SYMPOSIUM FF

FF: Advanced Magnetic Nanostructures

November 30 - December 4, 2003

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* Invited paper

TUTORIAL

FT FF: Self Assembly of Magnetic Nanostructures and Their Magnetic and Structural Characterization
Sunday, November 30, 2003
1:30 PM - 5:00 PM
Room 206 (Hynes)

The tutorial will cover the details of different techniques used to fabricate and characterize self-assembled magnetic nanostructures. Topics will include shape-controlled synthesis, self-organization of magnetic nanocrystals, and the techniques used to measure their structural and magnetic properties. The tutorial will also address experimental issues relating to the details of the fabrication and characterization techniques that are useful in practical laboratory situations. Experimentalists from both industrial and academic backgrounds will gain practical knowledge that will significantly benefit their programs.

Instructors:
Kannan Krishnan, University of Washington
Mark Tuominen, University of Massachusetts

SESSION FF1: Novel Fabrication Techniques
Chairs: Kristiaan Temst and Bruce Terris
Monday Morning, December 1, 2003
Commonwealth (Sheraton)

8:30 AM *FF1.1
Binary Superlattices of Magnetic Nanocrystals and Semiconductor Quantum Dots: Multi-component Nanoassembly. Christopher B. Murray, T.J. Watson Research Center, IBM, Yorktown Heights, New York.

Nanometer scale structures which are uniform size to + or - one lattice constant while controlling crystal shape, structure and surface passivation are now increasingly available. The tunability of the electronic properties of these structures and the development of discrete energy levels has leads these nanocrystals or quantum dots compared with a new artificial set of atoms. This talk will focus on the interesting binary superlattice systems that can be built with these "artificial atoms". We combine a high temperature solution phase synthesis with size selective processing techniques to produce organically passivated magnetic and nanocrystals with size distributions less than 5%. These nanocrystals then form the basis for a combined structural and magnetic study of the evolution nanocrystal properties with size. Two sets of monodisperse nanocrystals self-organize during controlled evaporation to produce 2D and 3D superlattices (colloidal crystals, opals) with well controlled structure. Co-assembly of magnetic nanocrystals and quantum dots into binary superlattices will be described. the resulting systems are found to self-assemble into AB13, AB2 and AB5 intermetallic structures under appropriate deposition conditions. The nanocrystals sit on regular close-packed superlattice sites, each separated by a selected organic spacer. The superlattices retain and enhance many of the desirable mesoscopic properties of individual nanocrystals and permit the first systematic investigation of new collective phenomena. Our goal is to study the properties of both the dispersed nanocrystals and assemblies as all major structural parameters are varied (composition, size, and spacing). Procedures have been developed for Co, Ni, FePt, and Fe2O3 magnetic nanocrystals as well as for CdSe, PbSe, PbS, PbTe and semiconductor quantum dots and quantum wires.

9:00 AM *FF1.2
Guided Self Assembly of Magnetic Nanostructures. Mark Tuominen[1], Andrei Ursache[1], Mustafa Bal[1], Qijun Xiao[1], James Goldbach[2] and Thomas Russell[2]; [1]Department of Physics, University of Massachusetts, Amherst, Massachusetts; [2]Department of Polymer Science and Engineering, University of Massachusetts, Amherst, Massachusetts.

Many future applications of magnetic technology require nanoscale magnetic elements configured into system architectures that provide useful functionalities. This talk will focus on highly dense arrays of magnetic and superconducting nanoscale elements made by new integrated nanofabrication techniques that utilize the guided microphase separation of diblock copolymers together with electrochemical deposition. First the magnetization properties of cobalt and permalloy nanowire arrays will be discussed as a model patterned magnetic system. We analyze the behavior these arrays with regards to magnetocrystalline anisotropy, shape anisotropy, and magnetostatic interactions. Secondly research will be presented on integrated magnetotransport nanowire devices in lateral and vertical transport geometries. Fabrication is achieved by combining nanoporous polymer templates with electron beam lithography. Measurements include spin-dependent electron transport GMR and AMR behavior, and Andreev-coupled superconducting behavior in nanoscale device geometries. This work is supported by NSF grants DMI-0103024, DMR-0071756, and MRSEC.

9:30 AM FF1.3
Ceramic Processing Advances for the 21st Century: Microwave-hydrothermal Synthesis of Nanostructured Magnetic Electroceramics. Anderson Dias, Engenharia Metalurgica e Materiais, UFMG, Belo Horizonte-MG, Brazil.

Chemical reactions responsible for producing high value-added products are, in most cases, also responsible for generating by-products and pollutants. New chemical and biochemical approaches are providing new reaction concepts. Among the as-called high value-added products, the nanostructured materials have generated great excitement and expectations in the last few years. There are many technologies currently employed for the production of nanostructured powders, with prominence for the environmentally friendly hydrothermal technology. The advantages and benefits include a high degree of chemical homogeneity achieved on the molecular scale, the use of mild temperatures and pressures, the single-step production of nanocrystalline powders, and the elimination of high-temperature calcination and milling procedures to react and remove aggregates. In the beginning of the 21st century, the hydrothermal technology represents the most promising route for environmentally friendly and low-cost production of advanced ceramic materials, either in batch reactors as well as in continuous reactors. A recent innovation in this technology was the introduction of microwaves into the reaction vessels to produce ceramic materials more rapidly. It offers many advantages over conventional autoclave heating, including rapid heating to crystallization temperature, homogeneous nucleation, fast supersaturation by the rapid dissolution of precipitated hydroxides, which leads to lower crystallization temperatures and shorter crystallization times. In this paper, we report the microwave-hydrothermal synthesis of nanostructured magnetic electroceramics. The fundamental issues relating to the hydrothermal processing conditions (temperature, pressure, time and pH) on the control of the phase behavior as well as of the morphological properties of these electroceramics are discussed in detail. X-ray diffraction, gas adsorption, SEM, TEM, FTIR, Raman and complex impedance spectroscopies were employed in the characterization of the ceramics.

9:45 AM FF1.4
Nanostrucuted NiFe2O4 Ferrite Fabricated by a Combined Chemical Synthesis and Consolidation Process. Heng Zhang, Shihui Ge and Y.D. Zhang; Inframat Corporation, Farmington, Connecticut.

A nanostructured NiFe2O4 ferrite has been fabricated using a combination of chemical synthesis and consolidation techniques. The NiFe2O4 precursors were synthesized using a sol-gel auto-combustion process. The bulk NiFe2O4 pieces were then consolidated through a hot pressing at different temperatures. The structure, electronic behavior and magnetic properties of the material have been investigated by using x-ray diffraction, SQUID magnetometer, impendence spectroscopy and high precision multimeter measurements. The study indicated that the grain size, microstructure, density and phase are determined by hot-pressing temperature under an argon atmosphere. The packing density increases significantly with temperature. Higher temperature consolidation leads to high packing density but also phase decomposition. The oxygen desorption was observed during the hot-press process, and this characteristic has significant effect on the resistivity and permeability of NiFe2O4 ferrite. Details of the study will be addressed in this presentation. This work is supported by USAF under the contract No. F29601-02-C-0031

10:30 AM FF1.5
Peptide-Mediated Synthesis of Alloyed Ferromagnetic Nanostructures. Brian D Reiss and Angela Belcher; Biological Engineering, MIT, Cambridge, Massachusetts.

Ultrafine magnetic nanoparticles have numerous applications in magnetic memory devices, biosensors, and nanoscale elctronics. Currently such materials are prepared as colloidal sols, and while these preparations yield monodisperse, crystalline solids, the dispersions are often expensive to prepare and usually lack long-term stability, limiting their applications. For this reason alternative synthetic strategies are currently under investigation. Peptide mediated synthesis of magnetic nanoparticles is one such alternative since it has previously been used to successfully synthesize

semiconducting nanoparticles and since it should provide a low temperature alternative to the traditional preps of magnetic nanoparticles. To accomplish this goal, a combinatorial phage library was exposed to the surfaces of nanoparticulate thin films of magnetic materials. These phage libraries contained phage which were functionalized with a random 12 mer or attached to their P3 coat proteins, and peptides were identified that bind selectively to the L10 phase of FePt and CoPt. These peptides were then used to control the nucleation of nanoparticles of these materials, and nanoparticles of the L10 phase of CoPt and FePt have been prepared using these peptides as templates to control the crystallinity of the nanoparticles. These particles have been extensively characterized using high resolution TEM and SQUID magnetometry.

10:45 AM FF1.6
Magnetic Nanoparticle Fabricated by Ion Beam Induced Chemical Vapor Deposition (IBICVD). Takao Suzuki and Yasuyuki Kageyama; Information Storage Materials Laboratory, Toyota Technological Institute, Nagoya, Aichi, Japan.

It has been demonstrated that the ion-beam induced chemical vapor deposition (IBICVD) technique has a potential benefit for fabrication of nano-dots.[1,2] Fabrication of Co particles was performed by IBICVD method, and the result of their characterization is presented here. The submicron Co particles were deposited by a focused Ga+ ion beam (FIB) system equipped with a source reservoir filled with precursor of octacarbonyl dicobalt [Co2(CO)8] powders. Vapor of the precursor was generated by heating the reservoir, and introduced though a feeding nozzle (0.5mm diameter) above the substrate separated by 0.5 mm. The residual pressure of the deposition chamber was around 1 e-5 Pa. The ion current and the pressure at deposition were 6 - 14 pA and 0.7 - 1.4 e-4 Pa, respectively. The in-situ image of Co particles was observed by SEM of the FIB system. Under the condition of irradiation of ion beams, the particle formation process is rather complicated due to concurrence of competitive processes (etching and deposition), therefore the morphology of Co particles strongly depends on the ion beam dwell time (5 to 120 e-6 s) and the partial pressure of Co2(CO)8 precursor, as revealed by AFM analysis. The smallest size of Co particles obtained is about 100 nm so far. They exhibit ferromagnetic behaviors. Results about modification of properties by heating substrates, and on formation of Fe-Pt alloy particles by dual precursor source, will also be presented. 1 A. Lapicki, E. Ahmad, and T. Suzuki, J. Magn. Magn. Mat. 240 (2002) 47 2 A. Lapicki, K. Kang, and T. Suzuki, IEEE Trans. Magns. 38 (2002) 2589.

11:00 AM FF1.7
Fabrication of Magnetic Planar-Nanostructures Using Electron Beam Lithography and AFM Nano-Lithography Techniques. Keizo Watanabe[1], Yasushi Takemura[1], Yoshihiro Shimazu[1] and Jun-ichi Shirakashi[2]; [1]Yokohama National University, Yokohama, Japan; [2]Akita Prefectural University, Honjyo, Akita, Japan.

Lithography techniques using scanning probe microscopes have attracted much interest as novel tools for fabricating electron devices with well defined structures of a nano-meter scale. Ni(Fe)- and Co-based nano-structures fabricated by a combination of electron beam (EB) lithography and atomic force microscope (AFM) nano-oxidation techniques are reported in this paper. Metals are oxidized by applying a negative bias on the AFM cantilever. This anodic oxidation process is an electrochemical reaction between metals and water in air. The selectively oxidized region can be utilized as separations of magnetic nanostructures and potential barriers in spin tunneling devices. We have reported advantages in a planar-type magnetic tunnel junction (MTJ) whose junction area is smaller than that of a conventional multilayer-type, and proposed a single electron transistor based on the planar-type MTJ. After pattering Ni thin films by EB lithography, nanowires of Ni-oxide were fabricated by AFM nano-oxidation, which resulted in the formation of Ni/NiO/Ni planar-type MTJ. It is expected that this MTJ with its smaller junction area exhibits Coulomb blockade effect. Details of the fabrication method and characterization of the planar-type MTJ are discussed as well as theoretical analyses on tunneling magnetoresistance under Coulomb Blockade and single electron effects. Co-based nanostructures with circular and rectangular shapes were also fabricated by using EB lithography followed by AFM nano-oxidation technique. In case of the rectangles with their size of 2 um or larger exhibited multi domain structures in magnetic force microscope (MFM) measurement, whereas the rectangles 1um or smaller width exhibited single domain structures. Ni-oxide nanowire was fabricated by AFM nano-oxidation along the central line of the rectangle of 3 um length and 0.75 um width. The single domain structure observed before the nano-oxidation was divided into two parts of single domains at both sizes of the Ni-oxide nanowire. It was found that the AFM nano-lithography could modify the magnetic domain structures. In summary, AFM nano-oxidation technique was performed on ferromagnetic metal-based nanostructures. Their electrical and magnetic properties were modified, which could be utilized for fabrications of magnetic nanostructured materials and devices.

11:15 AM FF1.8
Self-assembly of embedded perpendicular α-Fe nanopillars for potential high density magnetic memory.
Ladan Mohaddes-Ardabili[1], Haimei Zheng[1], Satish B. Ogale[1], Manfred Wuttig[1], Ramamoorthy Ramesh[1], Beatrice Hannoyer[2], Wei Tian[3], Xiaoqing Pan[3] and Samuel E. Lofland[4]; [1]Materials Science and Engineering, University of Maryland, College Park, Maryland; [2]Institut des Materiaux, Universite de Rouen, Cedex, France; [3]Department of Materials Science and Engineering, University of Michigan, Ann Arbor, Michigan; [4]Department of Physics, Rowan University, Glassboro, New Jersey.

A novel approach to create self-assembled ferromagnetic nanostructures for new magnetic recording media with high storage capacity is reported, which involves spontaneous oxygen-deficiency-driven phase decomposition of a single-phase perovskite oxide during film growth. The growth of La0.5Sr0.5FeO3 films by pulsed laser deposition on LaAlO3 (001) under reducing conditions is shown to develop a fairly homogeneous out-of-plane self-assembly of ferromagnetic α-Fe nano-pillars embedded in an antiferromagnetic matrix of a layered perovskite LaSrFeO4 (a = 3.88; c = 12.76) with K2NiF4 structure. The lateral dimension, shape and density of nano-pillars depend systematically on growth conditions, which therefore affect the magnetic properties. At 820 C square shaped pillars with a lateral width of 50-70 nm are formed. As the deposition temperature is reduced the shape evolves progressively into octahedral and then circular section. The dimensions of the pillars shrink to 3-5 nm for growth at 560 C. As expected, a large anisotropy is observed between the in-plane and out-of-plane magnetizations, with a large out-of-plane coercivity of maximum 3400 Oe achieved at 760 C (M = 0.9 Msat). In this paper we also report the result of our studies to induce a long-range translational order among these ferromagnetic nano-pillars. This work is supported partly by NSF-MRSEC under contract No. DMR-00-80008 and by an ONR MURI program under contract No. N000140110761.

SESSION FF2: Organized Structures
Chair: Timothy Klemmer
Monday Afternoon, December 1, 2003
Commonwealth (Sheraton)

1:30 PM *FF2.1
Brillouin Scattering from Magnetic Nanodots.
Marcos Grimsditch[1], Valentin Novosad[1] and Paolo Vavassori[2]; [1]Argonne Nat. Lab., Argonne, Illinois; [2]INFM-Dipartamento di Fisica, Ferrara, Italy.

Spin excitations in magnetic nanodots have been investigated experimentally using Brillouin scattering. Results will be presented for the particles in both the saturated and vortex states. The nature of the spin excitations observed in the vortex state will be discussed in the framework of recent theoretical advances which include analytical, micromagnetic and a hybrid micromagnetic-dynamical matrix, approaches. Work at ANL supported by the US DOE, BES Materials Sciences under contractW-31-109-ENG-38.

2:00 PM *FF2.2
Magnetism and Self-Assembly of Shape-Controlled Cobalt Nanocrystals and Their Superlattices. Kannan M. Krishnan, Yuping Bao and Michael Beerman; Dept of Materials Science & Engineering, University of Washington, Seattle, Washington.

Size-dependent scaling laws and the magnetic behavior of small particles and nanostructured assemblies, as a function of size, shape, dimensionality and inter-particle interactions are increasingly of fundamental and technological interest. In this talk, I will present details of the chemical synthesis of mono-disperse, metallic, passivated cobalt nanocrystals with good size/shape control. This will be followed by recent results on controlled self-assembled arrays obtained from this single component nanocrystals system by a systematic variation of their size, shape and inter-particle interactions. The self-assembled arrays can be tuned to selectively achieve square packing, hexagonal close packing, linear chains, spatially segregated arrays as a function of particle size and lyotropic liquid-crystal-like arrays with orientation order. This richness in self-assembly is obtained when one of a set of competing forces (steric, van der Waals, depletion, or magnetostatic) are chosen to dominate and determine the resulting organization. The nature of the magnetostatic coupling between the nanocrystals will be elucidated by high-resolution electron holography measurements. A variety of SQUID-based magnetic measurements will be presented to discuss surface spin-glass transitions in individual nanocrystals and

the nature of inter-particle interactions in two dimensional arrays. The talk will conclude with a discussion of the potential application of such nanocrystals in information storage and biomedical technologies.

2:30 PM *FF2.3
Magnetic Recording Properties On Patterned Media.
Jerome Moritz[1], Bernard Dieny[1], Jean-Pierre Nozieres[1], Rene Van De Veerdonk[2], Thomas Mas Crawford[2] and Dieter Weller[2]; [1]SPINTEC, Grenoble, France; [2]Seagate Research, Pittsburgh, Pennsylvania.

