnetite (Fe_3O_4) is one of these promising oxide candidates due to its high Curie temperature (Tc=850 K) and nearly 100% spin-polarized current. We deposited $Mn_xFe_{3-x}O_4$ thin films on MgO and $SrTiO_3$ substrates by Pulsed Laser Deposition. Mn-doped Fe_3O_4 has higher chemical stability to oxidation with lower carrier concentration than its undoped counterpart [1] and it is compatible for the consecutive growth of other functional oxides such as gate insulators. We believe that by tailoring the thickness and the lateral dimensions of $Mn_xFe_{3-x}O_4$ nanostructures it is possible to control their magnetic properties and enhance their response to external perturbations, such as magnetic and electric fields. For this purpose, at first we present the magnetic and electrical characterization of $Mn_xFe_{3-x}O_4$ thin films as a function of the thickness; then, experiments on $Mn_xFe_{3-x}O_4$ nano-channels fabricated by AFM lithography. Our films exhibit room temperature ferromagnetism down to 5 nm. Hall Effect measurements show electronic-type conduction and hysteretic behaviour with the presence of the anomalous term. 30 nm films have typically carrier concentration of about $3x10^{20}/cm^3$ and electron mobilities around $0.22cm^2/Vs$ at 300 K. Films thinner than 20 nm are patterned by exploiting the local decomposition of magnetite under the electric field of the biased tip of an Atomic Force Microscope. Patterned areas have higher resistivity then the as-grown films and decreased magnetization [2]. By controlling the electrical current through the AFM tip [3], we modify magnetite thin films with a resolution of about 50 nm. This last technique, combined with other lithographic approaches, will be used to investigate magneto-electrical properties of nano-channels as a function of the width and to fabricate first examples of planar side-gate field effect devices based on $Mn_xFe_{3-x}O_4$ thin films, with the purpose to control its room temperature ferromagnetism in a reversible way. Nanostructuring of magnetite films and their integration with other oxides can lead to the realization of novel spintronic devices. [1] M. Ishikawa et al. Appl. Phys. Lett. 86 (2005) 222504 [2] M. Hirooka et al. Appl. Phys. Lett. 85, (2004) 1811 [3] L. Pellegrino et al Appl. Phys. Lett. (in press)

SESSION II9: Magnetic Nanoparticles and Nanocomposites (1)
Chair: Kornelius Nielsch
Wednesday Morning, November 30, 2005
Room 312 (Hynes)

10:30 AM *II9.1
Multi-Component Nanocrystal Assembly as a Route to Designer Magnetic Materials. Christopher B. Murray[1], Elena Shevchenko[1] and Stephen O'Brien[2]; [1]Nanoscale Materials and Devices, IBM Corp., T. J. Watson Research Center, Yorktown Heights, New York; [2]Materials Science and Engineering, Applied Physics and Applied Mathematics, Columbia University, New York, New York.

Colloidal magnetic nanocrystals with controlled composition, size, shape, structure and surface passivation are now increasingly available. The tunability of the magnetic properties of these structures motivates their use in the design new materials and assembly of new devices. This talk will focus on the interesting magnetic superlattice systems that can be built with these magnetic nanocrystals in combination with other nanoscale building blocks. We combine a high temperature solution phase synthesis with size selective processing techniques to produce organically passivated magnetic, metallic and semiconducting nanocrystals with size distributions less than 5%. These nanocrystals have formed the basis for studies of the evolution magnetic nanocrystal properties with size and are now exploited as "magentically tunable" building blocks. Combination of monodisperse nanocrystals self-organize during controlled evaporation to produce 2D and 3D superlattices (colloidal crystals, opals). The superlattices retain and enhance many of the desirable mesoscopic properties of individual nanocrystals and are now permitting the systematic investigation of new collective phenomena. Preliminary examples of superlattices with AB13, AB2, and predicted by theory as well as several previously unanticipated structures will be discussed. Procedures have been developed for Co, Ni, FePt, and Fe2O3 magnetic nanocrystals in combination with Ag, Au, and Pd as model metals in addition to PbSe, PbS, semiconductor quantum dots. It is hoped that these systems will provide the diverse sets of magnetically active materials for applications ranging from permanent magnets, and magnetoresistive element to perhaps some future optoelectronic or "spintronic device."

