SYMPOSIUM FF

FF: Advanced Magnetic Nanostructures

November 30 - December 4, 2003

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*Invited paper
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:
Ramamurthy, University of Washington
Mark Thummel, University of Massachusetts

SESSION FF1: Novel Fabrication Techniques
Chair: Kristian Tind 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 led 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 of 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 superlattices 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, Fe, Pt, and Fe203 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 Xuemeng, Andrei Urmule, Mustafa Bal, Qiang Xiong, James Goldbach, and Thomas Russell
Department of Physics, University of Massachusetts, Amherst, Massachusetts; Department of Polymer Science and Engineering, University of Massachusetts, Amherst, Massachusetts.

Many future applications of magnetic technology require magnetic elements configured into system architectures that are compatible with the requirements of future applications. This talk will focus on using colloidal suspensions of magnetic elements and superconducting elements made by new integrated nanofabrication techniques in the magnetic microphase separation of block copolymer systems with electrochemical deposition. The magnetization properties of cobalt and permalloy nanowire arrays will be discussed in a patterned magnetic system. We analyze the behavior of these arrays in front of magneto-crystalline anisotropy, shape anisotropy, and magnetostatic interactions. Second research will be presented on integrated magneto-electro transport devices in one-dimensional and two-dimensional geometries. Fabrication is achieved by combining nanometer precision polymer templates with electron beam lithography. Measurements include spin-dependent electron transport GMR and AMR behavior, and Andrew-coupled superconducting behavior in magnetic device configurations. This work is supported by NSF grants DMR-0133283 and DMR-0074175, and MRSEC.

9:30 AM FF1.3
Ceramic Processing Advances for the 21st Century: Microwave-hydrothermal Synthesis of Nanostructured Magnetic and Ceramic Nanostructures
Andres Diaz, Engenharia Metallurgica e Materias, 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. The so-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 promise 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 microwave into the reaction vessels to produce ceramic materials more rapidly. It offers many advantages over conventional autoclave heating, including rapid heating to crystallization temperature, homogenous nucleation, fast super saturation by the rapid dissolution of precipitated hydroxides, and the later crystallization at low temperatures and shorter crystallization times. In this paper, we report the microwave-hydrothermal synthesis of nanostructured magnetic electroceramic. The fundamental issues relating to the hydrothermal processing conditions (temperature, pressure, time and pH) on the control of the phase behavior and 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
Nanostructured NiFe204 Ferrite Prepared by a Combined Chemical Synthesis and Consolidation Process
Heng Zhang, Shui Gu and Y.D. Zheng, Inframat Corporation, Farmington, Connecticut

A nanostructured NiFe204 ferrite has been fabricated using a combination of chemical synthesis and consolidation techniques. The NiFe204 precursors were synthesized using a sol-gel auto-combustion process. The bulk NiFe204 particles were then consolidated through a hot pressing at different temperatures. The structure, electronic behavior and magnetic properties of the material have been investigated using X-ray diffraction, SQUID magnetometer, impedance spectroscopy and high precision millimeter 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 diffusion was observed during the hot-press process and this characteristic has significant effect on the reaction and density of NiFe204 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 Ferrimagnetic Nanostructures
Brian D. Reiss and Angela Belcher, Biological Engineering, MIT, Cambridge, Massachusetts

Ultrasmall magnetic nanoparticles have numerous applications in magnetic memory devices, biosensors, and magnetic electronics. Currently, such materials are prepared as colloidal solids, 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 being investigated. 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 nanoparticles with thin films of magnetic materials. These phage libraries contained phage which were
functioned with a random 12 mer or attached to their Ph cost proteins, and peptides were identified that select 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 in a new method to control the growth of these nanoparticles. These peptides 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). Takeshi 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 characteristic 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 octacarbonyldichloride [Co(CO)8] powders. Vapor of the precursor was generated by heating the reservoir, and introduced through a feeding nozzle (0.5 mm diameter) above the substrate, separated by 5.5 mm. The residual pressure of the deposition chamber was around 1 e-3 Torr. The ion current and the pressure at deposition were 6.6 ± 1 nA 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 beam, the particle formation process is rather complicated due to consecutive processes of etching, evaporation and deposition, therefore the morphology of Co particles strongly depends on the ion beam dwell time (5 to 120 μs) and the partial pressure of Co(CO)8 precursor, as revealed by AFM analysis. The smallest size of Co particles obtained is about 100 nm in size. They exhibit ferromagnetic behavior. Results about modification of properties by heating substrates, and on formation of FePt alloy particles by dual precursor source, will also be presented. A. Lapicki, E. Ahmad, and T. Suzuki. J. Magn. Magn. Mater. 240 (2002) 47 2 A. Lapicki, K. Kang, and T. Suzuki. IEEE Trans. Magn. 38 (2002) 2898.