The use of patterned media seems to be a promising way to increase the areal density in magnetic storage up to 1 Tbit/inch2 since they allow to circumvent the superparamagnetic limit which should be soon reached in continuous recording media. The current efforts in this area address several issues : on the one hand, techniques of fabrication of patterned media on large scale, with feature size down to tens of nanometer and at low cost must be developed. On the other hand, writing and reading tests must be performed to evaluate the recording performances of these media and address the issues of servoing, electronic channel and so on. We focused ourselves on the study of patterned media prepared from arrays of silicon dots obtained either by e-beam lithography and RIE etching techniques or by nanoimprinting. Pt(Co/Pt)n multilayers which exhibit a strong perpendicular magnetic anisotropy are subsequently sputtered onto these prestructured wafers, thus covering the top of the dots and the bottom of the trenches between them. Some geometric characteristics as the height of the dots, the edge to edge spacing as well as the incidence of the sputtered species are crucial in the sense that they play a key role in the direct coupling which could exists between the bits. When the dots are significantly decoupled and exhibit a single domain magnetic state, the useful part for storing the information is the top of the dots. The recording properties of this media were investigated with a quasi-static tester using a classical longitudinal head to manipulate the magnetization of rows of individual dots. The relative motion of the head over the media is controlled with a piezoelectric XY stage. The final magnetic state after writing is measured with the spin-valve reader of the head. These experiments lead to the conclusion that the signal to noise ratio (SNR) is higher than in classical perpendicular media for the same density and does not decrease with the bit length as expected theoretically. This property of the SNR could be explained by a relative vanishing of the transition noise. Consequently, the noise in patterned media is mostly a jitter one which origin is the topographical jitter due to the lithographic process. The subnanoseconde magnetization switching dynamics of individual dots is another key aspect to be investigated. Thus, the evolution of the dynamic coercivity of an assembly of dots under an applied field sweeping at rates ranging from 10Oe/s to 107Oe/s has been measured by magneto optical Kerr effect (MOKE). Furthermore, using a write head with specially large bandwidth supplied with pulse of current 1s to 100ps long, we investigated the dynamic coercitivity of individual dots and studied the stochastic character of their magnetization switching. These recent and original experiments give precious technological arguments in favor of the use of such patterned media made from pre-structured wafers as a new storage system.

3:30 PM FF2.4
Magnetic Reversal of Co/Pd Multilayer Films and Sub-100nm Islands.
G Hu[1], T Thomson[1], S Raoux[2], C T Rettner[2], G M McClelland[2], M W Hart[2], M E Best[1] and B D Terris[1]; [1]Hitachi San Jose Research Center, San Jose, California; [2]IBM Almaden Research Center, San Jose, California.

Patterned arrays of Co/Pd multilayer islands with perpendicular anisotropy are one approach to increasing magnetic recording density towards 1Tbit/in2. To realize this technology arrays consisting of single domain islands with sufficient anisotropy for thermal stability and a narrow switching field distribution will be required. In order to understand the reversal properties of islands we have compared the reversal mechanism and anisotropy of patterned arrays to nominally identical unpatterned, continuous films. The island arrays were fabricated by creating an etch mask using electron beam lithography and nano-imprinting followed by etching of a SiO2 substrate. Multilayer films of Co/Pd were then sputter deposited onto the topographically patterned substrates. We found that for the continuous films, the magnetic anisotropy is only sensitive to the Co and Pd layer thicknesses while coercivity and magnetization reversal mechanism can be easily tuned by varying the deposition conditions. However, for small, single domain islands, the coercivity is much less sensitive to deposition conditions and more sensitive to composition than for the continuous films. The coercivity of these islands is generally significantly greater than that of the continuous films. Moreover, the switching behavior of the islands does not exhibit any correlation with the film reversal mechanism, but rather follows the film magnetic anisotropy closely. Systematic studies have been carried out to adjust the magnetic anisotropy of the multilayer films by varying the cobalt and palladium layer thicknesses. Unlike the continuous films, the measured coercivity of the islands agrees well with the reversal field calculated based on the measured anisotropy of the film and the Sharrock equation.

3:45 PM FF2.5
Effective magnetic anisotropy in nanoparticle systems probed using transverse susceptibility experiments.
P Poddar[1], H Srikanth[1], D F Farrell[2], S A Majetich[2], S Morrison[3] and E E Carpenter[3]; [1]Department of Physics, University of South Florida, Tampa, Florida; [2]Department of Physics, Carnegie Mellon University, Pittsburgh, Pennsylvania; [3]Naval Research Laboratory, Washington, District of Columbia.

We have measured transverse susceptibility (TS) using a home-built tunnel diode oscillator technique on various nanoparticle systems to explore the effect of varying packing fraction, dipolar interaction and exchange interaction on the effective anisotropy. The measurements were done over a wide range in temperature and magnetic fields to map the magnetization dynamics across the superparamagnetic transition. Two different types of systems were studied to explore the influence of inter-particle interactions and thermal relaxation on TS. In one set of experiments, close-packed quasi-2D arrays of monodisperse, surfactant-coated iron nanoparticles ($\sim$ 6.8 nm) were studied. In these systems, our experiments reveal that magnetic behavior is largely dominated by the inter-particle dipolar interaction. Moreover, we observed a distinct difference in the interaction strengths when external magnetic field is applied parallel and perpendicular to the plane of the arrays. In a second set of experiments, as-fired samples of manganese zinc ferrite nanoparticles ($\sim$ 16.5 nm) were studied with the TS experiments. Unlike the case of iron nanoparticles, these ferrite systems did not have surfactant coating and the magnetic properties were influenced both by the exchange and dipolar interactions. In these samples at low temperatures, in addition to the two anisotropy peaks generally observed in TS experiments, a third peak associated with switching fields is also clearly resolved. Overall, we demonstrate the effectiveness of radio-frequency TS experiments in probing magnetic anisotropy and discuss our results in the context of a model first developed by Aharoni. USF authors acknowledge support from NSF grant # ECS-0140047

4:00 PM FF2.6
Magnetic Properties of Monodispersive Ni Nanoparticles Obtained by Laser Electrodispersion.
Maxim Odnoblyudov, Vladimir M Kozhevin, Denis A Yavsin, Michail A Zabelin, Pavel A Tret'yakov, Irina N Yassievich and Sergei A Gurevich; Centre of Nanoheterostructure Physics, Ioffe Physico-Technical Institute, St.Petersburg, Russian Federation.

Recently, monodispersive Ni nanoparticles with the size of 2.5 nm have been obtained by laser electrodispersion (LE) method. These particles have single domain structure with magnetic moment per atom enhanced in comparison with bulk Ni. Selfordering effects in Ni granular films were observed induced by intergranular magnetic interaction. LE deposition experiment has been performed, in which Ni particles were impacted by an external magnetic field before being placed on the substrate. In the films fabricated in this way structural ordering was observed which manifests itself as more than three orders of magnitude difference in lateral film resistance appeared when magnetic field vector was set parallel or perpendicular to the gap between the contacts. Magnetoresistance of the films has also been studied in magnetic fields up to 5 T and in temperature range from 1.5K to 300K. Theoretical model for spin dependent hopping transport in magnetic granular media has been suggested to explain the experimental results. A single nanoparticle should exhibit superparamagnetic behavior, when thermal fluctuations result in fluctuation of the direction of nanoparticle magnetic moment. The ensemble of such particles may exhibit magnetic ordering due to intergranular interaction. This situation occurs in the films produced by the LE technique where the nanoparticle surface density can be made as high as 10^{12} cm^{-2}. We have performed theoretical modeling of the distribution of the nanoparticle magnetic moments in the Ni granular films. Magnetic structure of the films has been studied depending on granular density and arrangement, temperature, and external magnetic field. Possible applications of the films composed of such magnetic nanoparticles for ultrahigh density data storage and in spintronics are discussed.

4:15 PM FF2.7
Growth and Magnetic Properties of Co "Magic" Platelets on Si(111) Surface.
Jinfeng Jia, Ming-Hu Pan, Jun-Zhong Wang and Qikun Xue; The Chinese Academy of Sciences, Institute of Physics, Beijing, China.

Self-organized Co platelets with uniform size and shape were fabricated on identical Al nanocluster array formed on the Si(111)-7x7 surface. The Al nanocluster array not only suppresses the reactivity

between Si and Co, but also promises the formation of "magic" Co platelets. In-situ scanning tunneling microscopy reveals that almost all Co platelets appear as an equilateral triangle with a two-monolayer "magic" thickness and a fixed orientation, each platelet occupies N^2 halves of the 7x7 unit cells where N depends on the surface Co coverage. The magnetic properties of the platelets were investigated ex-situ by superconducting quantum interference device (SQUID). Steps found in hysteresis loop manifest the synergism between magnetic dipole interactions and magneto-crystalline anisotropy. The results demonstrate that the method we used is promising for incorporating magnetic nanostructures directly into Si-based electronic devices.

4:30 PM FF2.8
Magnetic Properties Characterization of Block Copolymer Templated Iron Oxide Nanoparticles Using Conventional Magnetometry and Neutron Scattering. Pinar Akcora[1], Robert M Briber[2] and Peter Kofinas[1,2]; [1]Chemical Engineering, University of Maryland, College Park, Maryland; [2]Materials Science and Engineering, University of Maryland, College Park, Maryland.

The aim of this project is to study the structure of magnetic nanoparticles templated by diblock copolymers and to investigate the magnetic properties of these nanoparticles in relation to the underlying self-assembled diblock nanodomain structure. Iron oxide nanoparticles using diblock copolymers as a template have been synthesized by ring opening metathesis polymerization (ROMP). The polymer consists of norbornene and deuterated norbornene dicarboxylic acid blocks. Deuteration of one of the blocks is essential to provide contrast for neutron scattering studies. The block ratios of the synthesized polymers were determined via gel permeation chromatography (GPC) and elemental analysis to be 360/120, 320/190 and 290/260. 5-15 nm iron oxide nanoparticles were produced within the polymer by solution association of iron salts to the carboxylic acid groups of one of the polymer blocks, subsequent solvent evaporation and oxidation upon formation of a solid nanocomposite film. Blocking temperatures of 70, 80 and 155K were determined by Superconducting Quantum Interference Device (SQUID) magnetometry for the 360/120, 320/190, and 290/260 samples, and their saturation magnetization values were calculated to be 60 emu/g of iron oxide. All the samples were superparamagnetic at 300K. At 10K there is a transition from superparamagnetic to ferrimagnetic behavior. The samples were characterized by room temperature Small-Angle Neutron Scattering (SANS) with and without an applied magnetic field. The effect of the polymer matrix morphology on the templated nanoparticle size, distribution and magnetic properties were also investigated. The domain sizes measured by SANS decreased upon doping with iron oxide. The SANS domain spacing of polymer 360/120 decreased from 73 nm to 53 nm after the formation of iron oxide and the polymer 320/190 showed a decrease in domain spacing from 67 nm to 37 nm, while sample 290/260 shows a change in domain spacing from 53 nm to 37 nm. The influence of polymer composition on nanoparticle size and distribution was also verified by transmission electron microcopy (TEM), where spherical, interconnected and wormlike polymer morphologies were observed.

SESSION FF3: Poster Session: Advanced Magnetic Nanostructures
Chair: Simone Raoux
Monday Evening, December 1, 2003
8:00 PM
Exhibition Hall D (Hynes)

FF3.1
Growth of BiFeO3 thin film on SrTiO3 substrate by LPE and sol-gel methods. Judith Louise MacManus-Driscoll[1,2], Veni Adyam[1], Xiaoding Qi[1] and Mark Blamire[1]; [1]Materials Science and Metallurgy, Univ. of Cambridge, Cambridge, United Kingdom; [2]MST-STC, Los Alamos National Lab, Los Alamos, New Mexico.

In recent years there is an increasing interest in a new class of materials, in which both electrical and magnetic ordering can coexist. Such so-called magnetoelectric materials have many potential applications including a new type of memory device based on the combination of ferromagnetism and ferroelectricity. BiFeO3 is one such material and has attracted recent, wide attention. Much of the current research on this material has been carried out using polycrystalline samples. Study on single crystal samples may lead to a better understanding of this material. However, growing bulk single crystal of BiFeO3 has been proven to be difficult with largest achievable size up to 5mm in one dimension. Epitaxial growth of thin films on single crystal substrates is more viable and probably more suitable for future applications. In this presentation, we report the growth of BiFeO3 thin films on SiTiO3 substrates by liquid phase epitaxy (LPE) and sol-gel methods. The obtained films have a high phase purity of BiFeO-3.and are highly textured, with FWHM=0.6∞ and 2∞ for out-plane and in-plane textures.

FF3.2
Effect of Synthesis Conditions and Spin Disorder on Magnetic Properties of Nanostructured Magnetic Particles. Shihui Ge[1,2], Yide Zhang[1], Shiqiang Hui[1], Heng Zhang[1], Joseph I. Budnick[2] and William A. Hines[2]; [1]Inframat Corporation, Willington, Connecticut; [2]Physics Department and Institute of Materials Science, University of Connecticut, Storrs, Connecticut.

Due to the potential for masa production, chemical synthesis approaches of nanostructured magnetic materials obtained considerable attentions in recent years. In chemical synthesis processing, two types of factors may effect the physical properties of magnetic nanoparticles. One relates to chemical reaction completion. Obviously, an incomplete reaction process results in lower saturation magnetization of the particle; the remaining raw materials play as impurities, leading to poor magnetic performance. Another important factor is surface or interface disorder. The surface region of a magnetic particle possesses crystallographically different microstructure from the interior of the particle and the electron spins in the surface region experience different atomic environment compared to that in the interior of the particle. Consequently, the long range exchange interaction in the surface becomes weaker than that in the interior, leading to somewhat disordered spin structure. The magnetic disorder causes reduced magnetization and increased anisotropy, both are harmful for magnetic softness. In this work we present the characterestics and fundamental effect of the two factors on the soft magnetic properties and some experimental observations of these two factors in Ni-ferrite, Fe- and FeNi-based nanocomposite particles. Based on the results, approaches for reducing surface disordering and improving synthesis conditons will be considered. Work supported by NSF Contract No. 0216929 and US Air Force Contract No. F29601-02-C-0031.

FF3.3
Abstract Withdrawn

FF3.4
Nanoscale Phosphorus Distribution and Magnetic Properties of Electrodeposited $[CoPtP_{100nm}/Cu_{xnm}]_n$ Multilayer Films. Kwan H Lee and Won Y Jeung; Materials Research Division, Korea Institute of Science and Technology, Seoul, South Korea.

Thin film CoPtP alloys have been known as one of the ferromagnetic alloys with the best PMA(perpendicular magnetic anisotropy) which can be obtained from electrodeposited materials. Therefore, some important studies have been devoted to the electrochemical fabrication of CoPtP alloys for the exploitation of their superior magnetic properties as well as relatively simple fabrication process. However, it has been also known that if the thickness of CoPtP film become more than about 1 μm, inherent high PMA was rapidly deteriorated with their thickness due to the formation of a columnar structure with larger grains. From this result, it can be expected that superior PMA of CoPtP film may be maintained or improved in the $[CoPtP_{(less than 1 \mu m)}/Cu_{(xnm)}]_n$ multilayers in which the thickness of each CoPtP layer was kept within 1 μm by using Cu(a typical non-magnetic material) interlalyers, and provided the motivation for this study. Moreover, we recently observed that the magnetic properties of electrodeposited $[CoPtP/Cu]_n$ films are also severely conditional on the thickness of Cu interlayers. Therefore, in order to produce thick magnetic films having high magnetization and coercivity, we have attempted the electrodeposition of $[CoPtP/Cu]_n$ multilayer films as an effective method to circumvent the thickness limitation through microstructural modification. Microstructural features of multilayered structures including nanoscale phosphorus distribution are also ascertained to elucidate the role of Cu thickness and relationship between microstructure and magnetic properties of electrodeposited CoPtP multilayers, which will lead to the plausible explanation on the role of Cu layers in controlling the magnetic properties of electrochemically multilayered $[CoPtP/Cu]_n$ films.

FF3.5
Surface Magnetism in Spinel Ferrite Nanoparticles. Christy Vestal and Z. John Zhang; School of Chemistry and Biochemistry, Georgia Institute of Technology, Atlanta, Georgia.

Surface chemistry is of great importance to the chemical and physical properties of nanoparticles. The magnetic structure at the surface layer usually is greatly different from that in the body of nanoparticle, and the magnetic interactions in the surface layer often have a notable effect on the magnetic properties of the nanoparticle. Understanding the influence of surface chemistry on the magnetic properties of nanoparticles certainly facilitates our fundamental understanding of the unique magnetic behavior in nanoparticles such as the quantum

origin of hysteresis in single domain magnetic nanoparticles. We will discuss the influence of a series of substituted benzoic acid ligands attached to the surface of $MnFe_2O_4$ nanoparticles upon the coercivity. Furthermore the synthesis and magnetic properties of $MgAl_2O_4/CoFe_2O_4$ core/shell nanoparticles will be discussed. As the core is non-magnetic this system provides a unique opportunity to isolate the contributions of a magnetic surface to the magnetic properties. The influence of surface spins upon the hysteresis properties will specifically be addressed.

FF3.6
Magnetic Nickel Ferrite Nanofibers Prepared by Electrospinning. Dan Li, Thurston Herricks and Younan Xia; University of Washington, Seattle, Washington.

We report a simple procedure based on electrospinning for generating random and uniaxially aligned nanofibers made of nickel ferrite. NiFe2O4 nanofibers with average diameter of 46 nm were prepared by electrospinning a solution containing poly(vinyl pyrrolidone) and the alkoxides of nickel and iron, followed by hydrolysis and calcination at 550 °C. Zero field cooled and field cooled scans and hysteresis measurements were performed on these fibers. Significant differences in magnetic properties were noted between the as-prepared nanofibers and powders prepared by a conventional sol-gel process. These differences can be attributed to long range morphology difference between a wire and a powder.