11:00 AM II9.2
Perpendicular magnetic anisotropy of $L1_0$-FePdCu nanoparticles induced by Cu addition. Hiroshi Naganuma, Kazuhisa Sato and Yoshihiko Hirotsu; The Institute of Scientific and Industrial Research, Osaka University, Ibaraki, Osaka, Japan.

$L1_0$-FePd and FePt nanoparticles have been attracting much interest for future ultra-high density magnetic storage media. $L1_0$-ordering temperature usually around 873 K were, however, quite high from the viewpoint of application. In our previous study [1)], we have revealed that the beginning of the $L1_0$-ordering in the FePd nanoparticle is 773 K, and it is 100 K lower than that of the FePt nanoparticles, because of low melting temperature of FePd. The present study aims at

lowering the formation temperature of the $L1_0$-FePd nanoparticles by additive Cu, and discussing the effect of Cu addition in the nanostructure and its relation to the magnetic properties. FePdCu nanoparticles were fabricated by successive evaporation of Pd, Cu and Fe onto NaCl (001) substrates heated at 673 K. Postdeposition annealing was performed in a high vacuum furnace. Structure and morphology were characterized by TEMs operated at 200 and 300 kV (JEM-2010, 3000F, LEO-922). Magnetic properties were measured using a SQUID magnetometer. A SAED pattern for the as-deposited specimen showed only diffraction spots from Cu-Pd and bcc-Fe with a mutual fixed orientation. The specimen heating stage attached to the TEM was used for the $in-situ$ observation of the changes of SAED patterns in the course of annealing. Weak 110 superlattice reflections from the $L1_0$-type ordered structure started to appear at 673 K, indicating the ordering temperature was reduced by 25-50 K due to the Cu addition compared with the case of FePd nanoparticles[2)]. The intensity of the 110 as well as 001 superlattice reflections increased on annealing. In order to investigate the preferential orientation of the c-axis in ordered FePdCu nanoparticles, we performed a dark-field TEM observation using a 110 superlattice reflection. It was revealed that 59% of the FePdCu nanoparticles have their c-axis oriented perpendicular to the film plane after annealing at 823 K for 3.6 ks. The magnetization curve measured perpendicular to the film plane showed a high coercivity of 3.6 kOe at 300 K, while less than 0.3 kOe for the in-plane one. FePd nanoparticles annealed at the same temperature showed a coercivity of 2.5 kOe for the perpendicular direction at 300 K [2)]. Thus, a strong perpendicular magnetic anisotropy was enhanced under the lower annealing temperature by a small amount of Cu addition. (1) K. Sato, B. Bian and Y. Hirotsu: Jpn. J. Appl. Phys. **39** (2000) L1121. (2) K. Sato and Y. Hirotsu :J. Appl. Phys. **93** (2003) 6291.

11:15 AM II9.3
Magnetic Properties of $MnPt_3$ Nanocrystals Synthesized via Colloidal Chemistry And Thin Film Patterning of Silica-Coated Nanocrystals. Doh C. Lee[1,2,3], Ali Ghezelbash[1,2,3], Cynthia A. Stowell[1,2,3] and Brian A. Korgel[1,2,3]; [1]Department of Chemical Engineering, University of Texas at Austin, Austin, Texas; [2]Texas Materials Institute, University of Texas at Austin, Austin, Texas; [3]Center for Nano- and Molecular Science and Technology, University of Texas at Austin, Austin, Texas.