11:00 AM FF1.7
Fabrication of Magnetic Planar Nanostructures Using Electron Beam Lithography and AFM Nano-Lithography Techniques. Keino Watanabe1, Yasushi Takeyama2, Yoshihiro Shinoda1 and Jun-ichi Shirakashi3. Yokohama National University, Yokohama, Japan; 1Akita Prefectural University, Honyo, Akita, Japan.

Lithography techniques using scanning probe microscopes have attracted much interest as novel tools for fabricating electronic devices with well defined structures of a nano-meter scale. Ni(Fe) and Co-based nanostructures fabricated by a combination of electron beam (EB) lithography and atomic force microscope (AFM) nanooxidation are reported in this paper. Metals are oxidized by applying a negative bias on the AFM cantilever. This anodic oxidation process is electrochemical reaction between metals and water in air. The selectively oxidized region can be utilized as a separation 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 patterning Ni thin films by EB lithography, nanowires of Ni were fabricated by AFM nano-oxidation, which resulted in the formation of Ni/NOx/Ni multilayer-type MTJ. In this 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 ratio, considering the 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 μm in height and 2 μm in width, we observed a single electron microscopy (MFM) measurement, whereas the rectangles lum 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 μm in length and 0.75 μm in width. The single domain structure observed before the nanooxidation was divided into two parts of single domain at both sizes of the Ni-oxide nanowire. It was found that the AFM nano-oxidation could modify the magnetic domain structure in the same way as the conventional oxidation technique was performed on ferromagnetic metal-based nanostructures. Their electrical and magnetic properties were modified, which could be utilized for applications of magnetic nanostructured materials and devices.

11:15 AM FF1.8
Self-assembled of embedded perpendicular a-Fe nanoparticles for potential high density magnetic memory. Linan Mohamedi-Ardebili1, Haimei Zheng2, Shish B. Ogale3, Manfred Wittig1, Rumamothu Ramesh2, Berndt Hansen2, Wei Tian4, Xiaoping Pan4 and Samuel E. Loffland1. 1Materials Science and Engineering, University of Maryland, College Park, Maryland; 2Institut des Matériaux, Université de Rennes, Cede, France; 3Department of Materials Science and Engineering, University of Michigan, Ann Arbor, Michigan; 4Department 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 La1.58Sr0.5FeO3 films by pulsed laser deposition on LaAlO3 (001) under reducing conditions is shown to develop a fairly homogeneous out-of-plane self-assembled of ferromagnetic a-Fe nano-pillars embedded in an antiferromagnetic matrix of a layered perovskite La2FeO4 (n = 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 in current directions and then cylindrical in normal directions of the pillars shrink to 3-5 nm for growth at 560°C. As expected, a large anisotropy is observed between in-plane and out-of-plane magnetizations, with in-plane out-of-plane coercivity of maximum 340 Oe, which is achieved at 760°C (M = 0.9 M0) [1,2,3]. We report the results 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-0450889 and by an ONR MURI program under contract No. N000140110760.

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

1:30 PM **FF2.1

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 Argonne is supported by the US DOE, BES Materials Sciences under contract W-31-109-ENG-38.