FF3.7
Magnetoimpedance of manganite films at high frequencies (f≥100 kHz). Djaffar Belharet[1], Pascal Xavier[1], Luana Fratila[2] and Catherine Dubourdieu[2]; [1]CRTBT, Grenoble, France; [2]Laboratoire des Materiaux et du Genie Physique, St Martin dHeres, France.

Manganite oxides such as $La_{0.7}Sr_{0.3}MnO_3$ exhibit colossal magnetoresistance, which is significant for magnetic fields of the order of Tesla. The magneto-transport properties of thin films have been extensively studied in DC conditions. On the contrary, it is yet not clear how these materials behave in high frequencies conditions. We report here on the magnetoimpedance measured in the range 100 kHz - 10 MHz of $La_{0.7}Sr_{0.3}MnO_3$ films. The films were grown either epitaxially on (001) $LaAlO_3$ or polycrystalline on (001) Si by metalorganic chemical vapor deposition. Different thicknesses were prepared in order to investigate strain effect. Both microstrip and coplanar devices were designed for the measurements, depending on the DC resistivity of the films. The magnetoimpedance was investigated in the temperature range 4 - 300 K, for magnetic fields up to 6 T. It was found that the magnetoresistance effect is still existing at high frequencies (e.g. at 220 K and 10 MHz : 7 % in 1 T and 26 % at 6 T for a polycrystalline film). The temperature and frequency dependence of the magnetoimpedance will be discussed and microstructure and thickness influence will be considered.

FF3.8
Enhancement of the thermal stability for Magnetic Tunnel Junctions with Pt-Added Pinned Layer. Il Suk Kang, Shin Hee Han, Yeo Geon Yoon and Seung Ki Joo; School of Materials Science and Engineering, Seoul National University, Seoul, South Korea.

Magnetic random access memory (MRAM) experiences near 400°C high temperature processes during manufacturing. So, the thermal stability of magnetic tunnel junctions (MTJs) near 400°C are requisite MRAM application. However, the tunnel magnetoresistance (TMR) signal is decreased after annealing above 300-350°C. Because Mn diffuses into the pinned ferromagnetic layer. We study the thermal stability effects in $NiFe/Al_2O_3/Co_{100-x}Pt_x$ MTJs as a function of Pt content. $NiFe/Al_2O_3/Co_{100-x}Pt_x/NiMn$ MTJs are prepared by RF magnetron sputtering and Al_2O_3 is oxidized by O_2 plasma. Successive annealing is performed up to 450°C. Decay of TMR elevated annealing temperatures is suppressed by increasing Pt content. This may be explained by the fact that Pt contributes to the improved barrier properties through thermal annealing by prevention of oxygen diffusion and interfacial mixing. Moreover, the enhancement of TMR is observed for Pt-added MTJs in comparison to the reference MTJs (x= 0).

FF3.9
Abstract Withdrawn

FF3.10
Nanocrystalline Iron Oxide Aerogels as Porous Magnetic Nanoarchitectures. Jeffrey Webster Long, Michael S. Logan, Brett M. Dening, Everett E Carpenter, Christopher P Rhodes, Rhonda M Stroud and Debra R Rolison; Chemistry Division, NavalResearch Laboratory, Washington, District of Columbia.

Aerogels are sol-gel-derived nanoarchitectures composed of a three-dimensional network of nanoscale particles intermingled with a continuous, aperiodic mesoporosity. The combination of properties intrinsic to aerogel-based architectures when coupled to functional oxides make them attractive candidates for a variety of applications including energy storage, electrochromics, fuel cells, and sensors [1]. We have adapted the methods of Gash et al. [2] to synthesize monolithic iron oxide aerogels. The amorphous, as-prepared iron oxide aerogels are converted to nanocrystalline forms, including Fe_3O_4 (magnetite) and γ-Fe_2O_3 (maghemite) under controlled temperature and atmosphere conditions. Nanocrystalline iron oxide aerogels exhibit magnetic properties ranging from superparamagnetism to ferrimagnetism. These magnetic solids retain the inherent characteristics of aerogels: high surface area, through-connected porosity in the mesopore (2 - 50 nm) range, and nanoscale particle sizes. On the basis of our ability to control both the pore-solid architecture and the nanocrystalline phase of these iron oxides, we can now design novel magnetic nanostructures. Of particular interest will be the interaction of guest ions and molecules within the magnetic nanoarchitectures, with potential applications for sensing and separations. We are also developing these materials as ion-insertion electrodes and as high-surface-area supports for heterogeneous catalysis. [1] D.R. Rolison, B. Dunn, J. Mater. Chem., 11, 963 (2001). [2] A.E. Gash, T.M. Tillotson, J.H. Satcher, J.F. Poco, L.W. Hrubesh, R.L. Simpson, Chem. Mater., 13, 999 (2001).

FF3.11
Study on Magnetic Properties of FePt Particles Assemblies. Xiangcheng Sun[1], David E. Nikles[1], J.B. Yang[2], M. Kim[2] and W. J. James[2]; [1]Center for Materials for Information Technology, The University of Alabama, Tuscaloosa, Alabama; [2]Materials Research Center and Department of Physics, University of Missouri-Rolla, Rolla, Missouri.

Monodisperse 4 nm diameter $Fe_{1-x}Pt_x$ nanoparticles with controlled compositions were synthesized by simple polyol reduction of platinum acetylacetonate and iron acetylacetonate. As prepared, the $Fe_{1-x}Pt_x$ particles had a disordered face-centered cubic lattice and were superparamagnetic. These $Fe_{1-x}Pt_x$ particles self-assembled into ordered 2D or 3D particles arrays when deposited onto some proper substrates. After heat treatment at temperature ranging from 500°C to 700°C under Ar with 5 percent H2 atmosphere, the $Fe_{1-x}Pt_x$ particles transformed into the tetragonal phase (L10, FCT). The coercivity of the annealed film strongly depended on the composition and the heat treatment temperature. This result was similar to that reported by the IBM group [1] for particles prepared from iron pentacarbonyl and platinum acetylacetonate. MÖssbauer spectroscopy measurements confirmed that, the as-prepared $Fe_{1-x}Pt_x$ films exhibited superparamagnetic characteristic due to the small particle size and disordered fcc phase. After heat treatment at temperatures greater than 500°C, the six line spectrum emerged, indicative of a ferromagnetic phase forming at the particles transformed to the L10 phase. Careful analysis of the spectra revealed a distribution of hyperfine fields, indicating the presence of the magnetically soft $FePt_3$. [1]. S. Sun, C. B. Murray, D. Weller, L. Folks, and A. Moser, Science 287, 1989 (2000).

FF3.12
Structural and Magnetic Properties of CoPtAg Nanoparticles Prepared by a Polyol Reduction Process. Xiangcheng Sun[1], Y.H. Huang[1], Z.Y. Jia[1], J.W. Harrell[1], David E. Nikles[1], K. Sun[2] and L.M. Wang[2]; [1]Center for Materials for Information Technology, The University of Alabama, Tuscaloosa, Alabama; [2]Nuclear Engineering and Radiological Sciences, University of Michigan, Ann Arbor, Michigan.

CoPtAg nanoparticles were prepared by the polyol reduction of cobalt chloride, platinum acetylacetonate and silver acetate in the presence of oleic acid and oleyl amine. By varying the reaction time and the amount of surfactant the particle size and shape could be varied. We chose to focus this study on a batch that gave particles with an average diameter of 10 nm. As prepared the particles were superparamagnetic, could be dispersed in hydrocarbons solvents. When the dispersions were cast onto either a silicon wafer or a TEM grid, the particles self-assembled into close-packed arrays. The films were heat treated at temperatures ranging from 550 to 700°C under Ar with 5 percent H_2 atmosphere to give a mixed phase with ordered fct (L10) CoPt and fcc (L12) $CoPt_3$. During heat treatment the silver left the particles as indicated by a Ag <111> x-ray diffraction peak. Unlike our experience with FePt, the addition of Ag seemed not promote phase transformation the transformation from the fcc to the L10 phase. The coercivity of the films increased with increasing heat treatment temperature and longer time. However, the coercivity values were still lower (maximum 3 kOe at RT) than that of FePt particles that is consistent with the structure analysis. The time decay of remanence coercivity at different temperatures was measured and fitted to Sharrocks formula and the thermal stability factor (KV/kT) was determined.

FF3.13
Phase Change of FePt nanoparticles in Dispersion by Pulsed-Laser Annealing. Soichiro Saita[1] and Shinya Maenosono[2]; [1]STRC Solid/Powder Processing Laboratory, Mitsubishi Chemical Corporation, Yokohama, Kanagawa, Japan; [2]The University of Tokyo, Bunkyo-ku, Tokyo, Japan.

Chemically synthesized FePt colloidal nanoparticles in dispersion were exposed to 400nm YAG-pulsed laser for the purpose of changing internal crystal structure of each particle like annealing in a furnace. With irradiation time increased from 6 sec to 1 Hr, the size of FePt nanoparticles in the dispersion became bigger. This meant the temperature of each particle reached high enough to aggregate each other without breaking surface organic molecules. The XRD measurement showed that the laser irradiation promoted the rearrangement of Fe and Pt atoms and improved long range chemical ordering. This ordering could be seen prior to the phase change into L10 fct structure which has large coercivity. Magnetic property of laser annealed particle films were evaluated using VSM.

FF3.14
Organic coating of gas-phase prepared Fe-Pt nanoparticles. Annegret Terheiden[1], Karsten Moh[2], Mehmet Acet[2], Christian Mayer[1] and Bernd Rellinghaus[3]; [1]Physical Chemistry, University Duisburg-Essen, Duisburg, Germany; [2]Experimental Physics, AG Farle, University Duisburg-Essen, Duisburg, Germany; [3]Institute of Combustion and Gasdynamics, University Duisburg-Essen, Duisburg, Germany.

Fe-Pt nanoparticles in the $L1_0$ phase have attracted considerable attention as potential material for media in future high density magnetic recording. Besides others, wet-chemical and gas-phase based preparation routines are employed to prepare such intermetallic nanomagnets. The wet-chemical method provides the advantages of producing monodisperse particles that arrange periodically via self assembly. However, post-deposition annealing is required to generate the $L1_0$ superstructure, which bears the disadvantage of inter-particle coalescence. Gas-phase based techniques, on the other hand, allow to establish the $L1_0$ phase in-flight prior to their deposition, but the deposited particles are usually randomly distributed on the substrate. In this contribution, we present a technique that aims at combining the advantages of both methods. Fe-Pt nanoparticles are prepared by inert gas condensation and sintered in-flight at elevated temperatures. The particles are then deposited onto substrates covered with films of oriented amphiphilic molecules. We show that this new approach leads to a self-coating of the metallic nanomagnets and an increased tendency of these organically coated particles to arrange in periodic patterns via self-assembly. Phospholipids are well known to form nanoscaled mono- and multilayers around curved structures in biological systems which allow for narrow curvatures. Their ionic head groups interact strongly with polar surfaces, so they are expected to form a thermodynamically stable layer around metallic nanoparticles. In most experiments, we have used phosphatidylcholine-(C18:2/C18:2), a phospholipid that carries two aliphatic chains, each consisting of 18 carbon atoms and two double bonds. All surfaces were coated by vesicle fusion out of a (TRIS-) buffered solution meant to control the zwitterionic nature of the phospholipid head group. Layers of these amphiphilic molecules are deposited on both amorphous SiO and thin Pt films. The quality of these layers is characterized by fluorescence microscopy, TEM, and AFM. Both types of substrates turn out to be homogeneously covered, and the thicknesses of the layers are determined by AFM to be roughly 7.3 nm. This is about three times the length of the molecules which indicates that the deposited films consist of triple layers of phospholipids. Fe-Pt nanoparticles which are deposited onto likewise pre-coated substrates exhibit a preferred separation of 2.1 nm which is compatible with a partial interdigitation of the aliphatic chains of adjacent lipid layers. In the sole presence of the TRIS-buffer (no phospholipids), the particles are separated by 1.2 nm (i.e. twice the length of the TRIS molecule) and display a strong tendency to arrange in hexagonal packings. In contrast, direct contact or a variety of separations is observed when the particles are deposited onto untreated substrates. The work is supported by the Deutsche Forschungsgemeinschaft within SFB 445.

FF3.15
Critical Thickness Issue in Magnetite-MgO Heteroepitaxy. Sunil Kumar Arora, R. G. S. Sofin and Igor V Shvets; SFI Nanoscience Laboratory, Physics Department, Trinity College, Dublin-2, Dublin, Ireland.

Epitaxial thin films of magnetite (Fe_3O_4) have recently attracted considerable attention as magnetite is an important material for spin electronics applications due to its half metallic nature, high Curie temperature and metal-insulator transition at 120K (Verwey Transition). There are several reports on the growth of magnetite films on a variety of substrates. MgO is an ideal template for epitaxy of magnetite because of the small lattice mismatch (0.33%). Understanding of the critical thickness behaviour in Fe_3O_4/MgO heteroepitaxy is a key issue in tailoring nano-structured devices based on magnetite. Here, we report on a systematic investigation of strain status in Fe_3O_4epitaxial thin films. The magnetite films were grown on (100) oriented MgO single crystal substrates using oxygen plasma assisted molecular beam epitaxy (MBE). The structural characterization of the Fe_3O_4 films was done via high resolution x-ray diffraction Reciprocal Space Maps (RSM). The RSM was performed about the non specular Bragg reflections (622/311) which are common to both the substrate and the overlayer. From the analysis of the RSMs we have determined the value of in-plane and out-of-plane lattice parameters of the film and these come out to be 0.421299nm and 0.418607nm($\pm$0.000005nm) respectively. The in-plane lattice parameter of the film (half of the spinel unit cell) is the same as that of the substrate (0.4213nm) and therefore the films are under tensile strain. The films do not show any relaxation with the increase in thickness and remain epitaxial even up to 700nm. This thickness is much larger than the predicted values of critical thickness ($\sim$60nm) from conventional models based on misfit strain [1]. A comparison with theoretical predictions of the relaxation behaviour of magnetite on MgO will be made and a model for the anomalous increase in the critical thickness value will be proposed. 1. A. Fischer, H Kuhne and H Richter, Phys. Rev. Lett. 73, 2712 (1994)

FF3.16
Electrodeposition of Ceramic Ferrite Nano Particles for Micromagnetic Applications. Cody Michael Washburn[1], Tejas Jhaveri[1], Michael Clement[2] and Santosh K Kurinec[1]; [1]Microelectronic Engineering, Rochester Institute of Technology, Rochester, New York; [2]Ferronics Incorporated, Fairport, New York.

In recent years there has been growing interest in building of micro magnetic components directly onto semiconductor substrates and the integration of magnetic components with other circuitry. Magnetic materials have unique properties that are also driving their integration with micro-electro-mechanical (MEM) devices. Various microfabrication technologies are being explored to integrate magnetic materials on chips for micro magnetic devices. In this study, application of electrophoretic deposition for depositing oxide magnetic material has been investigated. Electrophoresis (EP) is a process by which charged particles suspended in a solution are made to migrate by an electric field and are deposited on a conducting substrate. The magnetic material used for this study is a low coercivity soft spinel ferrite, manganese zinc ferrite (MnxZn1-xFe2O4) with initial permeability ranging from 5,000-10,000 for applications in micro inductors, micro transformers and other on chip magnetic devices. Micro/nano particles of sintered Mn-Zn ferrite have been prepared by jet milling technique followed by particle size reduction. EP deposition has been carried out from an isopropyl alcohol solution containing magnesium nitrate as the charging and binding agent. The solution composition has been optimized to obtain high zeta potential to prevent agglomeration. Micro toroids and inductors have been fabricated on silicon substrates using conventional photolithography and deep silicon reactive ion etching (DRIE). Initial permeability measurements suggest reasonable packing density of ferrite particles. The resolution and packing density obtained by this process are determined by the ferrite particle size distribution.

SESSION FF4: Ferroelectric/Ferromagnetic Nanostructures and Colossal Magnetoresistance
Chair: Thomas Thomson
Tuesday Morning, December 2, 2003
Commonwealth (Sheraton)

8:30 AM *FF4.1
Ferroelectric Field Effect Modulation of Magnetism in the Colossal Magnetoresistance Oxide $La_{1-x}Sr_xMnO_3$. Xia Hong, Agham-Bayan Posadas, Andrew Lin and Charles Ahn; Applied Physics, Yale University, New Haven, Connecticut.

The correlated properties of complex oxides such as the colossal magnetoresistance (CMR) oxides depend sensitively on the carrier concentration, making them attractive candidates for field effect experiments. Using the nonvolatile, reversible polarization field of the ferroelectric oxide $PbZr_xTi_{1-x}O_3$ (PZT), we have modulated the magnetic properties of $La_{1-x}Sr_xMnO_3$ (LSMO). Epitaxial ferroelectric PZT/LSMO heterostructures were fabricated using off-axis magnetron sputtering, with high quality crystalline structure and atomic level surface roughness being obtained. Switching the polarization field of the ferroelectric induces a reversible shift in the Curie temperature of the LSMO layer and also results in a change in the magnetoresistive properties. For samples close to the metal-insulator transition, reversible switching between metallic and insulating behavior is observed. This approach allows one to

investigate the role of charge in the CMR effect without introducing chemical or structural disorder.

9:00 AM FF4.2
Fabrication and Properties of Nanoscale Magnetic Oxide Multilayers and Supperlattices. Land Belenky[1], Xianglin Ke[2], Yanbin Chen[3], Mark Rzchowski[2], Xioaqing Pan[3] and Chang-Beom Eom[1,2]; [1]Materials Science and Engineering, University of Wisconsin, Madison, Wisconsin; [2]Physics, University of Wisconsin, Madison, Wisconsin; [3]Materials Science and Engineering, University of Michigan, Ann Arbor, Michigan.