New materials for high-density data information storage media have been pursued over the past decade, leading to intense investigation of new synthetic and processing methods for ferromagnetic nanocrystals. Colloidal chemistry has enabled syntheses of nanocrystals to be easily reproducible and predictable. However, despite recent synthetic advances for obtaining size-monodisperse nanocrystals, there remain challenges in film deposition and patterning to achieve device quality structures. For example, FePt nanocrystals, which have very high magnetic anisotropy, can be synthesized in large quantity with controlled size and shape, but the nanocrystals require high temperature annealing (>550°C) to exhibit room temperature ferromagnetism with relatively high coercivity. The annealing process leads to degradation of the organic passivation layer separating nanocrystals in the film and often leads to significant coalescence and sintering of the nanocrystals. In this talk, we will present a new colloidal synthesis of Mn-Pt alloy nanocrystals and their composition and phase-dependent magnetic properties. The nanocrystals are formed in solution by the rapid thermal decomposition of Mn precursors followed by Mn diffusion into Pt-rich nuclei. The Mn-Pt nanocrystal structure varies significantly depending on the alloy composition. Atomic Mn diffusion into the Pt clusters appears to be limited by the required structural rearrangement upon alloying, and residual Mn precursor forms Mn nanoclusters or remains unreacted. Under most synthetic conditions, monodisperse $MnPt_3$ nanocrystals form with a narrow composition range. Atomic ordering of Mn and Pt atoms in the unit cell of Mn-Pt alloy nanocrystals is observed from transmission electron microscopy (TEM) analysis and x-ray diffraction study. As-synthesized Mn-Pt nanocrystals have A1 structure, in which Mn and Pt atoms are randomly positioned in an fcc unit cell. Annealing at high temperature (580°C) leads to phase ordering of Mn and Pt to the $L1_2$ structure with Mn atoms at the unit cell corners and Pt atoms at the face center positions. As opposed to random orientation of Mn and Pt atoms in the as-made nanocrystals, atomic ordering in the annealed structure generates Mn-Mn interactions allowing the nanocrystals to be ferromagnetic. The restructuring affects nearest-neighbor and next-nearest-neighbor Mn-Mn interactions, thereby changing the magnetic structure of the materials. During annealing, nanocrystals grow via agglomeration which hampers characterization of the origin of magnetism changes in the material. To isolate the effect of atomic structure change, we studied coating of the nanocrystals and examined how the core-shell structure affects the morphology change at high-temperature annealing.

11:30 AM II9.4
Equiatomic FePt NPs' Synthesis via Pyrolysis of Iron(III)ethoxide and Platinum(II)acetylacetonate and its Reaction Mechanism. Soichiro Saita[1] and Shinya Maenosono[2]; [1]Mitsubishi Chemical Group Science and Tetchnology Research Center, Inc., Yokohama, Japan; [2]The University of Tokyo, Tokyo, Japan.

FePt nanoparticles (NPs) of $L1_0$ crystal structure have high magnetic anisotropy and keep ferromagnetic property even though their size is smaller than 10nm. Therefore, they are expected to be used in some kinds of application such as ultra-high-density recording media and nano-bio technology. There are several requirements for obtaining independent ferromagnetic FePt NPs. For example, their size should be more than 3.3nm, the composition should be equiatomic and no severe sintering between particles is allowed after annealing at 600C° to transform as-synthesized random fcc structure into ordered $L1_0$ structure. We have synthesized equiatomic FePt NPs which are more than 4nm using iron(III)ethoxide and platinum(II)acetylacetonate without any reducing agent. TEM-EDX analysis reveals each NP's composition distribution is 2.5 times narrower than that of NPs synthesized in a conventional method.[1] The mechanism of this reaction is studied and FePt NPs formation model is proposed based on a unique decomposition of iron(III)ethoxide which is called "β-hydrogen elimination". On the other hand so far, we have succeeded in transforming fcc into $L1_0$ after irradiating a suspension containing 2nm FePt NPs with pulsed laser.[2] We will report our trial to combine these two techniques and to make independent ferromagnetic FePt NPs. [1] Saita, S., Maenosono, S., *Chem.Mater.* **2005**, in press [2] Saita, S., Maenosono, S., *J.Phys.; Condens.Matter* **2004**, 16, 6385

11:45 AM II9.5
Phase selective fabrication of monodisperse FePt nanoparticles. Jiao-Ming Qiu and Jian-Ping Wang; The Center for Micromagnetics and Information Technologies (MINT), Department of Electrical and Computer Engineering, University of Minnesota, Minneapolis, Minnesota.