2:00 PM **FF2.2
Magnetism and Self-Assembly of Shape-Controlled Cobalt Nanocryts and Their Superlattices. Kaumud M. Krishnan, Yuping Bao and Michael Beeman; 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, pyrolyzed 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 composition, size and tetragonality of the constituent 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 driven 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-plate transitions in individual nanocrystals
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 **FP2.3**

Magnetic Recording Properties On Patterned Media,
Jerome Maitre1,2, Jean-Baptiste Dupeyr2, Jean-Pierre Noresner2, Rene Van De Venne2, Thomas Mac Crawford1 and Dieter Waller2; 1SPINTEC, Grenoble, France; 2Seagate 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 can be divided into three main issues: on the one hand, techniques for the 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 properties of these media. Therefore, we focused our research on the study of patterned media prepared from arrays of silicon dots obtained either by e-beam lithography and RIE etching techniques or by nanoinprinting. Pt(Co/Pt) 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 like the height of the dots, the edge to edge spacing as well as the incidence of the patterned dot arrays are critical in the sense that they play a key role in the line coupling which could exist between the bits. When the dots are significantly decoupled and exhibit a single-domain magnetic state, the useful information is the top of the dots. The recording properties of these media were investigated with a quasi-static tester using a classical longitudinal head to manipulate the magnetization of rows of individual dots. The relative accuracy of the signal and the head, the magnetic properties of the patterned 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, these patterned media are a mostly a jitter one which origin is the topographical jitter due to the lithographic process. The sub-nanoscondetent 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 1000/°s to 1070/°s has been measured by magneto optical Kerr effect (MOKE).

Furthermore, using a write head with specially large bandwidth supplied with pulse of current 1 to 1.8 pA long, we investigated the dynamic coercivity of individual dots and showed the stochastic character of their magnetization switching. These recent and original experiments give precious technological arguments in favor of the use of patterned media made from pre-structured wafers as a new storage system.

3:30 PM **FP2.4**

Magnetic Reversal of Co/Pd Multilayer Films and Sub-100nm Islands, G Hu1, T Thomson1, S Houx1, C T Retten1, M McCelland2, M W Hart2, M E Best2 and B D Terr2; 1Hitachi San Jose Research Center, San Jose, California; 2IBM 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 1 Tbit/inch2. 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 behavior of Co/Pd multilayer magnetization measured by the magnetic force microscopy (MFM) technique with the switching behavior of arrays of identically 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 were then deposited on 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 mechanisms are controlled by 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 magnetic anisotropy closely. Systematic studies have been carried out to adjust the anisotropy of patterned arrays 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 Shunmugam equation.

3:45 PM **FP2.5**

Effective magnetic anisotropy in nanoparticle systems probed using transverse susceptibility experiments, P Pedding1, H Srikunth1, D F Farrell1, S A Majetich2, S Morrison2 and E E Carpenter2; 1Department of Physics, University of South Florida, Tampa, Florida; 2Department of Physics, Carnegie Mellon University, Pittsburgh, Pennsylvania; 3Naval Research Laboratory, Washington, District of Columbia.

We have measured transverse susceptibility (TS) using a home-built tunnel diode oscillator and the magnetization perpendicular to the plane of the array. Two different types of experiments were carried out. In the first experiment, we used nanocrystals with mean diameter of 2.5 nm dispersed in a monolayer of surfactant-coated iron nanocrystals (~ 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 between 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 (~ 16.5 nm) were studied with the TS experiments. Unlike the case of iron nanoparticles, these ferrite nanoparticles did not have surface coatings and the magnetic properties were influenced both by the exchange dipole interactions. In these samples at low temperatures, in addition to the two anisotrophy peaks generally observed in TS experiments, a third peak associated with switching fields is also clearly resolved. Overall, we demonstrate the effectiveness of frequency-TS experiments in probing magnetic anisotropy and discern the results in the context of a model first developed by Abrahams. USE authors acknowledge support from NSF grant # ECS-0414007.

4:00 PM **FP2.6**


Recently, monodisperse 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 interactions. LE deposition experiments have 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 the ratio of film resistance appeared when magnetic field vector was set parallel or perpendicular to the gap between the contacts. Magnetic resistance of the films has also been examined 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 magnetic magnetic moment. The ensemble of such particles may exhibit magnetic ordering due to intergranular interaction. This situation occurs in the films produced by LE technique, where magnetic nanoparticles form arrays of very small dimensions. In this case the particles are highly anisotropic because the size of the continuous film. Moreover, the switching behavior of the islands does not exhibit any correlation with the film reversal mechanism, but rather follows the magnetic anisotropy closely. Systematic studies have been carried out to adjust the anisotropy of patterned arrays 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 Shunmugam equation.