Interfacial and reduced-dimensional effects in magnetic and electronic heterostrcutrues are of great technological and scientific interest. We have fabricated and measured nanoscale epitaxial magnetic oxide heterostructures, multilayers and superlattices based on ruthenates and manganates with atomic-layer control by pulsed laser deposition with in-situ, high-pressure RHEED. Structural characterization through atomic force microscopy, x-ray diffraction and transmission electron microscopy has been related to magnetic and electronic characterization. We employ a scanning probe microscope and conventional lithographic techniques for transport measurements of small structures. We will discuss measurements on nanoscale magnetic-oxide heterostructures, including both magnetic tunneling junctions and spin-valve structures.

9:15 AM FF4.3
Nano-scale characterization of the ultra thin (La,Ba)MnO3 film with room temperature ferromagnetism and their device application. Hidekazu Tanaka[1,2], Teruo Kanki[1], Takuya Matsumoto[1] and Tomoji Kawai[1]; [1]ISIR-Sanken, Osaka University, Ibaraki, Osaka, Japan; [2]PRESTO, Japan Science and Technology Corporation, Saitama, Japan.

We have fabricated La0.8Ba0.2MnO3 thin films with atomically flat surface on a SrTiO3(001) substrate according to the Pulsed Laser Deposition (PLD) technique, and have systematically investigated the magnetism for film thickness dependence in the ultra thin region down to 5nm. The enhancement of TC up to room temperature in (La,Ba)MnO3 thin films with 400 nm to 20 nm thickness was observed. The 20 nm thick film showed the maximum peak of TC (=310 K). It was found that even the 5 nm thick film still showed a TC of 290 K near room temperature. In addition, we have evaluated the local surface magnetism in (La,Ba)MnO3 thin films and succeeded in the detection of small magnetic domain behavior around TC using frequency shift mode Non Contact - Magnetic Force Microscopy (NC-MFM). The local magnetic domain behavior around the TC (303K) of the (La,Ba)MnO3 film was visualized. No magnetic domains existed above the TC. Only an atomically flat terrace with one unit cell steps of the LBMO surface can be confirmed. With decreasing temperature, the magnetic domains with 20 nm width appear at the flat terraces structure at the TC. Furthermore, the magnetic domains grow up to 200 nm at 301 K with cooling. By using the NC-MFM system, the appearance of room temperature ferromagnetism at the nano-scale level was also confirmed all over the film surface. The temperature dependence of local magnetism derived from height of MFM images corresponds to the magnetization curve reflecting the macro scale as measured by SQUID. We will also discuss the hetero-structure composed of ultra thin (La,Ba)MnO3 and ferroelectric (or semiconductive) thin films.

9:30 AM FF4.4
Huge Resistance Change in $La_{0.8}Ca_{0.2}MnO_3/PbZr_{0.2}Ti_{0.8}O_3$ Multilayers On Si Under Small Electric and Magnetic Fields. Tong Zhao[1], S B Ogale[1], R Ramesh[1], J Yu[2], R Droopad[2], K Eisenbeiser[2], M Zhu[3], T Egami[3] and J Misewich[4]; [1]Materials Research Science & Engineering Center, Univ. of Maryland, College Park, Maryland; [2]Physical Sciences Research Laboratories, Motorola Labs, Tempe, Arizona; [3]Univ. of Pennsylvania, Philadelphia, Pennsylvania; [4]Brookhaven National Laboratory, Upton, New York.

Colossal Magnetoresistance (CMR) manganites display a rich variety of phenomena attributed to the unique coupling of spin, charge, orbital, and lattice degrees of freedom and the attendant multiphase coexistence. Some recent theoretical studies have predicted that huge MR effect should be realized in these materials, if the microscopic aspects of phase separation could be suitably controlled and tuned. In this paper, we explore the possibility of achieving this objective by application of a significantly higher biaxial strain than examined before, by growing manganite $La_{0.8}Ca_{0.2}MnO_3$ (LCMO)/ferroelectric $PbZr_{0.2}Ti_{0.8}O_3$ (PZT) multilayers on $SrTiO_3$ (STO) buffered silicon. The strain in this case is 1.5% (tensile), as against 1.2% (tensile) and -1.0% (compressive) on STO and $LaAlO_3$ (LAO), which have been widely investigated. Moreover, the thermal mismatch induced strain on Si could not be fully released by increasing the LCMO thickness, which is different from the lattice mismatch induced strain on STO and LAO. A huge change in resistance (1000%) was induced in such configurations by application of small electric (4×10^5V/cm) and magnetic (about 100Oe) fields. We will discuss the possible intrinsic and extrinsic contributions to these observed huge effects. This work is supported by the NSF-MRSEC under contract No. DMR-00-80008 and by Brookhaven National Laboratory.

9:45 AM FF4.5
Influence of annealing on lattice constant and magnetic properties of epitaxial Fe_3O_4 (100) films. Yang Zhou, Xuesong Jin, S K Arora and Igor Shvets; SFI Lab, Dept. of Physics, Trinity College, Dublin, Ireland.

Single crystalline epitaxial Fe_3O_4 (100) thin films have been grown on MgO (001) using oxygen-plasma-assisted molecular beam epitaxy. The as-deposited films are fully strained which is confirmed by High Resolution X-ray Diffractometry (HRXRD). The changes in the crystalline structure and magnetic properties of the films caused by their annealing in air at the temperature up to 250 °C have been characterized by means of in-situ HRXRD and Alternating Gradient Force Magnetometer (AGFM). It has been found that the out-of-plane lattice constants of the films decreases with annealing time driven by the change in the film composition. In-plain lattice constant of the film remains the same as that of the MgO substrate. This implies that films maintain fully strained condition even as the stoichiometry changes during the thermal annealing. Saturation magnetization (Ms) increases to a maximum value at annealing time of 20 min and then starts decreasing with further annealing. The increase in Ms is attributed to the disappearance of antiphase boundaries in the films and change in stoichiometry is thought to be responsible for the decrease in Ms. Our results suggest that the antiphase boundary structure and the antiferromagnetic coupling between domains can be influenced by thermal annealing procedure.

10:30 AM FF4.6
Epitaxial growth and characterization of ferroelectric/ferromagnetic $BaTi_O3$-$CoFe_2O_4$ thin films. Haimei Zheng[1], Junling Wang[1], Valanoor Nagarajan[1], Jun Ouyang[1], Lourdes Salamanca-Riba[1], Ramamoorthy Ramesh[1], Wei Tian[2], Xiaoqing Pan[2] and Samuel E. Lofland[3]; [1]Materials Sci. & Eng., University of Maryland, College Park, College Park, Maryland; [2]Materials Sci. & Eng., University of Michigan, Ann Arbor, Michigan; [3]Physics, Rowan University, Glassboro, New Jersey.

Ferroelectromagnetic nano-composite $BaTi_O3$-$CoFe_2O_4$ thin films were successfully deposited on single-crystal MgO (001) and SrTiO3 (001) substrates by pulsed laser deposition (PLD) from a single Ba-Ti-Co-Fe-Oxide target. The spinel CoFe2O4 and perovskite BaTiO3 phases were spontaneously formed during deposition. The crystallography of the films was investigated using X-ray diffraction (XRD) and transmission electron microscopy (TEM). It was shown that films are epitaxial with CoFe2O4 pillars (20-80 nm dia) homogeneously distributed in the BaTiO3 matrix. The shape and the degree of ordering of CoFe2O4 pillars are studied by varying the growth rate, film thickness and substrate topography. Vibrating sample magnetometer (VSM) measurements exhibit that all the films have a uniaxial magnetic anisotropy with an easy direction normal to the film plane. The coercivity of the film is very sensitive to the changes of growth rate and film thickness, which suggest effect of stress and the shape of CoFe2O4 phase on the magnetic properties of the film. We measured the ferroelectric, piezoelectric and dielectric properties of the film, which are corresponding to the present of BaTiO3 phase. The coupling between the piezomagnetic phase of CoFe2O4 and piezoelectric phase of BaTiO3 is discussed in this paper. This work is supported by the NSF-MRSEC under contract No. DMR-00-80008.

10:45 AM FF4.7
Magnetotransport properties of epitaxial magnetic oxide heterostructures. Xianglin Ke, Mark Rzchowski, Land Belenky and C. B. Eom; University of Wisconsin-Madison, Madison, Wisconsin.

Magnetic oxide materials exhibit a wide range of electronic properties with only small changes in crystal structure and lattice constant. This makes them ideal materials for construction of magnetic heterostructures. We report magnetotransport properties of epitaxial magnetic oxide heterostructures grown by pulsed laser deposition with in-situ RHEED monitoring. Here we concentrate on the magnetic oxides LaSrMnO3, LaSrMnO3, and SrRuO3. Extensive in-situ and ex-situ evaluations show that resulting heterostructures are epitaxial, and in most cases strained to match the underlying substrate. Transmission electron microscopy indicates layer interfaces of very high quality. The structures are lithographically patterned at the micro and nano-scale for either current-in-plane or and current-perpendicular-to-plane magnetotransport measurements. We will discuss magnetic and magneto-transport measurements of exchange-bias bilayers, GMR mulitlayers, and magnetic tunnel junctions.

11:00 AM FF4.8
Spin-polarized quasiparticles injection in $La_{0.7}Sr_{0.3}MnO_3/SrTiO_3/Nb$ heterostructure devices.
L. Fratila[1], I. Maurin[1], C. Dubourdieu[1] and J.C. Villegier[2]; [1]Laboratoire des Materiaux et du Genie Physique - INPG-CNRS, Saint Martin d'Heres, France; [2]LCP-DRFMC/SPSMS-CEA, Grenoble, France.

The effect of spin-polarized quasiparticles injection from a ferromagnetic electrode into a conventional superconductor was investigated in $La_{0.7}Sr_{0.3}MnO_3/SrTiO_3/Nb$ heterostructures. The ferromagnetic $La_{0.7}Sr_{0.3}MnO_3$ underlayer (~95nm) and the $SrTiO_3$ thin barrier (2-8 nm) were grown epitaxially by pulsed-injection MOCVD on single crystal $SrTiO_3$ (100) substrates. The $SrTiO_3$ substrate was favoured because it exhibits an in-plane magnetisation with domains size up to tens of μm. In this case the magnetic domains are larger than the spin diffusion length in order to avoid averaging from adjacent domains and to obtain a good polarisation of the current. The cap layer is a conventional polycrystalline superconductor Nb film (~80 nm) prepared by DC magnetron sputtering. A 4 T in-line geometry was used, where the injected current I_{inj} enters into one end by tunneling and leaves symetrically the superconductor at the other end. The superconducting bridge length L (~20 μm) was chosen to be comparable or shorter than the transfer length in order to insure an uniform injection over L. A gain G = - dI_c/dI_{inj} were I_c is the critical current of the superconductor, of about 150 was obtained. The Joule heating effect was estimated in order to evaluate the resistive contribution to the supression of the critical current.

SESSION FF5: Magnetoresistance/Spintronics
Chair: Leonard Spinu
Tuesday Afternoon, December 2, 2003
Commonwealth (Sheraton)

1:30 PM *FF5.1
Magnetization Reversal by Injection and Transfer of Spin: Experiments and Theory. Albert Fert[1], Pierre Boulenc[1], Vincent Cros[1], Jean-Marie George[1], Julie Grollier[1], Henri Jaffres[1,2], Giancarlo Faini[3] and Amir Hamzic[2,1]; [1]Unite Mixte CNRS-Thales, Universite Paris-Sud, Orsay, France; [2]Faculty of Sciences, University of Zagreb, Zagreb, Croatia; [3]Laboratoire de Photonique et nanostructures, CNRS, Marcoussis, France.

Slonczewski (and also Berger) predicted in 1995 that the magnetization of a magnetic layer can be reversed by spin transfer from a spin-polarized current injected into the layer. Convincing experiments have been now achieved and several theoretical approaches, extending the initial theory, have been recently developed for the interpretation of the existing experimental data. The first part of the talk is a short presentation of experiments performed on Co/Cu/Co submicronic pillars fabricated by an e-beam lithography method. In a first type of experiment, we measure the critical current needed to switch the magnetic configuration of the trilayer from parallel to antiparallel (or antiparallel to parallel) and we study its dependence on the layer thickness, applied field and temperature. In another type of experiment, we use the current-induced interaction to control the magnetic configuration of the trilayer (parallel or antiparallel) and thus enhance or suppress the GMR. In the second part of the talk, I summarize the theoretical model we have developed for the interpretation of the experiments on pillars. This model is based on a self-consistent calculation of the longitudinal and transverse components of the spin current throughout the multilayered structure in the limit of quasi-interfacial spin transfer. The torques acting on the magnetic layers are derived from the transverse component of the spin current injected into each layer. I will compare our results for the torque with what is expected in other models and other limits. The critical currents are then calculated by introducing the torque in a LLG equation and I will discuss the different behaviors expected in different ranges of applied field (direct reversal or maintained precession). The experimental results on pillars will be compared with what can be predicted by our calculations or the calculations of other models. The third part of the talk is devoted to the motion of domain walls (DW) by transfer of spins from a spin-polarized current. I will present experiments in which we switch a spin valve (SV) without applied field by moving back and forth a DW in the permalloy layer of the SV. This type of current-induced magnetic switching requires smaller current densities than the magnetization reversal in pillars and is therefore promising for applications.

2:00 PM FF5.2
Current-Driven Magnetization Dynamics at High Magnetic Fields in Co/Cu/Co Nanopillars. Barbaros Oezyilmaz[1], Mariano Zimmler[1], Andrew D Kent[1], Jonathan Z Sun[2], Michael J Rooks[2] and Roger H Koch[2]; [1]Physics, New York University, New York, New York; [2]IBM T.J. Watson Research Center, New York, New York.

The observation of current induced angular momentum transfer in point-contact experiments on magnetic multilayers in the field perpendicular geometry [1] has boosted interest in spin-transfer effects in magnetic nanostructures. We have studied spin-transfer torques in the same field perpendicular configuration in both Co/Cu/Co and Cu/Co/Cu pillar devices at 4.2 K and 293 K. In this geometry for fields greater than the demagnetization field there is a high degree of symmetry. Also, the absence of an effective energy barrier between states simplifies the analysis of current induced magnetization dynamics. Of equal importance is the possibility of a direct comparison between point-contact and pillar device experiments. Sub-micron size (~ 50 nm) pillar devices have been fabricated by means of a new nano-stencil mask process, which enables the production of large arrays of templates ideal for systematic variation of layer thickness and composition. In Co/Cu/Co junctions I(V) measurements in large magnetic fields (>1.5T) show an abrupt and hysteretic increase in device resistance at high current densities for one current polarity. Comparison of the (spin-transfer induced) resistance change of the junction in perpendicular fields with the (in-plane) giant magnetoresistance value suggests that the peak in dV/dI corresponds to the switching of the layers into a state of anti-parallel magnetic alignment. Magnetoresistance measurements at large (positive) bias confirm our findings and micromagnetic modeling is in qualitative agreement with these experimental observations [2]. Recently, current induced spin-wave instabilities have also been predicted for Cu/Co/Cu pillar devices at current densities similar to the critical current densities j_c in Co/Cu/Co junctions [3]. We have conducted transport measurements in the same field-perpendicular geometry with pillar devices containing only a single ferromagnetic layer. The Co-layer thickness has been varied systematically from 2 nm to 17 nm and current densities (>¿j_c) were comparable to the ones achieved by means of point-contacts. In these single layer devices, I(V) measurements did not exhibit the characteristic spin-transfer effect features. Our results demonstrate that in pillar devices current induced magnetic heterogeneities of the kind reported by Ji et al. [4] in point contacts are absent. [1] M. Tsoi et al, Nature 406, 46 (2000). [2] B. Oezyilmaz et al., arXiv:cond-mat/0301324. [3] M.L. Polianski and P.W. Brouwer, arXiv:cond-mat/0304036. [4] Y. Ji, C. L. Chien, and M. D. Stiles, Phys. Rev. Lett. 90, 106601 (2003).

2:15 PM FF5.3
Energy Deposition Effects on Giant Magnetoresistive Spin-Valve Multilayer Materials. David Zou, Romney Katti, Daniel S. Reed, Gordy A. Shaw and Hassan Kaakani; Solid State Electronics Center, Honeywell International, Inc., Plymouth, Minnesota.

The development of Giant Magnetoresistive Random Access Memory (GMRAM) and nanoscale giant magnetoresistive (GMR) Spin-Valve (SV) magnetic memory elements has created a need for improved magnetic materials. In this work, the magnetotransport, switching, and microstructural properties of GMR multilayer materials and films grown using Ion Beam Deposition were shown to depend on deposition energy. Resistance, magnetoresistance, and hysteresis loop measurements were made on GMR multilayer films. Measurements showed that as deposition energy was increased, SV material sheet resistance increased and SV GMR coefficient decreased, while SV switching field (Hc), anisotropy field (Hk), and exchange field (He) did not change significantly. An Atomic Force Microscope (AFM) was used to measure thin film surface roughness on single-layer (SL) films. AFM measurements showed that increasing deposition energy increased surface roughness. The AFM measurements on SL films showed that the roughness induced by changing deposition energy was induced within a single film and did not require intermixing nor interlayer diffusion. At higher deposition energy, the increase in resistivity and reduction in GMR coefficient is consistent with the increase in surface roughness that increased scattering. As deposition energy is increased, the insensitivity of the magnetic material field parameters is attributed to no change in the SV material's defectivity that is separable from the scattering mechanism. The increase in surface roughness at higher deposition energy corresponded to an increase in both the amplitude and wavelength of the roughness. In applications, reducing roughness and increasing the GMR coefficient in GMR multilayers has been determined to be particularly important in improving switching and signal characteristics

2:30 PM FF5.4
Observation of pinhole magnetoresistance in Cr film.
Xuesong Jin, Ciaran J McEvoy and Igor Shvets; SFI Lab, Dept. of Physics, Trinity College, Dublin, Ireland.