Ferromagnetic nanoparticles with sizes from 1 nm to 20 nm have unique physical properties compared with their counterpart of bulk materials. Because of this, they have broad range applications in extremely high magnetic recording media[1], catalyst[2], biomedicine[3], biosensor[4], and ferrofluid[5], etc. $L1_0$ phase FePt nanoparticles are currently considered as the best candidate for future magnetic recording media. However, a chemically disordered form of FePt (A1 phase) with much lower magnetocrystalline anisotropy than the desired $L1_0$ phase is almost always obtained in conventional fabrication processes either physically or chemically. The transformation from the A1 to $L1_0$ phase generally requires high temperature post-annealing treatment that will easily agglomerate the FePt nanoparticles and broaden their size distribution[6]. Here we report a unique protocol to fabricate monodisperse FePt nanoparticles with specified phases via gas phase aggregation. A magnetron sputtering based nanocluster source was used to fabricate FePt nanoparticles. By varying the deposition parameters, uniform and highly crystalline FePt nanoparticles could be fabricated with either the chemically disordered A1 phase or the chemically ordered $L1_0$ phase, respectively. For the $L1_0$ phase, room temperature coercivity was measured by SQUID to be 8.2 kOe and the estimated anisotropy constant is 4 x 10^7 erg/cm^3. The coercivity and saturation magnetization were found to increase with the decrease of the measurement temperature. At 35 K, a huge coercivity of 24.1 kOe was revealed with a saturation field over 66.0 kOe. These A1 and $L1_0$ FePt nanoparticles are contamination free and made to be flying freely in vacuum, which makes it easy to manipulate their physical and magnetic properties. This phase selective fabrication protocol can also be extended to other material systems with both high and low temperature solid phases. ———————— 1. C. A. Ross, Annu. Rev. Mater. Res. 31, 203, (2001) 2. S. L. Brock, S. C. Perera, and K. L. Stamm, Chem. Eur. J. 10(14), 3364 (2004) 3. C. C. Berry, S. G. Curtis. J. Phys. D: Appl. Phys. 36(13), R198 (2003) 4. S. H. Gee, Y. K. Hong, D. W. Erickson, M. H. Park, and J. C. Sur, J. Appl. Phys. 93(10, Pt. 2), 7560 (2003) 5. S. Odenbach, J. Phys.: Condens. Matter. 16(32), R1135 (2004) 6. Z. R. Dai, S. Sun, and Z. L. Wang, Nano Letters, 1(8), 443 (2001)

SESSION II10: Magnetic Nanoparticles and Nanocomposites (2)
Chair: Christopher Murray
Wednesday Afternoon, November 30, 2005
Room 312 (Hynes)

1:30 PM II10.1
Crystal Growth of Magneto-Optical Bi-YIG Nanoparticles and Composite Thin Films. Taegyun Kim[1], Saburo Nasu[2] and Mutsuhiro Shima[1]; [1]Dept. of Materials Science and Engineering,

Rensselaer Polytechnic Institute, Troy, New York; [2]Graduate School of Engineering Science, Osaka University, Toyonaka, Osaka, Japan.

Bi substituted yttrium iron garnet (Bi-YIG) nanoparticles and their composite thin films have been investigated with particular focus on the crystal growth, magnetic and magneto-optical properties toward future nano-scale magneto-optical device applications. The $Bi_xY_{3-x}Fe_5O_{12}$ (x=0-2) nanoparticles chemically synthesized by co-precipitation crystallize into the garnet phase after annealing above 700^oC, according to x-ray diffraction and transmission electron microscopy. The average size of Bi-YIG nanoparticles is 60 nanometers with relatively weak dependence on the growth condition. The as-synthesized nanoparticles are nanocrystalline or amorphous, while they transform to the garnet phase at temperatures above 700^oC. The isothermal phase transformation from the non-magnetic amorphous to magnetic garnet phases at 700^oC, estimated from the onset of magnetization, follows the Johnson-Mehl-Avrami equation with the exponent value of n = 1.8, implying a low-dimensional nucleation and growth of the magnetic garnet phase in the particles. According to the Mossbauer spectra of the annealed nanoparticles, the hyperfine fields at ^{57}Fe nuclei at the octahedral and tetrahedral sites in the garnet are 38.7 and 47.9 Tesla, respectively, which are fairly close to those obtained in YIG bulk or films. As the Bi composition increases from x = 0 to 1.8, the saturation magnetization and coercivity of Bi-YIG linearly increase presumably due to the enhanced magnetic moment of tetrahedral Fe^{3+} via charge transfer from hybridized dodecahedral Bi^{3+} 6p and the adjacent O^{2-} 2p orbitals. The chemically prepared Bi-YIG nanoparticles are synthesized into composite thin films with various matrix materials including polymethylmethacrylate (PMMA) and silica glass. The Bi-YIG/PMMA composites have been prepared by ball-milling with enhanced particle dispersity via a surface modification process. The Bi-YIG/silica composites are synthesized by a sol-gel process. We have found that the crystal phase and intrinsic magnetic properties of the individual garnet nanoparticles do not change by the composite synthesis, though the magnetic and magneto-optical properties of the composite films sensitively depend on the morphology and particle dispersity in the films. For magneto-optical device applications such as optical isolators, it is crucial to be able to control the particles morphology and optimize the optical and magneto-optical parameters including the figure of merit for the magneto-optical Faraday effect and the difference in the refractive indices between Bi-YIG and matrix materials. In this report, we will present the crystal growth and magnetic properties of the Bi-YIG nanoparticles and the magneto-optical effects of the Bi-YIG composite films.