4:15 PM **FP2.7**

Growth and Magnetic Properties of Co "Magic" Platelets on Si(111) Surface, Jingfeng Jin, Ming-Hu Pan, Jun-Zhong Wang and Qian 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 nanochannel array formed on the Si(111) 7×7 surface. The Al nanochannel array not only supports the activity...
between Si and Co, but also promises the formation of a magnetic Co
platelets. In-situ scanning tunneling microscopy reveals that almost all Co platelets appear as an equatorial nanoscale "mirror-like"
thickness and a fixed orientation, each platelet occupies N
halves of the 7x7 unit cell where N depends on the surface Co
coverage. The magnetic properties of the platelets were investigated,
ourselves by superconducting quantum interference device (SQUID).
Steps found in hysteresis loop manifest the synergism between
magnetic dipole interactions and magnetic-crystalline anisotropy. The
results demonstrate that the method we are using 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 Aksan1, Robert
M Birner1 and Peter Kofman1,2, 1Chemical Engineering, University of
Maryland, College Park, Maryland; 2Chemical 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 deuteronorbornene
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 390/120, 320/190
and 290/260. 5-15 nm iron oxide nanoparticles were produced within the
polymer by solution synthesis of iron salts to the carbonyl acid
groups of polymer blocks, followed by heating, pyrolysis and oxidation
upon formation of a solid nanocomposite film. Blocking
10-15k were determined by Superconducting Quantum Interference Device
(SQUID) magnetometry for the 390/120, 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 ferromagnetic behavior to ferromagnetic 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 the 390/120
decreased from 23 nm to 53 nm after the formation of iron oxide and the polymer 390/190 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 microscopy (TEM). Therefore, high PMA
values were determined with their thickness due to the formation of a columnar
structure with larger grains. From this, it can be expected that superior PMA of CoPd film may be maintained or improved in the
[CoPd]_{n=1,h=30} /Cu_{n=1,h=30} multilayers, which have the thickness
of each CoPd layer was kept within 1 μm by using Cu (a typical non-magnetic material) interlayers, and provided the motivation for this study. Moreover, we recently observed that the magnetic properties of electrodeposited [CoPd/Cu]_{n=1,h=30} films are also severely
conditioned 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 [CoPd/Cu]_{n=1,h=30} multilayers 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 magnetic and microstructural properties of electrodeposited CoPd multilayers, which will lead to the plausible
explanation on the role of Cu layers in controlling the magnetic properties of electrodeposited multilayered [CoPd/Cu]_{n=1,h=30} films.

FF3.3
Abstract Withdrawn

FF3.4
Kwan H Lee and Won J Yeung; Materials Research Division, Korea Institute of Science and Technology, Seoul, South Korea.

Thin film CoPd alloys have been known as one of the ferromagnetic
alloys with the best PMA/perpendicular magnetic anisotropy which
can be obtained from electrodeposition materials. Therefore, some
important studies have been devoted to the electrochemical fabrication
of CoPd 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 CoPd film becomes more than about 100 nm, the PMA of CoPd and hence the
magnetic properties are substantially decreased due to the formation of a columnar structure with larger grains. From this,
it can be expected that superior PMA of CoPd film may be maintained or improved in the
[CoPd]_{n=1,h=30} /Cu_{n=1,h=30} multilayers, which have the thickness
of each CoPd layer was kept within 1 μm by using Cu (a typical non-magnetic material) interlayers, and provided the motivation for this study. Moreover, we recently observed that the magnetic properties of electrodeposited [CoPd/Cu]_{n=1,h=30} films are also severely
conditioned 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 [CoPd/Cu]_{n=1,h=30} multilayers 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 magnetic and microstructural properties of electrodeposited CoPd multilayers, which will lead to the plausible
explanation on the role of Cu layers in controlling the magnetic properties of electrodeposited multilayered [CoPd/Cu]_{n=1,h=30} films.
origin of hysteresis in single domain magnetic nanoparticles. We will discuss the influence of a series of substituted benzonic acid ligands attached to the surface of \( \text{MgFe}_2\text{O}_4 \) nanoparticles upon the coercivity. Furthermore the synthesis and magnetic properties of \( \text{MgAl}_2\text{O}_4/\text{CoFe}_2\text{O}_4 \) core/shell nanoparticles will be discussed. As the core is non-magnetic this 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.