(5 nm) Cr/(x nm) MgO/(30 nm) magnetite (Fe_3O_4) /MgO (100) substrate (1≤x≤5 nm), as well as (5 nm) Cr/(5 nm) MgO/ MgO

(100) substrate structures, have been grown using Molecular Beam Epitaxy. The correlation of interface roughness is confirmed by using X-ray reflectivity technique. The influence of the magnetite layer on the in-plane transport and magnetotransport properties of the Cr layer was studied. The existence of pinholes in the MgO layer is explored by evaluating Resistance versus Temperature, R(T), dependencies. A hump is observed on the R(T) curve when the MgO layer thickness (T_{MgO}) is less than 3 nm. This results from the electrical coupling between the Cr film and magnetite layer through the pinholes in the MgO layer. The MR of the Cr film in the Cr/MgO/magnetite structure shows a negative value which is a reversal of the sign of the MR for Cr film in a Cr/MgO/MgO structure. This reversal of the MR sign was observed even when T_{MgO} is up to 5 nm thick at which there is no electrical coupling between Cr and magnetite. We demonstrate that the effects of the electrical coupling through pinholes and magnetostatic coupling are not the reasons for the observed negative MR. A model is proposed which suggests that magnetic structure in the Cr film adjoining a pinhole is distorted because of the exchange coupling. Such areas in the Cr film are thought to contribute to the negative MR.

2:45 PM FF5.5
Accurate and realistic ab initio theory of spin-dependent interfacial scattering. Ivan Daykov and Tomas Arias; Physics, Cornell University, Ithaca, New York.

The development of novel spintronics devices requires detailed understanding of the microscopic phenomena at level sufficient to differentiate different materials and the impact of defects. We present a new parameter-free method for calculation of the quantum scattering amplitudes which are necessary to determine the torques in spin-transfer switches. This allows for first time to include all potentially important relaxations in these systems such as atomic positions, eletron densities and spin orientations in a fully self-consistent manner. Based on plane wave pseudopotential density functional theory, the approach is not only highly efficient and systematic, but because it is free of unnecessary simplifications it alows for reliable and realistic calculaton of the properties of spin-switching devices.

3:30 PM FF5.6
Increased Gilbert Damping in Spin-valve and Magnetic Tunnel Junction Devices. Liesbet Lagae[1,2], Wouter Eyckmans[1,2], Roel Wirix-Speetjens[1,2], Wayne Hiebert[1] and Jo De Boeck[1]; [1]IMEC, Leuven, Belgium; [2]ESAT/KULeuven, Leuven, Belgium.

The Gilbert damping parameter α is the key parameter that distinguishes precessional from damping dominated dynamic magnetization reversal modes. One of the predicted consequences of the spin transfer of a precessing magnetization into adjacent normal metals is an increased Gilbert damping parameter [1]. We systematically study α in $Ni_{80}Fe_{20}$ thin films with time-domain ferromagnetic resonance (FMR) using the (Scanning) Time-Resolved MOKE technique to monitor the damped precessional pulse response of magnetic structures excited by integrated coplanar waveguides [2]. From these experiments three major conclusions are drawn: 1) The Gilbert damping parameter is strongly enhanced over the bulk value in ferromagnetic $Ni_{80}Fe_{20}$ films thinner than 10 nm 2) The Gilbert damping parameter in thin film $Ni_{80}Fe_{20}$ (5 nm) is increased when adding Ta and Cu as a seed or capping layer and modeling the data using Tserkovnyak's model [3] results in reasonable scattering parameters of 0.29 for Ta and 0.09 for Cu. 3) The non-locality of spin transfer is proven by the observed α for a $Ni_{80}Fe_{20}$ (5nm)/Cu(2nm)/Ta(5nm) layer stack with no direct interface between Ta and $Ni_{80}Fe_{20}$. These results can then be used to explain the α-values that we observe in spin-valves (SV) and magnetic tunnel junction (MTJ) with a $Ni_{80}Fe_{20}$ free layer. An additional effect of the magnetization state of the pinned layer on the damping of the $Ni_{80}Fe_{20}$ free layer is revealed in SV's and not in MTJ's. The study is completed by the spatially resolved observation of full reversal in patterned SV devices (12 x 3 μm^2) using the magnetic imaging capabilities of our measurement technique. The locally observed α is consistent with the experimental film values from the FMR geometry even for highly non-uniform magnetization reversal modes. These insights support the development of magnetic devices aiming for numerous high-speed applications such as fast sensors, MRAM memories or RF applications. [1] L. Berger, Phys. Rev. B 54, 9353 (1996). [2] W. K. Hiebert et al., Phys. Rev. Lett. 79, 1134 (1997). [3] Y. Tserkovnyak et al., Phys. Rev. Lett. 88, 117601 (2002).

3:45 PM FF5.7
Magnetism in Polycrystalline Transition-Metal-Substituted Zinc Oxide. Aditi Risbud[1], Gavin Lawes[2], Nicola Spaldin[1] and Ram Seshadri[1]; [1]Materials, UCSB, Santa Barbara, California; [2]LANL, Los Alamos, New Mexico.

The wide bandgap semiconductor zinc oxide has been proposed as a candidate material for a dilute magnetic semiconductor (DMS), in which Zn^{2+} ions are replaced with other transition metal (TM) ions (such as Co^{2+} or Mn^{2+}). Such novel materials can be used for spintronics applications, for which both the spin and the charge of the electron can be utilized simultaneously. Theoretical predictions have suggested that TM-substituted ZnO could be a room temperature ferromagnet with additional hole doping. The polycrystalline system $Zn_{1-x}Co_xO$ was synthesized using a precursor decomposition technique with x = 0.05, 0.10, 0.15. Characterization was performed via x-ray diffraction, transmission electron microscopy, and DC magnetization measurements. Computational results were calculated using density functional theory. Both experimental and theoretical results indicate that for well-characterized samples, the dominant magnetic interaction is nearest-neighbor antiferromagnetic. Subsequent work on mixed-metal substitutions, such as $Zn_{0.85}M1_{0.15-x}M2_xO$ (M1, M2 are $3d$ TMs) will also be presented.

4:00 PM FF5.8
Ferromagnetic Interactions in Manganese doped Cadmium Selenide Nanoparticles. Donny Magana and Geoffrey F. Strouse; Chemistry and Biochemistry, University of California, Santa Barbara, Santa Barbara, California.

Ferromagnetic properties of Semimagnetic semiconductors that exhibit ferromagnetic behavior have been long sought for applications in spintronics. Of particular interest is Manganese doped II-VI materials, where ferromagnetic, antiferromagnetic, and spin glass behavior has been observed. Although in analyzing the ferromagnetic behavior arises in metal-doped quantum dot, by coupling to vacancies and intrinsic charge carriers. Manganese doped Cadmium Selenide was synthesized and in the analysis of the magnetic properties, rather strong ferromagnetic interactions are observed, which are dependent on size. Although the Curie temperature is observed to be at 41 Kelvin a small coercivity is still observed at 50 Kelvin. This shows that there is still some type of ferromagnetic interactions that can be due to a pinning effect in the intrinsic environment.

4:15 PM FF5.9
Half-metallic ferromagnetism and structural stability of zincblende phases of transition-metal pnictides and chalcogenides. Bang-Gui Liu[1], Wen-Hui Xie[1], Ya-Qiong Xu[1] and David G Pettifor[2]; [1]Institute of Physics, Chinese Academy of Sciences, Beijing, China; [2]Department of Materials, University of Oxford, Oxford, United Kingdom.

Half-metallic ferromagnets, especially those which are compatible with III-V or II-VI semiconductors, are seen as a key ingredient in future high performance spintronic devices, because they have only one electronic spin channel at the Fermi energy and, therefore, may show nearly full spin polarization at quite high temperature. Although zincblende phases of MnAs, CrAs and CrSb have been fabricated as epitaxial nanodots or ultrathin films, it has not been possible to grow the zincblende half-metallic ferromagnetic phases as high-quality layers or films thick enough. However, spintronic devices require these films or layers. Therefore, theoretical exploration for these materials are highly desirable. We predicted the zincblende phases of MnBi and CrSb are excellent half-metallic ferromagnets by using accurate density-functional method. Furthermoe, we studied systematically all zincblende phases of transition-metal pnictides and chalcogenides, and hereby found the zincblende phases of VTe, CrSe, and CrTe are the excellent half-metallic ferromagnets, which are not only low in energy with respect to the corresponding ground-state phases but also mechanically stable against structural deformations and therefore would be realized in the form of epitaxial films or layers thick enough for real applications. These half-metallic ferromagnetic phases should be useful in future spintronic applications because of their compatibility with the binary semiconductors. References: [1] Y-Q Xu, B-G Liu and D G Pettifor, Phys. Rev. B 66, 184435 (2002). [2] B-G Liu, Phys. Rev. B 67, 172411 (2003). [3] W-H Xie, Y-Q Xu, B-G Liu, and D G Pettifor, Phys Rev Lett, (accepted 2003).

4:30 PM FF5.10
Fabrication and controlled magnetic properties of Ni/ZnO nanorod heterostructures. Sug Woo Jung[1], Gyu-Chul Yi[1] and Miyoung Kim[2]; [1]Materials Science and Engineering, POSTECH, Pohang, Kyungbuk, South Korea; [2]Samsung Advanced Institute of Technology, Suwon, South Korea.

The ability to fabricate nanoscale heterostructures opens up many new device applications as already proven in microscale electronics and photonics. A prime example of the heterostructures is magnetic random access memory which is based on a magnetic/semiconductor heterostructure that exploits both the spin and charge of the carriers. The combination of the two degrees of freedom promises new functionality in memory devices, detectors, and light-emitting sources. Hence, fabrication of magnetic-material/semiconductor nanorod

heterostructures is of particular interest in nanoscale spintronics. Controlled growth of nanoscale magnetic layers on a single nanorod would enable novel physical properties such as size-dependent magnetism to be exploited, which offers the tuning of remanent magnetization and coercive fields by varying the magnetic layer thickness. In this presentation, we report on the fabrication of magnetic-metal/semiconductor nanorod heterostructures and the metal layer-thickness dependent magnetic properties due to a crossover from ferromagnetism to superparamagnetism. In this research, magnetic-metal/ZnO nanorod heterostructures were fabricated by evaporating metal on ZnO nanorods. Before metal evaporation, ZnO nanorods were prepared using metalorganic vapor-phase epitaxy (MOVPE) without employing any metal catalyst as previously reported by Park et al. The synthesis of ZnO nanorods by MOVPE results in a preferentially dominant nanorod growth direction along the c-axis of ZnO, normal to the substrate surface. Since no metal particles were employed as a catalyst, no metal nanoscale clusters were observed on the tips of the nanorods. Using this method, several magnetic nanorod heterostructures including Fe, Co, Ni, and Ni1-xFex were easily fabricated on vertically-aligned ZnO nanorods. Furthermore, we investigated magnetic properties of Ni/ZnO nanorod heterostructures. In addition, we investigated magnetic properties of Ni/ZnO nanorod heterostructures. We will discuss a crossover from ferromagnetic to superparamagnetic behavior of the nanorod heterostructures depending on the magnetic metal layer thickness.

SESSION FF6: Surface and Interface Magnetism
Chairs: Karine Chesnel and David Lederman
Wednesday Morning, December 3, 2003
Commonwealth (Sheraton)

NOTE EARLY START

8:15 AM FF6.1
Anomalies in the Magnetic Properties of NiO Nanoparticles.
Hyunja Shim, Ayyakkannu Manivannan and Mohindar S Seehra; Department of Physics, West Virginia University, Morgantown, West Virginia.

For nanoparticles of NiO of size D = 5.1, 7.0, 8.1, 11.8 and 15.8 nm, the magnetization M is measured against temperature T from 5 K to 350 K in magnetic field H up to ±55 kOe. These samples were synthesized by the sol-gel technique involving calcination of the $Ni(OH)_2$ gel at T = 250, 300, 350, 400, and 450° C respectively, and followed by x-ray diffraction for phase and size analysis. In H = 100 Oe, the data of M vs. T for the ZFC cases peaks at T_B = 210, 185, 134, 142 and 158 K for the D = 5.1, 7.0, 8.1, 11.8 and 15.8 nm respectively. This anomalous change of T_B with increase in D can be understood if anisotropy increases rapidly with decrease in D, perhaps due to increase in surface anisotropy. For $T > T_B$, M varies approximately as 1/D as reported by others [1], and M vs H at different T is used to show that (M - χ_aH) scales as H/T expected for superparamagnetism. However, there are small deviations from the Langevin behavior (possibly due to anisotropy) with anomalously large magnetic moment ≈ 1500 μ_B/particle. For $T < T_B$, large coercivities H_c and exchange bias H_e are observed, dependent on D. These results will be discussed in terms of multisublattice model of antiferromagnetism in nanoparticles of NiO for D ≤10 nm proposed recently [2]. *Work supported by the U.S. Air Force Office of Scientific Research. [1]. Richardson et al, J. Appl. Phys. 70, 6977 (1991); Makhlouf et al, J. Appl. Phys. 81, 5561 (1997). [2]. R. H. Kodama and A. E. Berkowitz, Phys. Rev. B 59, 6321 (1999).

8:30 AM *FF6.2
Magnetic Speckles From Nanostructures.
Karine Chesnel[1], M. Belakhosky[2], G. van der Laan[3], G. Beutier[2], A. Marty[2] and F. Livet[4]; [1]ALS, LBNL, Berkeley, California; [2]DRFMC, CEA-Grenoble, Grenoble, France; [3]SRS, Daresbury, United Kingdom; [4]LTPCM, Saint Martin d, France.

The recent development of Resonant Magnetic Scattering (XRMS) in the soft X-ray range provides increasing opportunities to study magnetic order and reversal processes in nanostructures. Indeed, besides the chemical selectivity and the polarization sensitivity, this technique gives the possibility to penetrate thin layer in depth and study the magnetic ordering at the nanoscopic scale. Moreover, the use of coherent light and 2D detection provides remarkable speckle patterns that are related to the local magnetic topology. Magnetic speckles have been recorded in a reflection geometry on two types of systems with perpendicular magnetic anisotropy: thin epitaxied FePd films with striped magnetic domains [1] and etched lines grating covered by Co/Pt multilayer [2]. The resulted images from FePd layers exhibit magnetic speckles with a strong intensity contrast, evidencing the high coherence of the incident light [3]. This coherence degree, close to 90%, results from the excellent beam quality and the use of a pinhole placed very close to the sample, thus opening possibilities to perform real space reconstruction. In case of CoPt lines, the scattering pattern presents a serial of sharp peaks related to the grating periodicity. In some specific demagnetized state, remarkable magnetic satellites appear in between the structural peaks, evidencing a tendency to antiferromagnetic order [2]. This scattering pattern is significantly modified when a magnetic field is applied on the system, perpendicularly to its surface. By following the signal variations through the whole magnetization loop, starting from the demagnetized point, one can observe antiferromagnetic satellites disappearing at the saturated state, then a wider magnetic signal appearing at the coercive point. This magnetic signal evolution gives information about the ordering and switching processes. In conclusion, these coherent - XRMS results performed with in situ magnetic field show rich possibilities to study local magnetic behavior in nanostructures and open the door to dynamic studies. [1] H.A. Durr and al., Science **284**, 2166 (1999) [2] K.Chesnel and al., Phys. Rev. B **66**, 024435 (2002) [3] K.Chesnel end al., Phys. Rev. B **66**, 172404 (2002)

9:00 AM FF6.3
Unconventional Magnetism of Monatomic Co-wire at the Pt(111) Surface Step-Edge.
Peter Oppeneer[1], Alexander B. Shick[2] and Frantishek Maca[2]; [1]Leibniz Institute for Solid State and Materials Research, Dresden, Germany; [2]Institute of Physics, Prague, Czech Republic.

Recently, a very unusual magnetic behavior was reported by Gambardella *etal.* [1] for monatomic Co-wires grown at the Pt(997) step edge. The easy magnetization axis was found to rotate away from the (111) - normal, pointing towards the step edge. In addition, a huge enhancement of the Co-atom orbital magnetic moment M_L∼0.7 μ_B - as compared to the Co-bulk M_L value of 0.14 μ_B - was deduced from XMCD measurements. Here, we present a computational investigation of this phenomenon. We apply *abinitio* full-potential linearized augmented plane wave method to calculate the magneto-crystalline anisotropy energy (MAE) and orbital magnetic moment M_L for simple super-cells modelling the Co-wire on the Pt-step-edge. We find that the lowering of magnetic symmetry permits the non-collinearity between spin and orbital magnetic moments even in the case of a collinear spin moment configuration. We find a large MAE (∼1-4 meV/Co, depending on the size of the super-cell) forcing the magnetization in the plane perpendicular to the Co-wire. As for the easy magnetization direction, we find it being away from the (111) surface normal, in qualitative agreement with Ref. [1]. Also, we investigate the enhancement of the orbital moment, making use of the LSDA+U method. We find a substantial enhancement of the Co-M_L (∼0.3-0.5 μ_B, depending on the choice of Coulomb-U and the size of the super-cell), which is still somewhat smaller than observed in the experiment. Finally, we relate our computed MAE and M_L results to the microscopic features of the Co-wire electronic structure. [1] P. Gambardella *etal.*, *Nature* **416**, 301 (2002).