1:45 PM II10.2
Soft magnetic vapor phase co-deposited polymer-metal nanocomposites for high frequency applications. Henry Greve[1], Abhijit Biswas[1], Vladimir Zaporojtchenko[1], Michael Frommberger[2], Eckhard Quandt[2] and Franz Faupel[1]; [1]Chair for Multicomponent Materials, Faculty of Engineering of the Christian-Albrechts University of Kiel, Kiel, Germany; [2]Smart Materials Group, center of advanced studies and researchFaculty of Engineering of the Christian-Albrechts University, Bonn, Germany.

Recent growing markets for mobile communication handsets and portable information tools require further miniaturization and lower insertion losses for inductive components installed in Monolithic Micowave Integrated Circuits (MMIC). The possible carrier frequency range is from 800 MHz to 3 GHz including audio and intermediate frequencies. Magnetic thin-film inductors will be advantageous over currently used air-core spirals if loss generation in the magnetic film is low at the frequency of interest. Besides parasitic effects due to the design of the magnetic device, two magnetic device, two main loss mechanisms limit the applicability of soft magnetic films at very high frequencies ($\geq$ 1 GHz): (a) eddy currents, (b) ferromagnetic resonance (FMR). Two component nanocomposites of either magnetic nanoparticles protected inside an insulating polymer matrix or of a multilayer system of ferromagnetic thin films alternating with insulating layers are promising candidates and could play important roles particularly in such magnetic high frequency applications. Here, we present vapor phase co-deposition method in which we prepare such particulate or multilayer structured, softmagnetic nanocomposite films. These films are several hundred nanometers thick and consist of $Fe_{54}Ni_{27}Co_{19}$ as ferromagnetic and Teflon® AF or PTFE as the insulating material component. The filling factors of the films were determined by EDX and the structure was observed by TEM and SEM. The magnetic properties were measured by VSM and a high frequency permeameter. So far we were able to obtain cut off frequencies of more than 2 GHz for the multilayer structured films.

2:00 PM II10.3
Synthesis and Characterizations of Magnetic Core-Shell Nanocomposite Materials. Lingyan Wang[1], Masatsugu Suzuki[2], Itsuko S. Suzuki[2], Jian Q. Wang[2], Jin Luo[1], Mark H. Engelhard[3], Chongmin Wang[3], Yuehe Lin[3] and Chuan-Jian Zhong[1]; [1]Chemistry, State Univ. of New York at Binghamton, Binghamton, New York; [2]Physics, State Univ. of New York at Binghamton, Binghamton, New York; [3]Environmental and Molecular Sciences Laboratory, Pacific Northwest National Laboratory, Richland, Washington.

Core-shell nanostructured materials derived from iron oxide and composites provide intriguing opportunities for designing chemical/biological sensors with high sensitivity and selectivity because of the unique magnetic properties. In this paper, we will describe recent results of an investigation of the synthesis of iron oxide nanoparticles and their composite nanoparticles. By controlling the reaction temperatures and manipulating the capping agent properties and solution compositions, we have prepared Fe3O4 nanoparticles in 2-20 nm size range with controllable sizes, shapes, and core-shell compositions. The size-defined iron oxide nanoparticles were used as seeding materials for the reduction of gold precursors to form Fe oxide@Au core/shell nanoparticles. The core-shell nanocomposites have been characterized using TEM, XRD, XPS, UV-vis, DCP-AES , and SQUID techniques. While magnetization, remance magnetization, blocking temperature, and susceptibility were found to decrease after coating iron oxide with Au, the coercivity was shown to increase after coating. The average sizes of the nanoparticles derived from the magnetic measurements were consistent with data from the other characterization methods. The implications of the findings to the design of novel magnetic materials will be discussed.