**F3.6 Magnetic Nickel Ferrite Nanofibers Prepared by Electrosprinning.** Dan Li, Thurston Herricks and Younan Xia; University of Washington, Seattle, Washington.

We report a simple procedure based on electrosprinning for generating random and uniaxially aligned nanofibers made of nickel ferrite. NiFe204 nanofibers with average diameter of 40 nm were prepared by electrospraying a solution containing polyvinylpyrrolidone 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 differences between a wire and a powder.

**F3.7 Magnetoeimpedance of manganese films at high frequencies (10 kHz - 1 Mhz) of N. Sekhar, P. Chandra, Laura Crandall, and Catherine Dubourdieu; CRIBIT, Grenoble, France; Laboratoire des Matériaux et du Genie Physique, St Martin d’Heres, France.

Manganite oxides such as \( \text{La}_0.50\ldots \text{Sr}_0.50 \text{Mn}_2\text{O}_4 \) exhibit colossal magnetoresistance, which is significant for magnetic fields of the order of Tesla. The magnetotransport 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 magnetoeimpedance measured in the range 100 kHz - 10 MHz of \( \text{La}_0.50\ldots \text{Sr}_0.50 \text{Mn}_2\text{O}_4 \) films. The films were grown either epitaxially on (001) \( \text{LaAlO}_3 \) 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 magnetoeimpedance 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: \( \sim 7 \% \) in 1 T and 36 \% at 6 T for a polycrystalline film). The temperature and frequency dependence of the magnetoeimpedance will be discussed. Microstructure and thickness influence will be considered.

**F3.8 Enhancement of the thermal stability for Magnetic Tunnel Junctions with Pt-Added Pinned Layer.** Il Suk Kang, Shinn 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 is a major concern for MRAM application. However, the tunnel magnetoresistance (TMR) signal is decreased after annealing above 300-350°C. Because Mn diffusion into the pinned magnetic layer. We study the thermal stability effects in NiFe/\( \text{Al}_2\text{O}_3/\text{CoFe}_2\text{O}_4 \) as a Pt MJs as a function of Pt content. NiFe/\( \text{Al}_2\text{O}_3/\text{CoFe}_2\text{O}_4 \) MJs are prepared by RF magnetron sputtering and \( \text{Al}_2\text{O}_3 \) is oxidized by O2 plasma. Successive annealing is performed up to 450°C. Decay of TMR elevated annealing temperatures is suppressed by increasing Pt content. This may be due to the surface of \( \text{MgFe}_2\text{O}_4 \) nanoparticles upon 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 MJs in comparison to the reference MJs (\( L_{\text{in}} \)).

**F3.9 Abstract Withdrawn**

**F3.10 Nanocrystalline Iron Oxide Aerogel as Porous Magnetic Nanomaterials.** Jeffrey Webster Long, Michael S. Logan, Brett M. Dening, Everett E Carpenter, Christopher P Rhodes, Rhonda M Stroud and Debra R Rollison; Chemistry Division, Naval Research 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 mesoporous. The combination of properties intrinsic to aerogel-based architectures when coupled to functional oxides make them ideal materials for a variety of applications including energy storage, electrochromics, fuel cells, and sensors [1]. We have adapted the methods of Gazay et al. [2] to synthesize monolithic iron oxide aerogels. The aerogels, as-prepared iron oxide aerogels are converted to magnetic nanocrystalline materials including \( \text{Fe}_3\text{O}_4 \) (magnetite) and \( \gamma -\text{Fe}_2\text{O}_3 \) (maghemite) under controlled temperature and atmosphere conditions. Nanocrystalline iron oxide aerogels exhibit magnetic properties ranging from superparamagnetic to ferromagnetism. These magnetic materials retain their inherent characteristics of aerogels: high surface area, through-connected porosity in the mesopore (2 - 50 nm) range, and nanoscale particle size. On the basis of our control we can believe both the particle architecture and the nanocrystalline phase of these iron oxides, we can now design novel magnetic nanomaterials. 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 for ion-insertion electrodes as well as high-surface-area supports for heterogeneous catalysis [1] D.R. Rollison, B. Dunn, J. Mater. Chem., 11, 967 (2001) [2] A.E. Grash, T.M. Tilley, J. L. Satcher, J.F. Poro, L.W. Hrubesh, R.L. Simons, Chem. Mater, 13, 999 (2001).