9:15 AM FF6.4
Aspect Ratio Dependence of Hysterisis Property of 50 nm Interval Co Wire Array Buried in Porous Alumina Template.
shoso shingubara, kazunori morimoto, mamoru nagayanagi, tomohiro shimizu, osamu yaegashi, hiroyuki sakaue and takayuki takahagi; graduate school of ADSM, hiroshima university, higashi-hiroshima, Japan.

There is a strong demand for realizing ultra high-density magnetic recording beyond 400 Gbit/inch2. Perpendicular magnetic anisotropy is required for the ultra high-density magnetic recording, although it is not easy to attain it by granular films or self-assmbled magnetic nanoparticle films[1]. Magnetic nanowire array buired in a self-organized porous alumina nanhole array is one of promising materials for realizing perpendicular magnetic anisotropy. We fabricated Co wire array with 50nm intervals by electrodeposition in porous alumina template that was formed on Si substrate. At first pure aluminum was sputtered on Si, and two step anodic oxidation of Al [2] was carried out at the anode volate of 20 V with 0.15 M sulfuric acid. Finally Co wires of 30 nm in diameter with various heights from 20 to 500 nm were electrodeposited with AC current of 1 KHz. We evaluated aspect ratio (AR: a ratio of height to diameter) dependence of M-H hysterisis property by magnetic optical Kerr effect. When perpendicular magnetic field was applied, the coercive field (Hc) exhibited a clear dependence on AR. The Hc was negligibly small when AR was smaller than 1.5. It rapidly increased to 1.5 kOe when AR increased from 1.5 to 2.5, and almost saturated when AR was beyond 3.0. X-ray diffraction analysis revealed that the Co(0001) axis (i.e.easy axis) was not perpendicular to the substrate, and Co(1012) axis was rather perpendicular. We also carried out micromagnetic simulation based on LLG equation for M-H property of a single Co wire with various aspect ratios, and thhe results suggest that when crystalline anisotropy is different from the perpendicular axis against substrate plane, the Hc increases critically when Co wire aspect ratio

is aroud 1.5. These results strongly suggest that the magnetic anisotropy is determined mainly by the aspect ratio of Co wires that were formed in our experiments. [1] S.Sun, et al., in "The Physics of ultra-high-density magnetic recording", edited by Plumer, van Ek Weller, Springer series in surface sciences (2001). [2] S.Shingubara et al., Solid State Electronics 43 (1999) 1143.

9:30 AM FF6.5
FMR Study of Square Arrays of Thin-Film Permalloy Rings of Variable Inner Diameter. Lance Eric De Long[1], Daniel Byron Watkins[1,2], Wentao Xu[1], John B Ketterson[2], Venkat Chandrasekhar[2] and Vitali V Metlushko[3]; [1]Physics and Astronomy, University of Kentucky, Lexington, Kentucky; [2]Physics and Astronomy, Northwestern University, Evanston, Illinois; [3]Electrical and Computer Engineering, University of Illinois-Chicago, Chicago, Illinois.

Arrays of thin-film rings of magnetic materials are candidates for magnetic memory applications. We have measured the 9.5 GHz, room-temperature ferromagnetic resonance (FMR) spectra of square arrays of permalloy rings of thickness 25 nm, spacing a = 1 micron, outer diameter D = 750 nm and inner diameters d = 0, 40, 80, and 300 nm, in fields up to 0.6 T, applied in the array plane. The spectra are complex (compared to the isolated uniform mode of an unpatterned control film) with structure extending to near zero field, and exhibit marked dependences on the ring dimensions and the angle between the applied field and square array axis.

9:45 AM FF6.6
Magnetization reversal of single Fe nanoparticle studied by Hall magnetometry. Yongqing Li[1], Peng Xiong[1], Stephan von Molnar[1], Yuzo Ohno[2] and Hideo Ohno[2]; [1]MARTECH and Department of Physics, Florida State University, Tallahassee, Florida; [2]Research Institute of Electrical Communication, Tohoku University, Sendai, Japan.

We will present our recent work on improving the sensitivity of submicron Hall magnetometry for single nanoparticle measurement. The submicron Hall magnetometers are based on a GaAs/AlGaAs 2-dimensional electron gas (2DEG) heterostructure. We have performed a series of low frequency noise measurements in order to understand the microscopic origin of the 1/f noise in the Hall signal and to improve the device performance. Moment sensitivity better than 10^4 $\mu_B/\mathrm{Hz}^{1/2}$ has been obtained by a moderate gating of the 2DEG. With the improved sensitivity we have performed magnetic measurements on individual iron nanoparticles fabricated with a scanning tunneling microscopy assisted chemical vapor deposition technique. Magnetization reversal of such cylinder-shaped Fe nanoparticles with high aspect ratios (d<10nm and h~120 nm) have been studied in various tilted applied fields and different temperatures. We will discuss our results in the context of recent work on individual electrodeposited nanowires, as well as various theoretical models. The work was supported by NSF-DMR grant #0072395 and DARPA through ONR grants N-00014-99-1-1094 and MDA-972-02-1-0002.

10:15 AM *FF6.7

MRS MEDAL AWARD TALK PRESENTATION

Exchange Biased Nanostructures. Ivan K. Schuller[1], Igor V. Roshchin[1], J. Eisenmenger[2,1], O. Petracic[1], Z-P Li[1], C-P Li[1], M Viret[1] and K Liu[3]; [1]Physics Department, University of California, San Diego, La Jolla, California; [2]Abteilung Festkorperphysik, Universitaet Ulm, Ulm, Germany; [3]Physics Department, University of California, Davis, Davis, California.

Magnetic nanostructures are receiving increasing attention in recent years, motivated by the interesting phenomena when the physical size becomes comparable to relevant magnetic length scales. In addition a number of important potential applications in the sensors and storage industries have emerged. When magnetic nanostructures are in contact with other dissimilar magnetic materials and because their magnetic fields extend considerably outside the physical structure they are very susceptible to interactions with the surrounding environment. A particularly interesting situation is one in which a ferromagnetic nanostructure is in contact with an antiferromagnetic substrate. In this "exchange biased" configuration, a variety of unusual phenomena arise; the reversal mode of the ferromagnet changes considerably, the superparamagnetic transition temperature is affected and there is a noticeable change in the microscopic spin configuration. I will describe a series of experiments in which we studied these phenomena in nanostructured ferromagnets prepared by electron beam lithography and self assembly. Work supported by AFOSR, DOE, NSF and the A. von Humboldt Foundation.

10:45 AM FF6.8
Determination Of Exchange Anisotropy By Means Of Transverse Susceptibility Experiments In (IrMn/FeCo) Multilayers. Leonard Spinu[1], Cosmin Radu[1], Alexandru Stancu[2], Yukiko Kubota[3], Ganping Ju[3] and Dieter Weller[3]; [1]AMRI & Physics, University of New Orleans, New Orleans, Louisiana; [2]Faculty of Physics, Al. I. Cuza University, Iasi, Romania; [3]Seagate Research, Pittsburgh, Pennsylvania.

As discovered in 1957 by Meiklejohn and Bean the exchange anisotropy (EA) arises from the exchange coupling at the interface between a ferromagnet (F) and an antiferromagnet (AF) [1]. The AF/F exchange coupling renewed interest in recent years because of its application to giant magnetoresistive heads for high-density recording systems and sensors. Usually the typical signature of the EA is a displaced hysteresis loop along the field axis with a field value equal to the exchange field, from which the exchange anisotropy can be determined. Recently, it has been shown that other measurement techniques as anisotropic magnetoresistance, ac susceptibility, ferromagnetic resonance and Brilouin light scattering that previously were proposed to assess the EA may lead to results in disagreement with those obtained from hysteresis loop measurements [2]. In the present paper we propose a new method to measure the EA based on the transverse susceptibility (TS) measurements, which combines the advantages of the reversible measurement techniques by using a small ac field and the simplicity of the irreversible measurement technique as the hysteresis displacement. In the case of TS the EA is determined from the asymmetry in the position of the characteristic peaks. The model we propose for the TS takes into account, apart from the EA, different other types of anisotropies usually present in F/AF coupled systems and allows a proper deconvolution of EA from the experimentally measured TS signal. The TS signal was measured using a sensitive method based on a tunnel-diode oscillator technique [3]. The materials considered in our study is a [IrMn 12 nm / FeCo 50 nm]x4 multilayer with Cu 4 nm seedlayer deposited on a glass substrate [4]. The sample was fabricated with a commercial disc media sputter deposition system, Unaxis M12. [1] W.H. Meiklejohn and C.P. Bean, Phys. Rev. B, 102 (1957) 1413. [2]H. Xi et al,. Phys. Rev. B, 60(1999) 14837. [3] L. Spinu et al., IEEE Trans. Mag., 37 (2001) 2188. [4] H.S. Jung and W.D. Doyle, IEEE Trans. Magn. 39, 679 (2003)

11:00 AM FF6.9
Phase Transformation in Sputter Deposited Ni-Mn Thin Films. Mianliang Huang, Materials Science and Engineering, University of Wisconsin-Madison, Madison, Wisconsin.

Sputter deposited, Ni-Mn thin films used in giant magnetoresistive (GMR) spin valves are found not to exist in the antiferromagnetic state required for device operation. Therefore, an annealing step is needed to induce a phase transformation from the as-deposited, amorphous phase to the antiferromagnetic L10 phase. The L10 phase is the thermodynamically stable configuration, but favorable kinetics for the transformation were only found above 300 øC. The amorphous to fcc and then to L10 phase transformation was studied by X-ray diffraction, transmission electron microscopy (TEM), and differential scanning calorimetry (DSC). The nucleation and growth conditions were evaluated and an total exothermic transformation enthalpy of -7.24 kJ/mol of atoms was determined.

11:15 AM FF6.10
Ultrathin Fe Films on the Vicinal Pt(997) Surface: The Role of Steps for Growth and Magnetic Properties. Taeyon Lee[1], Axel Enders[1], Klaus Kuhnke[1], Diego Repetto[1], Jan Honolka[1], Cesare Grazioli[2], S. R. Krishnakumar[3], Marco Veronese[2], Carlo Carbone[2] and Klaus Kern[1]; [1]Max-Planck-Institute for Solid State Research, Stuttgart, Germany; [2]Institute of Structure of the Matter, National Research Council, Trieste, Italy; [3]International Center for Theoretical Physics, Trieste, Italy.

A stepped Pt(997) substrate is employed as a template for the fabrication of magnetic Fe nanostructures, from monatomic chains to films of a few monolayers' thickness. The growth mode and structure of the MBE-grown Fe on Pt(997) under ultrahigh vacuum are investigated by thermal He-atom scattering (TEAS), low energy electron diffraction (LEED), and Auger electron spectroscopy (AES). Monatomic chains and a pseudomorphic monolayer of Fe grow with lowest defect density at substrate temperatures between 300 K and 400 K. The magnetic properties of Fe wedges grown at 300 K are explored by the magneto-optical Kerr effect (MOKE) and X-ray magnetic circular dichroism (XMCD). The experiments show a spin reorientation transition of the remanent magnetization from perpendicular to in plane direction at an Fe thickness of about 1.5 ML. For comparison, no perpendicular component is observed for Fe wedges (in the range 0 - 5 ML) grown on a flat Pt(111) substrate which demonstrates the important role of the steps for the magnetic properties of the films. We will discuss the results with respect to step induced changes of the film structure, anisotropy contributions, and exchange coupling at the Fe/Pt interface.

11:30 AM FF6.11
Magnetization of Fe/Pd Bilayers Enhanced by Hydrogen Absorption. Rafael J. Matelon[1], David Lederman[2], Guerau B. Cabrera[1], Erie H. Morales[2], Yikuan Wang[2], Ulrich G. Volkmann[1] and Alejandro L. Cabrera[1]; [1]Facultad de Fisica, Pontificia Universidad Catolica de Chile, Santiago, Chile; [2]Department of Physics, West Virginia University, Morgantown, West Virginia.

The magnetization of Fe/Pd bilayers grown on Al_2O_3 substrates was studied as a function of H_2 pressure. The samples were grown via magnetron sputtering and the interface roughness studied with x-ray reflectivity. Magnetization measurements were carried out via the magntooptic Kerr effect (MOKE). For 5.0 nm Fe/5.0 nm Pd films the magnetization of the film increased by 25% when exposed to 1 atm of hydrogen. The increase in magnetization begins to saturate at approximately 25 Torr of H_2 pressure. The effect is inversely proportional to the Fe thickness, indicating that the enhancement occurs due to the presence of hydrogen at the Fe/Pd interface. No enhancement is observed with N_2 gas or in Co/Pd bilayers of similar thickness exposed to H_2. This indicates that the effect is electronic in origin and may be related to known strong magnetic interactions between the Fe and Pd atoms. This work was supported by FONDECYT (project 1030642) and MECESUP (project PUC00006) in Chile and the AFOSR in the U. S. Additional support at PUC was provided by FONDECYT grants #1010548 and #7010548.

11:45 AM FF6.12
On the relation between the electronic structure of thin films and bulk alloys. Anders Mauritz Niklasson and John M. Wills; Theoretical Division, Los Alamos National Laboratory, Los Alamos, New Mexico.

An investigation of the relation between the electronic structure of thin films and bulk alloys has been performed by means of first principles electronic structure calculations. The magnetization and layered projected density of states of thin films (1 and 2 monolayers) of Cu embeded in fcc Ni, fcc Co and bcc Fe as well as layers of Ni, Co and Fe embedded in fcc Cu have beed compared with binary alloys, where the alloy concentrations where determined by nearest-neighbor coordination of the thin films. The qualitative behavior of the magnetization is shown to be an effect of band filling and coordination for the alloys as well as for the thin films. However, the comparison elucidates both similarities and discrepancies. The experimental possibility of detecting single embeeded monolayers from photoemission data is also discussed and analyzed. The spectra for embedded single monolayers, double layers and dilute alloys are calculated and compared.

SESSION FF7: Magnetic Clusters and Molecular Magnets
Chair: Marcos Grimsditch
Wednesday Afternoon, December 3, 2003
Commonwealth (Sheraton)

1:30 PM *FF7.1
Magnetic Phase of Nanosized Metallic Particles. J. Escrig[1], P. Landeros[1], D. Laroze[2], Dora Altbir[1], J. D'Albuquerque e Castro[3], P. Vargas[2] and J. C. Retamal[1]; [1]Physics Dept, Universidad de Santiago de Chile, Santiago, Region Metropolitana, Chile; [2]Physics Dept, Universidad Tecnica Federico Santa Maria, Valparaiso, Region Metropolitana, Chile; [3]Physics Institute, Universidad Federal do Rio de Janeiro, Rio de Janeiro, Brazil.

Magnetic particles with nanometer dimensions have become the subject of increasing interest in the past few years because of their potential applications. Based on a simple scaling technique, the magnetic phase diagram of the particles is obtained. The diagram is based on the relative stability of three internal configurations of the clusters, namely, ferromagnetic in-plane, ferromagnetic out-of-plane, and vortex. The technique is illustrated by the determination of the phase diagram of cylindrically and conical shaped particles. By means of numerical simulations we found that the magnetic phase diagram for large particles and full strength of the exchange coupling, J, can be obtained from those corresponding to smaller systems and weaker values of J by scaling the dimensions of the particles using a scaling factor,η. Such technique strongly reduces the computation time and provides a new approach to the investigation of the magnetic ordering of nanoparticles. The role of uniaxial anisotropy in determining the magnetic properties of such particles is discussed, and a simple method for establishing its strength is proposed. Comparison with continuum theory is presented and the behaviour of η is analytically obtained.

2:00 PM *FF7.2
Magnetization Reversal In Patterned Magnetic Nanostructures Using Neutron Reflectivity. Kristiaan Temst[1], M. J. Van Bael[1], J. Swerts[1], H. Loosvelt[1], O. Popova[1], C. Van Haesendonck[1], Yvan Bruynseraede[1] and H. Fritzsche[2]; [1]Laboratorium voor Vaste-Stoffysica en Magnetisme, K.U. Leuven, Heverlee, Belgium; [2]Hahn-Meitner-Institut, Berlin, Germany.

In this contribution we review recent work on the study of magnetic domain states and magnetization reversal in patterned magnetic nanostructures using polarized neutron reflectivity techniques. It remains a challenge to elucidate how reversal occurs in different types of patterned structures and complex systems like exchange biased materials. Polarized neutron reflectivity has the unique advantage that it can provide direct information about the magnetization reversal mechanism since it probes simultaneously magnetization components parallel and perpendicular to the applied field [1]. This vectorial magnetization information allows to discriminate between domain wall motion and coherent rotation of the magnetization. Traditionally polarized neutron reflectivity has been restricted to large-area samples. When the magnetic nanostructures are placed in a regular grid, however, polarized neutron reflectivity can be used in the off-specular mode by analyzing in detail the satellite reflections occurring because of the in-plane periodicity of the nanostructures [2]. We will report here on the study of magnetization reversal and the influence of shape anisotropy in ferromagnetic dots and lines [3-4], as well as patterned exchange-bias structures. The polarized neutron reflectivity experiments are accompanied by detailed structural studies [5] and will be compared with other magnetization measurements and with model calculations based on micromagnetic simulations. [1] H. Zabel and K. Theis-Brohl, J; of Physics: Condens. Matt. 15, S505 (2003) [2] K. Temst, M.J. Van Bael, and H. Fritzsche, Appl. Phys. Lett. 79, 991 (2001) [3] K. Temst, M.J. Van Bael, V.V. Moshchalkov, Y. Bruynseraede, H. Fritzsche, and R. Jonckheere, Appl. Phys. A 74, S1538 (2002) [4] J. Swerts, K. Temst, M.J. Van Bael, C. Van Haesendonck, and Y. Bruynseraede, Appl. Phys. Lett. 82, 1239 (2003) [5] K. Temst, M.J. Van Bael, V.V. Moshchalkov, and Y. Bruynseraede, J. Appl. Phys. 87, 4216 (2000)

2:30 PM FF7.3
Magnetic and Structural Properties of NiFe/Polymeric Nanocomposites. Michael J. Bonder, Y. Zhang, H. L. Wang and G. C. Hadjipanayis; Physics and Astronomy, University of Delaware, Newark, De, Delaware.