2:15 PM II10.4
Structural and Magnetic Properties of Self-assembled Fe Nanoparticles in Al_2O_3 Thin Film Matrix. Alok Gupta[1], Dhananjay Kumar[1,2], Maria Varela[2] and Stephen J. Pennycook[2]; [1]Department of Mechanical Engineering, North Carolina A & T State University, Greensboro, North Carolina; [2]Condensed Matter Sciences Division, Oak Ridge National Laboratory, Oak Ridge, Tennessee.

This investigation has focused on layered self-assembly of well separated Fe nanoparticles in an Al_2O_3 thin film matrix using a pulsed laser deposition based technique. Nanoparticles embedded thin films were deposited on single crystal silicon (100) and sapphire (0001) substrates using laser energy of $2J/cm^2$, repetition rate of 30 Hz and substrate temperature in the range of 500-600 ^oC. Structural characterization, performed using sub-Angstrom resolution scanning electron microscopy with atomic number (STEM-Z) contrast, has indicated that islands of different sizes successively reach a common size, forming a highly ordered structure with very narrow particle size distribution. In addition to narrow particle size distribution, interparticle spacing has also been observed to become more regular in successive layers. We also did calculations, based on Continuum Theory of Elasticity for the appropriate spacer layer thickness at a given deposition temperature, at which Fe nanoparticles prefer to align on top of nanoparticles in previous layers. Our results from STEM-Z observation show that predictions derived from above calculations are achievable and particle size varies from 5-8 $\AA$. Fine particle magnetism measurements carried out using superconducting quantum interference device magnetometer have shown that nanoparticles are superparamagnetic and magnetization versus field/temperature (M vs. H/T) scaling fits well to the Langevin Function.

SESSION II11: Magnetic Disks, Dots and Rings
Chair: Dan Dahlberg
Wednesday Afternoon, November 30, 2005
Room 312 (Hynes)

3:30 PM *II11.1
FMR fingerprints of nanostructured magnetic rings. Fabian Giesen, Jan Podbielski and Dirk Grundler; Institut fuer Angewandte Physik, Universitaet Hamburg, Hamburg, Germany.

Dynamic properties of ferromagnetic nanostructures on the sub ns time scale have become increasingly important due to the increased data transfer rates in magnetoelectronic devices. Recently an intriguing novel phenomenon like DC current induced spin dynamics [1] has been discovered in nanomagnets. The generated spin waves however have been found to be rather complex [2]. A spin battery for semiconductors has already been proposed which is based on spin precession, i.e. ferromagnetic resonance (FMR) [3]. Spin dynamics in nanopatterned magnets is hence a topic of great current interest in magnetism research and in spintronics. All-electrical measurement techniques might be useful to acquire a detailed insight. We have set up a broadband microwave spectrometer incorporating a vector network analyzer (45 MHz $-$ 20 GHz) and have studied the FMR of periodic arrays of $Ni_{80}Fe_{20}$rectangles and nanostructured rings [4] at room temperature. The 20 nm thick devices were fabricated by means of electron beam lithography and lift-off processing on coplanar wave guides exhibiting a high bandwidth. The magnetic structures are located within the in-plane magnetic field H generated by crossed