**F3.11 Study on Magnetic Properties of FePt Particles Assemblies.** Xiaoheng Sun, David E. Nilles, J.B. Ying, M. Kim and W.J. James; Center for Materials for Information Technology, The University of Alabama, Tuscaloosa, Alabama; Materials Research Center and Department of Physics, University of Missouri-Rolla, Rolls, Missouri.

Monodisperse 4 nm diameter Fe-PtP$_x$ nanoparticles with controlled compositions were synthesized by simple polyol reduction of platinum acetylacetonate and iron nitratoxide. As prepared, the Fe-PtP$_x$ particles had a disordered face-centered cubic lattice and were superparamagnetic. These Fe-PtP$_x$ particles self-assembled into ordered 2D or 3D particle arrays when deposited onto some proper substrates. After heat treatment at temperature ranging from 500°C to 700°C under Ar with 5 percent H$_2$ atmosphere, the Fe-PtP$_x$ 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 is reported by the IBM group [1] for particles prepared from iron pentacarbonyl and platinum acetylacetonate. MDGibson spectroscopy measurements confirmed that the as-prepared Fe-PtP$_x$ 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 FeP$_x$ [1]. S. Sun, C. B. Murray, D. Weller, L. Folks, and A. Mozer, Science, 287, 1889 (2000).


CoPt$_2$Ag nanoparticles were prepared by the polyol reduction of cobalt chloride, platinum acetylacetonate and silver nitrate 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 nanoparticles could be dispersed in hydrocarbons solvents. When the suspensions 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 fcc (110) CoP$_2$ and fcc (111) CoP$_3$. During heat treatment the left the left the particles as indicated by an Ag (111) x-ray diffraction peak. Unlike our experience with FePt, the addition of Ag seemed not promote phase transformation of the transformation from the fcc to the L1$_0$ phase. The coercivity values were still lower (minimum 3 kOe at RT) than that of FePt particles that is consistent with the structure analysis. The time dependence of remanence coercivity at different temperatures was measured and fitted to Sherwood formula and the thermal stability factor (KV/RT) was determined.
FS3.13
Phase Change of FePt nanoparticles in Dispersion by Laser Annealing
Soledad Silva1 and Shinzo Mino1,2.
1STRC Solid Powder Processing Laboratory, Mitsubishi
Chemical Company, Yokohama, Kanagawa, Japan; 2The University of Tokyo,
Bunkyo-ku, Tokyo, Japan.

Chemically synthesized FePt colloidal nanoparticles in dispersion were exposed to 400m W 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 measurements 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 L1_0 fct structure which has large coercivity. Magnetic property of laser annealed particle films were evaluated using VSM.

FS3.14
Organic coating of gas-phase prepared FePt nanoparticles.
Amaeget Terasawa1, Kazumi Mok2, Mahmet Acet2, Christian Mayer2 and Bernd Rellinghaus3.
1Physical Chemistry, University Duisburg-Essen, Duisburg, Germany; 2Experimental Physics, AG
Phys, University Duisburg-Essen, Duisburg, Germany; 3Institute of Combustion and Gas Dynamics, University Duisburg-Essen, Duisburg, Germany.

Fe-Pt nanoparticles in the L1_0 phase have attracted considerable attention as potential material for media in high density magnetic recording. Benefits of these materials include high magnetic anisotropy, short read/write wavelengths and high coercivity. However, there is a need for the development of high speed, high resolution, low cost and reliable data storage devices. In this study, we have investigated the magnetic properties of Fe-Pt nanoparticles with different particle sizes, and their potential for use as magnetic recording media.

FS3.15
Critical Thickness Issue in Magnetic-MgO Heteroepitaxy.
Sri Madhumita Aretia, R. G. S. Sufian and Igor V Stava.
SFI Nanoelectronics Research Laboratory, Trinity College,
Dublin-2, Dublin, Ireland.