Polymeric naocomposites are of current interest for their potential use as left handed materials as well as in biomedical applications such as drug delivery and enhanced detection of cancer.This paper discusses the structural and magnetic properties of NiFe Nanoparticles with particle size below 10 nm that have been embedded in a polymer matrix by multilayering nanoparticles from a high pressure sputtering cell with rf sputtering from a plexiglas target. The resulting nanocomposite material is magnetically soft with a face centered cubic structure. The coercivity of the particles is low with values of 26 Oe attained. Transmission electron microscopy shows well separtated to highly dense arrangements of nanoparticles depending on deposition conditions. Work is underway to investigate the effect of particle size and spacing on the dc and high frequency magnetic properties.

2:45 PM FF7.4
Magnetic Anisotropy in Icosahedral Cobalt Clusters. Robert Morel, Ariel Brenac, Celine Portemont and Lucien Notin; CEA Grenoble, Grenoble, France.

The magnetic properties of nanometer size clusters is of current interest because of their potential applications in magnetic storage and spintronic applications. Among these, the magnetic anisotropy show interesting behavior due to size effects and the relative importance of the surface contribution to the overall anisotropy energy. From a theoretical point of view ab-initio calculations to investigates the magnetic anisotropy properties of small clusters are rare and do not go beyond a few atoms. Nevertheless, these calculations indicate that the anisotropy is very sensitive to the atoms environment and first neighbors distances. Recently we report on the growth of cobalt clusters with icosahedral shape, by the use of a gas-aggregation source. With this technique we can produce cobalt clusters with diameter below ten nanometers. High resolution electron microscopy reveals that their structure is that of small icosahedra, made out of twinned fcc tetrahedra. This structure is theoretically stable for clusters below 10 nm due to the smaller surface energy, with all the facets of a closed-shell clusters being (111) close-packed planes. However, as the size of the cluster grows the elastic strain energy inherently present increases up to the point where the fcc structure becomes energetically favorable. The anisotropy energy of icosahedral structure is interesting from two points of view. First, if one consider a closed-shell cluster, due to compensation effects there is no contribution from the magnetocrystalline anisotropy. On the other hand, with incomplete outer shell the magnetoelastic and the shape anisotropy are present. In this paper, we consider the magnetic

anisotropy in the frame of the pair model that was proposed by Néel to characterize surface anisotropy. This model, although partly phenomenological, can easily take into account the lattice strain and the effects due to incomplete shells of atoms. We will present calculations based on numerical simulations of the structure of relaxed icosahedral cobalt clusters and compare the results with magnetization measurements on deposited clusters.

3:30 PM FF7.5
Magnetic Excitations in S = 1/2 Spin Clusters: Energy Eigenstates, Magnetic Susceptibility, Heat Capacity, and Inelastic Neutron Scattering Intensities.
Jason Thomas Haraldsen[1], Janice Musfeldt[2] and Ted Barnes[1,3]; [1]Department of Physics and Astronomy, University of Tennessee, Knoxville, Tennessee; [2]Department of Chemsitry, University of Tennessee, Knoxville, Tennessee; [3]Physics Divison, Oak Ridge National Laboratory, Oak Ridge, Tennessee.

Using near-neighbor antiferromagnetic exchange Hamiltonians, we calculated the theoretical energy eigenstates for a variety of S = 1/2 antiferromagnetic spin cluster systems. From an understanding of the magnetic excitations in these clusters, we extracted useful measurable properties, such as the magnetic susceptibility, heat capacity, and inelastic neutron scattering intensity. Systems of interest include: dimers, trimers, and tetramers, the latter two in a variety of different configurations. Applications of these results to that of molecule based magnets will be discussed.

3:45 PM FF7.6
Effects of Cobalt Substitutions in Spring Magnets.
Monica Sorescu[1], Lucian Constantin Diamandescu[1] and Mihaela Valeanu[2]; [1]Physics, Duquesne University, Pittsburgh, Pennsylvania; [2]Materials Science, Institute of Atomic Physics, Bucharest, Romania.

Spring magnets are nanocomposites which consist of a soft magnetic and a hard magnetic phase, exchange coupled. They have high energy product and low cost. In this paper we examine the effect of cobalt substitutions on the hyperfine magnetic fields and site populations. We prepared by melt spinning ten compositions of cobalt-substituted spring magnets: Nd11Fe80.6Co2.6B5.8 annealed for 3 min at 690, 720 and 755 C, Nd10.5Fe78.4Co5.3B5.8 annealed for 3 min at 690, 720, 755 and 775 C, and Nd10Fe76.5Co7.9B5.6 annealed for 3 min at 690, 720 and 755 C. X-ray diffraction experiments showed the presence of the alpha-Fe(Co) phase and a Co-doped Nd2Fe14B phase, which is amorphous. For this reason, the Mossbauer spectra of these compounds were fitted with a crystalline sextet corresponding to the soft alpha-Fe(Co) phase and a distribution of hyperfine magnetic fields, corresponding to the amorphous Nd2Fe14B hard phase. The hyperfine magnetic field of the crystalline phase first decreases with decreasing Fe content from 80.6 to 78.4 %, and then increases with decreasing Fe concentration down to 76.5 %, due to the prevailing effect of Co content increase. Indeed, it is known that Co may have the effect of increasing the value of the hyperfine magnetic field at Fe sites. Moreover, the decrease in the Fe content throughout the ten samples correlates with an increase in the percentage of the distribution area in the set of samples. This amorphous component represented by a hyperfine magnetic field distribution exhibits an increased hyperfine field with decreasing the Fe content, such that we can say that Co substitutions enter not only the soft phase with Fe, but are also present as a constituent of the hard magnetic phase.

4:00 PM FF7.7
Photo-Induced Ferromagnetism above 300K in a Polymeric Fullerene Nanostructure. Frank J. Owens[1], Zafar Iqbal[2], Lyubov Belova[3] and K. V. Rao[3]; [1]Army Research & Engineering Center, Picatinny, New Jersey; [2]Chemistry and Environmental Science, New Jersey Institute of Technology, Newark, New Jersey; [3]Materials Science & Engineering, Royal Institute of Technology, Stockholm, Sweden.

Carbon-60 transforms to a polymeric chain structure when it is subjected to ultraviolet to visible radiation in vacuum. A ferromagnetic phase is formed on irradiation in the presence of low pressure of oxygen, as shown by the appearance of a temperature-dependent ferromagnetic resonance (FMR) signal which persists to well above 300K. SQUID magnetometry clearly showed hysteresis loops, with an extrapolated Curie temperature well in excess of 300K. The intrinsic coercivity is around 110 Oe at 20K, which reduces to about 20 Oe at 300K, with a temperature dependence that is typical for a ferromagnet. A possible model for the ferromagnetism based on Raman data and molecular orbital calculations, will be discussed. Properties of ink-jet printed arrays of this structure on flexible substrates will also be presented.

4:15 PM FF7.8
Electronic Structure of Molecule-Based Magnets: Mn12-acetate, V15, and Fe8-tacn. Janice L Musfeldt[1], Jongwoo Choi[1], Roman Wesolowski[1], Andrei Sushkov[1], Scott Oppenheimer[1], Randy Achey[2], Micha North[2], Naresh Dalal[2], Arkady Ellern[3] and Paul Kogerler[3]; [1]Chemistry, University of Tennessee, Knoxville, Tennessee; [2]Chemistry, Florida State University, Tallahassee, Florida; [3]Ames Laboratory, Ames, Iowa.

We report the reflectance and optical conductivity of solid (Mn12O12(CH3COO)16(H2O)4)2CH3COOH.4H20, K6[V15As6O42(H2O)].8H2O, and Fe8O2(OH)12(tacn)6Br8.9H20 over a wide frequency range in order to investigate the charge degrees of freedom in several different classes of molecule-based magnets. We compare the observed optical excitations and optical gaps with predictions from electronic structure calculations and dc transport results. While there is excellent agreement between theory and experiment for Mn12-acetate and V15, the case of Fe8-tacn is more challenging. It demonstrates, in a very compelling way, the need for a collaborative approach to
the understanding of charge transport and dynamics in these materials.

SESSION FF8: High Anisotropy Magnetic Nanostructures
Chairs: David Nikles and David Sellmyer
Thursday Morning, December 4, 2003
Commonwealth (Sheraton)

NOTE EARLY START

8:00 AM *FF8.1
Magnetization and Structural Studies of Self-Assembled, Polymer Mediated FePt Nanoparticle Arrays.
Thomas Thomson[1], Michael F Toney[2], Simone Raoux[3] and Shouheng Sun[4]; [1]Hitachi San Jose Research Center, San Jose, California; [2]Stanford Synchrotron Radiation Laboratory, SLAC, Menlo Park, California; [3]IBM Almaden Research Center, San Jose, California; [4]IBM T.J.Watson Research Center, Yorktown Heights, New York.

Self-assembled FePt nanoparticles with dia. = 4 nm and a narrow size distribution σ<5% are currently attracting considerable attention as potential data storage media [1-2]. It is well known that as-deposited, particles are not in the required chemically ordered, high anisotropy $L1_0$ phase and that annealing at T > 500°C is required to achieve $L1_0$ ordering. To understand the complex thermodynamic behavior during annealing, we first study the as-deposited arrays using magnetometry, x-ray diffraction (XRD), small angle neutron scattering (SANS) and Near Edge X-ray Absorption Fine Structure (NEXAFS) spectroscopy. The data show that while the physical dimensions of the particles are close to 4nm, the x-ray coherence length together with magnetic particle volume, determined from fitting the Langevin function to magnetization curves, give a particle diameter of 2.2 nm. Upon annealing both the particle size and magnetic moment increase significantly. Coercivity increases with annealing temperature from H_c = 2.6kOe for annealing conditions of 580°C/30mins to 26.2kOe for 800°C/5mins. We conclude that a simple model of FePt nanoparticle arrays where annealing simply induces chemical order as particles progress from the disordered fcc phase to the ordered $L1_0$ phase does not describe all the thermodynamic processes. We present a model that provides a more complete description of the annealing process. [1] S. Sun, C.B. Murray, D. Weller, L. Folks, A. Moser, Science 287, 1989, (2000) [2] S. Sun, S. Anders, H.F. Hamann, J-U. Thiele, J.E.E. Baglin, T.Thomson, E.E. Fullerton, C.B. Murray, B.D. Terris, J. Am. Chem. Soc. 124, 2884, (2002)

8:30 AM *FF8.2
Computational Models Of The Properties Of FePt Self-Organised Magnetic Arrays. Roy Chantrell, Seagate Research, Pittsburgh, Pennsylvania.

Self-Organised Magnetic Arrays (SOMA) comprising granular films of high anisotropy FePt particles have considerable potential for future high-density storage media. The particles are prepared by chemical techniques and coated onto substrates. As prepared the particles are in the disordered state and it is necessary to anneal the particles to produce the high anisotropy L10 phase. This has been shown to give rise to significant aggregation and sintering, leading to strong exchange coupling between the particles. We will present a monte-carlo model of the magnetic properties of FePt media. The model gives good agreement with experimental data and can be used to extract materials parameters from the data. The MC model is also supported by simulations of the self-organisation process, from which inferences about the nature of the interparticle interaction potential are obtained. A model of the intrinsic properties of FePt particles at the atomistic level has also been developed, which correctly predicts the temperature variation of anisotropy and gives atomistic calculations of the magnetisation reversal process, which shows the reversal mechanism to be non-uniform even for particle sizes as small

as 3nm.

9:00 AM FF8.3
Structural study of epitaxial L10 FePt magnetic thin films sputtered on Cu (001). Cheng-Jun Sun[1,2], Gan-Moog Chow[1] and Jian-Ping Wang[3]; [1]Department of Materials Science, National University of Singapore, Singapore, Singapore; [2]Data Storage Institute, Singapore, Singapore; [3]Department of Electrical and Computer Engineering, The Center for Micromagnetics and Information Technologies (MINT), University of Minnesota, Minneapolis, Minnesota.

The crystallographic texture [1-7] and the control of L10 ordering [8-10] of face-centered-tetragonal (fct) FePt thin films have been widely studied as potential high areal density magnetic recording media due to its extremely high magnetocrystalline anisotropy. The growth of magnetic layer can be interfacially controlled by the underlayer, and magnetocrystalline anisotropy optimized by controlling the easy-axis distribution of magnetic layer. Various underlayers or substrates, such as MgO [1-4], Ag [5], CrRu [6], and oxidized Si [7], have been successfully used to promote the fct FePt (002) texture in case of perpendicular magnetic recording. However, little has been reported to induce fct FePt (200) texture for longitudinal magnetic recording. The reduction of L10 ordering temperature has been attempted by various methods, such as alternate monatomic layer deposition [8], Cu [9] and Zr doping [10]. It is desirable to achieve fct FePt (200) longitudinal film with reduced ordering temperature for longitudinal magnetic recording media. Epitaxial Fe50Pt50 (30 nm) magnetic thin films were sputter-deposited on Cu (001) single crystal substrate. The fct L10 ordered FePt (200)<001> // Cu (002)<100> epitaxial relationship was observed using HR x-ray scattering. The L10 ordered FePt film sputtered at 400 degrees centigrade with well-controlled easy-axis distribution (FWHM=2.36 degree), small grain size (10 nm), and high in-plane coercivity (4.4 kOe) is a potential candidate for ultra-high density longitudinal recording media. It is suggested that a textured Cu (001) could be a potential underlayer for the growth fct FePt (200) films in case of longitudinal magnetic recording. References: 1. M. R. Visokay and R. Sinclair, Appl. Phys. Lett. 66, 1692 (1995). 2. T. Shima, K. Takanashi, Y. K.Takahashi, and K. Hono, Appl. Phys. Lett. 81, 1050 (2002) 3. Mu-Gyeom Kim, Sung-Chul Shin, and Kyongha Kang, Appl. Phys. Lett. 80, 3802 (2002) 4. R. F. C. Farrow, D. Weller, R. F. Marks, M. F. Toney, A. Cebollada, and G.R. Harp, J. Appl. Phys. 79, 5967 (1996). 5. Y.-N. Hsu, S. Jeong, D. Laughlin, and D. N. Lambeth, J. Appl. Phys. 89, 7068 (2001). 6. Yingfan Xu, J. S. Chen, and J. P.Wang, Appl. Phys. Lett. 80, 3325 (2002) 7. H. Zeng, M. L. Yan, N. Powers, and D. J. Sellmyer, Appl. Phys. Lett. 80, 2350 (2002). 8. T. Shima, T. Moriguchi, S. Mitani, and K. Takanashi, Appl. Phys. Lett. 80, 288 (2002) 9. Tomoyuki Maeda, Tadashi Kai, Akira Kikitsu, Toshihiko Nagase,and Jun-ichi Akiyama, Appl. Phys. Lett.80, 2147 (2002) 10. Seong-Rae Lee, Sanghyun Yang, Young Keun Kim, and Jong Gab Na, Appl. Phys. Lett.78, 4001 (2001)

9:15 AM FF8.4
Oriented FePt Nanoparticles for Perpendicular Magnetic Recording. Zhengang Zhang, Takao Suzuki and Kyongha Kang; ISML, Toyota Technological Institute, Nagoya, Japan.

With the recording density approaching toward 1 Tera bits/in^2 in hard disk drives, the medium grain size should be well below 10 nm in order to obtain high enough signal to noise ratio. However, the concern in thermal stability of recorded bits consisting of these nanoparicles makes it indispensable to replace the currently used CoCrPt-based alloys by novel materials with a much higher magnetic anisotropy constant (Ku). As a possible candidate, FePt is very attractive since it exhibits a Ku of the order of 10^7 erg/cc. For application in perpendicular magnetic recording hard disks, the FePt grain size and the grain magnetic easy-axis orientation should be well controlled below 10 nm and along the film normal direction, respectively. A multilayered structure of (FePt/Ag, MgO) films were fabricated onto glass substrate by using sputter-deposition method in the present study. Upon annealing, the FePt nanoparticles are found to be well isolated by the Ag or MgO grains. The FePt particle size can easily be controlled through changing the layer thickness. The epitaxial growth between FePt and Ag or MgO keeps the (001) texture of the FePt layers. To obtain the (001)-texture of FePt onto glass substrate, MgO underlayer was grown by rf sputter, which induces the (001)-textured fct FePt films upon annealing. The FePt grain size and the magnetization switching volume varying with the layer thickness and the annealing conditions have been systematically studied. The magnetic switching volume can be controlled in a range of 10^{-19} cm^3, leading to a lower recording noise. Using the optimized film stack structure and annealing condition, double-layered perpendicular magnetic recording disk were prepared, where 400 nm FeTaC film serves as a magnetic soft underlayer (SUL) and FePt/Ag or FePt/MgO laminated layers composed of the recording layer. In order to magnetically decouple the SUL and recording layer and to induce the (001) texture in FePt films, the combined SiO_2/MgO intermediate layers were employed. The disk recording property evaluation will also be presented.