pairs of field coils. For 1 μm wide rectangles we observe a characteristic series of FMR absorption lines exhibiting distinct magnetic field dispersions. The spectra reflect spin wave modes which are on the one hand quantized via the finite width and on the other hand localized via the inhomogeneous internal field. In the rings we detect sharp FMR absorption lines which shift characteristically as a function of width [5] and external magnetic field H. The spin wave modes are hysteretic and show irreversible switching. In particular in the narrow rings of width w = 250 nm and diameter d = 2 μm we attribute them to spin waves localized in different ring segments. This is due to the inhomogeneous internal magnetic field which spatially oscillates along the perimeter. Very intriguingly the dynamic response can be controlled via the static spin configuration of the rings, i.e., it provides a fingerprint of the vortex and the onion states [6]. As a result in the same external magnetic field we observe different FMR absorption spectra depending on the magnetic history. In the talk we will discuss our recent results. We thank D. Heitmann and T. Korn. Financial support by the BMBF via 13N8283 and by the DFG is gratefully acknowledged. References: [1] S. I. Kiselev et al., Nature **425**, 380 (2003). [2] K. J. Lee et al., Nature Materials **3**, 877 (2004). [3] A. Brataas et al., Phys. Rev. B **66**, 060404 (2002). [4] J. Podbielski et al., Superlattices and Microstructures **37**, 341 (2005). [5] F. Giesen et al., J. Appl. Phys. **97**, 10A712 (2005). [6] F. Giesen et al., Appl. Phys. Lett. **86**, 112510 (2005).

4:00 PM II11.2
Giant Magnetoresistance in Multilayered Elliptical Ring Devices. F. J. Castano, D. Morecroft, W. Jung and C. A. Ross; Depart. of Material Science and Engineering, MIT, Cambridge, Massachusetts.

Despite their possible applications in magnetoelectronic devices, multilayered rings remain unexplored. We have fabricated elliptical rings from NiFe/Cu/Co pseudo-spin-valve (PSV) multilayers and connected them with non-magnetic wires. Devices investigated consist of elliptical rings with outer diameters of 1.7 microns or 3.8 microns and widths from 90 nm to 350 nm. The rings show room temperature giant magnetoresistance with distinct resistance levels due to changes in the relative alignment between the magnetization in the soft (NiFe) and hard (Co) layers. Interactions between the layers prevent the formation of the flux-closure (vortex) state in the soft NiFe, and instead cause the NiFe ring to adopt a novel twisted-onion state, which resembles a bidomain (onion) state with additional 360deg walls, and which forms at low applied fields. Intermediate resistance levels are observed on cycling both magnetic layers, indicating that onion-to-reverse onion switching occurs via a vortex state, as well as on cycling only the soft NiFe layer. Computational analysis of 3D micromagnetic simulations reproduces the giant-magnetoresistance response of the rings. The behavior of devices with different ring dimensions and layer thicknesses will be presented, and applications of multiple low-field resistance levels in storage and logic devices will be discussed.

4:15 PM II11.3
Fabrication and magnetic properties of 100 - 500 nm ferromagnetic nanorings arrays with high areal densities. F. Q. Zhu and C.L. Chien; Physics and Astronomy, Johns Hopkins University, Baltimore, Maryland.

Magnetic nanoring is one structure that can support a stable vortex state. In contrast, the vortex core at the center of a magnetic disc destabilizes the vortex state. The two chiralities of the vortex state in nanorings have been proposed for magnetic storage such as vertical magnetic random access memories (VMRAM). Electron beam lithography has been used nearly exclusively to fabricate a small number of mostly micron-size rings with low areal density. As such, the magnetic signal of a small number of nanorings is too weak for most measurements except surface magneto-optical Kerr effect. Here we present a nanosphere template assisted method, without using electron lithography, for the fabrication of a large number (1E9) of 100 to 500 nm nanorings over a macroscopic area (cm2) with very high areal densities (up to 45 rings/micron2). This versatile method allows easy control of the diameter, thickness, composition and areal density of nanorings. Because of the large number of nanorings in each sample, the intricate magnetic properties can be readily measured with magnetometry. Starting from the saturation state of nanoring in a large field, the onion state is formed upon the removal of the field. The onion state has two semi-circular domains separated by two domain walls (DWs). Hysteresis measurements and micromagnetic simulations revealed two magnetic switching processes. One process is the vortex formation process. When a small negative field is applied, the two DMs first move towards the same direction and after annihilation form the vortex state. The robust vortex state remains stable until a larger field (0.2 T for 100 nm Co rings) generates two new domain walls and the reversed onion state is formed. The other process, called onion rotation process, has a small switching field (about 15 mT for 100 nm Co rings) and involves only the rotation of the onion state with the two domain walls always separated by 180 degrees during the whole process. In uniform Co nanorings of 100-500 nm diameters, both reversal processes exist with comparable probability, and the hysteresis behavior is consequently the superposition of those of the two processes. Our simulation results agreed very well with the observed behaviors. The systematic dependence of magnetic switching properties on the ring shape including diameter and thickness has also been studied. We found that if the ring thickness is less than 12 nm, the vortex formation process cannot be sustained. This can be understood in lights of the fact that a minimum cross section area is required to execute domain wall annihilation. For nanorings with thickness greater than 12 nm, the probability of vortex formation process increases with the ring diameter. In general, the larger or thicker the nanoring is, the higher the probability of obtaining the vortex states. This work was supported by NSF and DARPA.