Epitaxial thin films of magnetic (FePt) have recently attracted considerable attention as magnetic is an important material for spin electronics applications due to its half metallic nature, high Curie temperature and metastable transition at 120K (Verwey Transition). There are several reports on the growth of magnetic films on a variety of substrates. MgO is an ideal template for epitaxy of magnetic because of the small lattice mismatch (0.3%). Understanding of the critical thickness behaviour in FePt/MgO heteroepitaxy is a key issue to realize nanoscale devices based on magnetic. Here, we report on a systematic investigation of strain status in FePt/MgO epitaxial thin films. The magnetic films were grown on (100) oriented MgO single crystal substrates using oxygen plasma enhanced molecular beam epitaxy (MBE). The structural characterization of the FePt/MgO films was done via high resolution x-ray diffraction Reciprocal Space Maps (RSM). The RSM was performed for the non specular Bragg reflections (022/111) which are common to both the substrate and film. 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 0.42129nm and 0.41860nm respectively. The in-plane lattice parameter of the film (half of the planar 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 70nm. This thickness is much larger than the predicted values of critical thickness (~15nm) from conventional models based on misfit strain [1]. A comparison with theoretical predictions of the relaxation behaviour of magnetic on MgO will be made and a new model based on critical thickness value will be proposed.


FS3.16
Electrodeposition of Ceramic Ferrite Nano particles for Micromagnetic Applications. Cody Michael Wamburu1, Teja
Jhaveri2, Michael Clement2 and Santosh K Kurinc2.
1Microelectronics Engineering, Rochester Institute of Technology,

In recent years there has been growing interest in the use of micro magnetic components directly onto semiconductor substrates and the integration of magnetic components with other components. In this case, 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 with chips and wireless devices. In this study, the application of electrochemical deposition for depositing oxide magnetic material has been investigated. Electrochemical (EC) is a process by which charged particles suspended in a solution are made to migrate by an electric field and then used to construct structures. The magnetic material used for this study is a low coercivity soft ferrite, magnetite oxide ferrite [Mn2Zn1.8Fe2O4] with initial permeability ranging from 5,000-10,000 for applications in micro inductors, micro transformers, and other magnetic devices.

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

8:30 AM  **FF4.1**
Ferroelectric Field Effect Modulation of Magnetism in the Colossal Magnetoresistance Oxide La$_2$Sr$_{0.1}$MnO$_3$. Xin Hong,
Agham-Hayam Poudel, Andrew Lin and Charles Alan, Applied
Physics, Yale University, New Haven, Connecticut.

The correllated properties of complex oxides such as the colossal magnetoresistance oxide (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 Pt/Co/Pt (PZT), we have modulated the magnetic properties of La$_2$Sr$_{0.1}$MnO$_3$ (LMO). Epitaxial ferroelectric PZT/LMO 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 induced a reversible shift in the Curie temperature of the LMO layer and also results in a change in the magnetic properties. For samples close to the metal-insulator transition, reversable switching between metallic and insulating behavior is observed. This approach allows one to...
investigate the role of change in the CMR effect without introducing chemical or structural disorder.

9:00 AM FF4.2
Fabrication and Properties of Nanoscale Magnetic Oxide Multilayers and Superlattices, Land Belenky1, Xinling Ke2, Yantin Chen1, Mark Rachowski1, Xiaoying Pan3 and Chung-Beom Eom1,2,3,1Material Science and Engineering, University of Wisconsin-Madison, Madison, Wisconsin; 2Physics, University of Wisconsin-Madison, Madison, Wisconsin; 3Materials Science and Engineering, University of Michigan, Ann Arbor, Michigan.

Interfacial and reduced-dimensional effects in magnetic and electronic heterostructures are of great technological and scientific interest. We have fabricated and characterized nanoscale epitaxial magnetic oxide heterostructures, multilayers and superlattices based on ruthenates and manganites with atomic-layer control by pulsed laser deposition with in-situ, high-pressure RHEED. Structural characterization through structural, surface 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
Nanoscale characterization of the ultra thin (La,Ba)MnO3 film with room temperature ferromagnetism and their device application, Hidetaka Tanaka1,2, Teruo Kasai1, Takuya Matsumoto3 and Tomoji Kawai3, 1ISRI-Sankai, Osaka University, Hario, Osaka, Japan; 2PRESTO, Japan Science and Technology Corporation, Saitama, Japan.