9:30 AM FF8.5
Microscopic characterization of the degree of $L1_0$ order in Fe-Pt nanoparticles from the gas-phase. Bernd Rellinghaus[1], Olga Dmitrieva[2] and Sonja Stappert[2]; [1]Institute of Combustion and Gasdynamics, University of Duisburg-Essen, Duisburg, Germany; [2]Experimental Physics, AG Farle, University of Duisburg-Essen, Duisburg, Germany.

$Fe_{62}Pt_{38}$ nanoparticles are prepared by inert gas condensation in an Ar / He mixture by means of DC sputtering from an FePt alloy target. Prior to their deposition, the particles are subjected to thermal annealing (sintering) in the gas phase [1]. The gas pressures and sintering temperatures can be varied in the range 0.5 mbar $\leq$ p $\leq$ 2 mbar and 293 K $\leq$ T_S $\leq$ 1273 K, respectively, in order to control the morphology and crystal structure of the particles. High resolution transmission electron microscopy (HRTEM) shows that for $Fe_{62}Pt_{38}$ nanoparticles which are prepared at p = 1.5 mbar, the degree of crystallinity of the particles improves and the particle structure changes from disordered face-centered cubic (fcc) to the $L1_0$ ordered face-centered tetragonal (fct) phase with increasing sintering temperature. Concurrently, the magnetic properties of the particles change from superparamagnetic to ferromacnetically blocked at room temperature (RT). However, the maximum measured coercive field of H_C(RT) = 1.2 kOe and the maximum effective anisotropy constant of $K_{eff} \approx 8{\cdot}10^5$ Jm^{-3} which are obtained for particles that have been sintered at the highest sintering temperatures of T_S = 1273 K are much smaller than what is to be expected for fully ordered particles. Furthermore, electron diffraction does hardly provide any evidence for the occurrence of the $L1_0$ superstructure. In order to characterize both the number of ordered particles and the degree of $L1_0$ order S, statistical HRTEM studies combined with HRTEM contrast simulations were performed. From these investigations, the fraction of ordered particles and their degree of order are determined to be 0.30 $\leq f \leq$ 0.44 and 0.3 $\leq$ S $\leq$ 0.76, respectively. From this, the volume averaged order parameter $S_{av} = f{\cdot}S$ of the FePt nanoparticle ensemble is determined to be 0.09 $\leq S_{av} \leq$ 0.33. Taking this value for the average order parameter into account, the experimental data for both the coercive fields and the effective anisotropy are in good aggreement with data for partially ordered Fe-Pt reported in the literature. [1] S. Stappert, B. Rellinghaus, M. Acet, and E.F. Wassermann, J. Cryst. Growth 252 (2003) 440-450. [2] B. Rellinghaus, S. Stappert, M. Acet, and E.F. Wassermann, J. Magn. Magn. Mater., in print (2003). [3] M.F. Toney, W.-Y. Lee, J.A. Hedstrom, and A. Kellock, J. Appl. Phys. 93 (2003) 9902-9907. The work is supported by the Deutsche Forschungsgemeinschaft within SFB 445.

9:45 AM FF8.6
Magnetization Reversal in FePt Thin-Film Composites. David J. Sellmyer[1,2], Minglang Yan[1,2], Yingfan Xu[1,2], Arti Kashyap[1,2], Renat F. Sabiryanov[1,2] and Ralph Skomski[1,2]; [1]Department of Physics and Astronomy, Univ. of Nebraska, Lincoln, Nebraska; [2]Ctr Matls Res & Ana, Univ. of Nebraska, Lincoln, Nebraska.

Particulate FePt-based thin films for high-density magnetic recording are investigated experimentally and by theoretical calculations. The key question is how the real structure of the nanostructured films affects the hysteretic behavior and spatial magnetization correlations. The structures, produced by various methods, consist of FePt nanoparticles embedded in nonmagnetic matrices, such as a C and Ag, and have varying sizes, packing fractions, and crystalline orientations [1, 2]. They are investigated by X-ray diffraction, electron microscopy, magnetic force microscopy, and magnetization measurements. Both the slope of the hysteresis loop, as epitomized by the parameter alpha, and the coercivity depend on the volume fraction of the magnetic particles and on their geometrical arrangement. Model calculations and micromagnetic simulations are used to explain the experimental trends. With increasing packing fraction, the exchange interaction between the magnetic grains increases through the matrix [3] or due to direct contact. As a consequence, the reversal mechanism changes from a localized mechanism, such as Stoner-Wohlfarth rotation in very small particles, to a cooperative reversal mechanism [4]. In the present case, there is a unique transition from localized nucleation to domain-wall pinning when the interparticle interaction exceeds a real-space dependent threshold of the order of 0.1 KV, where K and V are the anisotropy and the volume of the particles, respectively. Both regimes can be modeled numerically, but in the second case the presence of a domain wall must be included in the micromagnetic starting configuration. A specific result of the calculations is that details of the hysteresis loop shape depend not only on the packing fraction but also on the symmetry of the packing. For example, particles forming a square lattice yield smaller parameters alpha than triangular lattices with equal net exchange per particle. This work is

supported by DOE, INSIC, NSF MRSEC, Keck Foundation, ARO and CMRA. [1] M.L. Yan, N. Powers, and D. J. Sellmyer, "Highly Oriented Nonepitaxially Grown L10 FePt Films," J. Appl. Phys. 93, 8289-8291 (2003). [2] Y.F. Xu, Z. G. Sun, Y. Qiang, and D. J. Sellmyer, "Magnetic Properties of L10 FePt and FePt:Ag Nanocluster Films," J. Appl. Phys. 93, 8292-8294 (2003). [3] R. Skomski, "Nanomagnetics," J. Phys.: Condens. Matter 15, R841-896 (2003). [4] R. Skomski, A. Kashyap, Y. Qiang, and D. J. Sellmyer, "Exchange Through Nonmagnetic Insulating Matrix," J. Appl. Phys. 93, 6477-6479 (2003).

10:30 AM FF8.7
Inducing chemical ordering and enhancing magnetic anisotropy in FePt and FePd by ion irradiation - an atomistic computer simulation study. Karl-Heinz Heinig[1], Harry Bernas[2], J.-Ph. Attane[3], A. Marty[3], P. Auric[3], D. Halley[3], Y. Samson[3], D. Ravelosona[4] and C. Chappert[4]; [1]Inst. Ion Beam Physics & Materials Research, Research Center Rossendorf, 01314 Dresden, Germany; [2]CSNSM, CNRS-University Paris XI, 91405 Orsay, France; [3]DRFMC - Service de Physique des Materiaux & Microstructures, CEA Grenoble, 38054 Grenoble, France; [4]Inst. d'Electronique Fdtale., CNRS-University Paris XI, 91405 Orsay, France.

The FePd and FePt ordering temperatures may be substantially reduced by ion irradiation [1]. Alignment of the strong magnetic axis normal to the surface layer was achieved. We show ([2] and this Meeting) experimentally and via kinetic Monte Carlo simulations that (i) ion beam-induced reduction of the $L1_0$ transition temperature may be understood in terms of vacancy-assisted atomic ordering and that (ii)superstructure alignment results from a small directional short range order (DSRO) of the as-deposited films. The long-rang order evolves like a competitional grain growth between superstructure domains where those $L1_0$ domains having their c-axis normal to the layer plane are favoured due to the initial DSRO. Here, we present predictive atomistic simulations on ion-assisted $L1_0$ ordering and superstructure domain alignment in different initial configurations (corresponding to different preparation conditions), and compare them with experimental results. The influence of ion irradiation on $L1_0$ ordering of FePd or FePt nanoparticles will be discussed. [1] D. Ravelosona, C. Chappert, V. Mathet and H. Bernas, *Appl.Phys.Lett.***76**, 236 (2000) [2] H. Bernas, J.-Ph. Attane, K.-H. Heinig, D. Halley, D. Ravelosona, A. Marty, P. Auric, C. Chappert, Y. Samson, to appear in *Phys.Rev.Letters* (2003)

10:45 AM FF8.8
X-Ray Magnetic Circular Dichroism Study of FePt and Fe_3O_4 Nanoparticle Arrays. Simone Raoux[1], Shouheng Sun[2], Thomas Thomson[3], Robin F. C. Farrow[1], Elke Arenholz[4], Tobias Funk[4], Christopher B. Murray[2] and Bruce D. Terris[3]; [1]IBM Almaden Research Center, San Jose, California; [2]IBM T. J. Watson Research Center, Yorktown Heights, New York; [3]Hitachi San Jose Research Center, San Jose, California; [4]Lawrence Berkeley National Laboratory, Berkeley, California.

Nanoparticles of FePt and Fe_3O_4 were made by solution-based high-temperature synthesis from which self-assembled arrays have been fabricated. Subsequent annealing of the FePt nanoparticle arrays in an inert atmosphere led to a transformation from the chemically disordered fcc phase of the as-deposited nanoparticles to the $L1_0$ phase which exhibits high magneto-crystalline anisotropy. We have studied the magnetic properties of these assemblies using X-ray magnetic circular dichroism (XMCD), vibrating sample magnetometer (VSM), and magneto-optical Kerr effect (MOKE) measured at a wavelength of 633 nm, and have compared their properties to various iron oxide reference samples. For some annealing conditions of the FePt nanoparticle arrays (in particular high temperature annealing) the MOKE hysteresis loops differ considerably from VSM loops. The VSM loops show a superposition of a magnetically hard and soft phase while the MOKE loops show only the hard phase. Fe_3O_4 nanoparticle arrays are superparamagnetic at room temperature and VSM and MOKE loops are similar but the Kerr rotation is very weak. XMCD measurements on Fe_3O_4 nanoparticle arrays and Fe_3O_4 and Fe_2O_3 thin film reference samples show the characteristic three peak structure at the Fe L_3 absorption edge. The near-edge X-ray absorption fine structure spectra of the annealed FePt arrays indicate that a fraction of the Fe is oxidized but the XMCD spectra exhibit only one peak at an energy that is characteristic of metallic Fe. This indicates that the soft magnetic phase seen in the VSM loops for the FePt nanoparticle arrays does not stem from a magnetic oxide with a smaller specific Kerr rotation compared to FePt. The origin of this low (or absent) Kerr signal of the soft phase will be discussed in terms of previous results on fcc FePt and other possible phases.

11:00 AM FF8.9
Ion irradiation ordering of intermetallic alloys for magnetic media. Harry Bernas[1], Jean Philippe Attane[2], Karl Heinz Heinig[3], David Halley[2], Alain Marty[2], Pierrette Auric[2], Dafine Ravelosona[4], Claude Chappert[4] and Yves Samson[2]; [1]CSNSM, Orsay, France; [2]CEA Grenoble, DRFMC,Service de Physique des Materiaux & Microstructures, (assoc. with Universite J. Fourier), Grenoble, France; [3]FZ Rossendorf, Inst. Ionenstrahlphys. & Materialforsch, Dresden, Germany; [4]Inst. d'Electronique Fdtale., CNRS Universite Paris XI, Orsay, France.

We have triggered and controlled the transformation from chemical disorder to order in thin films of an intermetallic ferromagnet (FePd) by combining He ion irradiation and thermal mobility below 600K. Kinetic Monte Carlo simulations show that the initial directional short range order determines the transformation. Magnetic ordering perpendicular to the film plane was achieved, promoting the initially weak magnetic anisotropy to the highest values known for FePd films. Applications to ultrahigh density magnetic recording are suggested.

11:15 AM FF8.10
Nanocomposite Films of High K_u Magnetic Grains Prepared By Pulsed Filtered Vacuum Arc Deposition. Y.W. Lai[1,3], M.F. Chiah[1,3], N. Ke[1,3], Y. Gao[1,3], W.Y. Cheung[1,3], Q. Li[2,3], H. Wang[1] and S.P. Wong[1,3]; [1]Electronic Engineering, Chinese University of Hong Kong, Shatin, Hong Kong; [2]Physics, Chinese University of Hong Kong, Shatin, Hong Kong; [3]Materials Science & Technology Research Center, Chinese University of Hong Kong, Shatin, Hong Kong.

Nanocomposite films consisting of high K_u magnetic grains embedded in non-magnetic matrices are of great interest for their potential applications as high-density magnetic recording media. In this work, nanocomposite films of fct-CoPt or fct-FePt grains embedding in carbon, copper or silver matrix of various compositions were prepared by a pulsed filtered vacuum arc deposition technique in which multilayers of three elemental components with an appropriate design of thickness and sequence were first deposited followed by a rapid thermal annealing in an argon atmosphere. Characterization of these films was performed using Rutherford backscattering spectrometry, x-ray diffraction, transmission electron microscopy, and vibrating sample magnetometry. The temperature-time profile of the RTA process consisted of three regions, namely, a transient overshoot region with a typical rising time of 2 s and a falling time of 2 to 3 s, a constant temperature region at the set annealing temperature T_A for a period of typically several tens of seconds, and the cooling region where the temperature fell rapidly from T_A to the ambient temperature. The overshoot peak temperature T_P is typically 50 degree centigrade higher than T_A. The dependence of the structure and magnetic properties, such as the phase and size of the magnetic grains and the coercivity of these films, on the deposition parameters and annealing conditions were studied in details. Both x-ray diffraction and transmission electron microscopy analyses confirmed the formation of $L1_0$ phase CoPt and FePt nano-grains after appropriate annealing. For example, for the film with a particular composition of $Fe_{43}Pt_{45}Cu_{12}$, the $L1_0$ phase formation was observed after the above-described RTA process at T_A of 400°C, and the film exhibited a coercivity of 6.7 kOe. This work is supported in part by the Research Grants Council of Hong Kong SAR (Ref. Number: CUHK4216/00E).

11:30 AM FF8.11
Magnetic interactions in 3d-5d bi-metallic nano-particles. Oleg N Mryasov, Seagate Research, Pittsburgh, Pennsylvania.

The effective spin Hamiltonian for 3d-5d (FePt, CoPt) bi-metallic nano-particles layered ferro-magnets have been investigated on the basis of the first-principles calculations for non-collinear configurations [1] and site resolved magneto-crystalline anisotropy energies [2]. We find that in these layered ferromagnets isotropic exchange interaction parameters are strongly affected by the fact that the 5d(4d) sites magnetic moment is entirely due to the 3d sites exchange fields. We find large differences in the interaction parameters within J_{in} and out of the 3d atom layers J_{out}. For example, for the FePt the exchange length in the <001> direction (ξ_{001}) was found to be ~1.7 times smaller than for the <100> direction (ξ_{100}) . It has been demonstrated that electronic degrees of freedom of the Pt can be effectively described within the Stoner model with intra-atomic exchange parameter of about 200 meV. Then the induced magnetism on the Pt site and a large difference in the spin-orbit coupling constants of the 3d and 5d elements results in large effective anisotropic exchange and additional ferromagnetic isotropic exchange. The strength of this effective anisotropic exchange is found to be dependent on the Stoner parameter for the 5d site (I_{5d}), on the value of the induced 5d/4d magnetic moment (for the FePt m_{5d} is about 0.36 μ_b), the exchange interaction parameter J_{3d-5d} which is about 2 meV for the FePt and the single-ion anisotropy $D^{(0)}$ which is estimated to be about 1.6 meV for the FePt. To investigate effects of the finite particles size on magnetization fluctuation and temperature dependence of magnetic anisotropy we calculate surface anisotropy and renormalization of the exchange at the surface layers. Effects of these features of the magnetic interactions on the spin wave excitations in FePt and CoPt nano-particles are discussed on the basis

of the available models. In particular, we consider unusually large contributions of the effective anisotropic exchange to the critical temperature and spin wave dispersion relations. We demonstrate that these unusual for the itinerant ferromagnets properties originate from the induced magnetism of the 5d/4d shell and layered structure with alternating 5d/4d and 3d element layers. [1] O. N. Mryasov, A. I. Liechtenstein, and V. A. Gubanov, Phys. Rev. B 45, 12330 (1992); [2] A. B. Shick and O. N. Mryasov, PRB. v. 67, 172407 (2003)

11:45 AM FF8.12
Composition Control of CoPt Nanoparticles by Chemical Reduction. Hongli Wang[1], Yong Zhang[1], yuwen zhao[1], Micheal John Bonder[1], Yunhe Huang[2] and George Hadjipanayis[1]; [1]Department of Physics, Univercity of Delaware, Newark, Delaware; [2]Center for Materials for Information Technology (Mint), The University of Alabama, Tuscaloosa,, Alabama.

Recent interest in magnetic nanoparticles has been focused on ultra-high density magnetic recording, nanocomposite permanent magnets and biological applications, etc.. In this paper, CoPt nanoparticles were produced following the procedure used by Sun et al.(1). A 0.5 mmol PtCl4 and CoCl2·H2O solution in the range of 0.5 and 2.0 mmol was used. the reaction has the form: PtCl4 + 4LiBEt3H = Pt + 4LiCl + 4BEt3 + 2H2 ↑ CoCl2 + 2LiBEt3H = Co + 2LiCl + 2BEt3 + H2 ↑ In the samples studied here, using 0.5 mmol PtCl4 and 1.5 mmol CoCl2· H2O solution leads to nanoparticles with a Co50Pt50 composition. As made particles are superparamagnetic and chemically disordered with particle size of 1-2 nm shown by TEM image. M vs T and M vs H/T curves show a blocking temperature around 150 K. Further annealing transforms the chemically disordered fcc structure into chemically ordered fct structure and thus leads to a coercivity of 4.2 kOe as a result of the high anisotropy constant of the fct structure.Further investigations are underway to form ordered arrays and lower the transformation temperature. Work supported by NSF DMR 9972035 (1) Shouheng Sun et al. J.Phys. Chem. B 2003, 107, 5419-5425 To whom correspondence should be addressed. Email: hlwang@udel.edu