4:30 PM II11.4
Fabrication and Characterization of Nanomagnetic FePd Dots Array. Jun Yuan, Peiwen Wu, Wei Peng, Xingling Tuo and Xiaogong Wang; Materials Science and Engineering, Tsinghua University, Beijing, China.

Ordered FePd and related alloys have high magnetocrystalline anisotropy constants, hence are candidates for high density magnetic storage applications. They are particularlly suitable for high density magnetic quantum dot recording media application. At the moment, such application is limited by suitable nanoarray fabrication technique and associated material processing optimzation. In this paper, we will report the fabrication and characterization of ultra high density (>150Gbits/inch) FePd magnetic dot arrays using a modified low cost nanosphere self-assembely method. The atomic structure characterization has been carried out by using XRD, SEM, TEM, NC-AFM. This is correlated with the magnetic characterization by AGM, SQUID as well as high-resolution MFM in order to study the morphorlogy as well as the magnetic properties as a function of the preparation parameters. Magnetic characterization is supported by nanomagnetic modelling to reveal a largely single domain magnetic states in FePd nanodots of 20-50 nm size range.

4:45 PM II11.5
On the Spin Structure of the Magnetic Vortex Core in Permalloy Disks Studied by LPM. V. V. Volkov[1], Y. Zhu[1], K. Buchanan[2], V. Novosad[2] and S. Bader[2]; [1]Center for Functional Nanomaterials, Brookhaven National Laboratory, Upton, New York; [2]Materials Science Division, Argonne National Laboratory, Argonne, Illinois.

Understanding the spin behavior in magnetic building blocks or elements is crucial to the development of telecommunication hardware and spintronic devices. The vortex states defined as magnetization curl appearing at the intersection of Neel walls and in crosstie walls (known as antivortex), are often observed in arrays of patterned nano- and mesoscale magnetic elements. They are also present in patterned circular disks, in this case with no visual presence of any domain walls. Here we use Lorentz phase microscopy (LPM) to study the bulk magnetization distribution of the magnetic vortex state, in particular, the profile of the vortex core. Recent qualitative experiments by MFM and spin polarized-STM have shown the 3D-structure of vortex core with curling magnetization turning out-of-plane, avoiding the high energetic cost of anti-aligned moments. However, these methods are surface probes, which do not reveal the bulk spin structure of vortex core. In contrast, LPM based e-beam probe is free from artifacts specific to tip-surface interactions; furthermore, it provides bulk magnetic information averaged over the film thickness. The core profile is an important attribute of the magnetic vortex state, especially in determining the dynamic properties. The key elements of LPM are Fresnel defocused imaging followed by quantitative retrieval of the electron wave phase shifts due to the magnetic potential in the sample. In the present work, we studied the local magnetization of patterned Permalloy (Py) disks 40 nm thick with diameters of 500-2500 nm, as fabricated on electron transparent Si_3N_4 membranes by a combination of e-beam lithography, magnetron sputtering and lift-off procedures. The grain of polycrystalline Py elements was 6-8 nm in size. The in-plane projected magnetization in close proximity to the vortex cores was retrieved by LPM. Using the commonly accepted assumption that the total magnetization over the exchange length compatible with the film grain size remains constant, we obtain a good approximation for the M_z(x,y), or out-of-plane magnetization component, derived from the 2D-distribution of in-plane $M_{x,y}$(x,y) components. A line profile for such z-component across the vortex core exhibits a sharp narrow maximum at the vortex center that is independent of the direction of in-plane magnetization curling, i.e. the vortex chirality. These results are well reproduced for Py disks with various diameters, and therefore, provide a clear experimental evidence of the out-of-plane bulk spin structure of the vortex core in Py disks.