We have fabricated La-Ba 3MnO3 thin films with atomically flat surface on a Si(100) 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 300 K at room temperature. In addition, we have enhanced 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 (300K) of the (La,Ba)MnO3 film was visualized. No magnetic domains existed above the TC. Only an atomically flat terrace with one unit cell step of the LBM O surface can be confirmed. With decreasing temperature, the magnetic domains with 20 nm width appearing at the first terrace structure in the TC. Furthermore, the magnetic domains grow up to 200 nm at 300 K with cooling. By using the NC-MFM system, the appearance of room temperature ferromagnetism at the nanoscale level was confirmed in 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 heterostructure of the ultra thin (La,Ba)MnO3 and ferroelectric (or semiconductor) thin films.

9:30 AM FF4.4
Huge Resistance Change in La0.5Ca0.5MnO3/PhZr2Tio4/Fe3O4 Multilayers On Si Under Small Electric and Magnetic Fields, Ting Zhao1, 2Sh Ogaki2, Ramesh1, Y Xu1, R Droop1, K Eisenbeiser1, M Zhu1, T Egami1 and J Mischew1, 1Materials Research Science & Engineering Center, Univ. of Maryland, College Park, Maryland; 2Physical Sciences Research Laboratories, Motorola Labs, Tempe, Arizona; 3Univ. of Pennsylvania, Philadelphia, Pennsylvania; 4Brookhaven National Laboratory, Upton, New York.

Giant Magnetoresistance (GMR) magnetism displays a rich variety of phenomena attributed to the unique coupling of spin, charge, orbital, and lattice degrees of freedom and the attendant multiferroic 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 a combination of highly biaxial strain studied by application of a significantly higher biaxial strain than examined before, by growing an appropriate La0.5Ca0.5MnO3/PhZr2Tio4/Fe3O4 multilayer on SrTiO3 (STO) buffered silicon. Since we can achieve a 1.5% strain in Fe3O4 and 1.2% strain in STO and LCMO (La0.5Ca0.5MnO3/PhZr2Tio4), 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 LCMO. A huge change in resistance (100%) was induced in such configurations by application of small electric (4x10^4 V/cm) and magnetic (about 1000 Oe) fields. We will discuss the possible intrinsic and extrinsic contributions to the observed electric field effects.

9:45 AM FF4.5
Influence of annealing on lattice constant and magnetic properties of epitaxial Fe3O4 (100) films, Ying Zhou, Xuesong Jin, S K Arora and Igor Shvets, SF Lab, Dept. of Physics, Trinity College, Dublin, Ireland.

Single crystalline epitaxial Fe3O4 (100) thin films have been grown on MgO (001) using oxygen-plasmas-assisted molecular beam epitaxy. The nanodeposited films are fully strained which is confirmed by High Resolution X-ray Diffractionmetry (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-situ 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 of ferroelectric/ferromagnetic BiTa3.3CoFeO4 thin films. Haimi Zheng1, Junling Wang1, Vahnamour Ganjerjan2, Jian Ouyang1, Lourdes Salamancab-Hin2, Ramamooty Ramesh1, Wei Tian2, Xiaoying Pan3 and Sunino E. Lollond3, 1Materials Sci. & Eng., University of Maryland, College Park, College Park, Maryland; 2Materials Sci. & Eng., University of Michigan, Ann Arbor, Michigan; 3Physics, Rowan University, Glassboro, New Jersey.

Ferroelectric/ferromagnetic nano-composite BiTa3.3CoFeO4 thin films were successfully deposited on single-crystal MgO (001) and SrTiO3 (001) substrates by pulsed laser deposition (PLD) from a single BiTa3.3CoFeO4-Fe oxide target. The spinel CoFe2O4 and peroxytite BiTaO3 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 BiTaO3 matrix. The shape and the degree of ordering of CoFe2O4 pillars are studied by varying the growth rate, film thickness and substrate topography. Varying substrate 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 strain and the shape of CoFe2O4 pillars 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 BiTaO3 phase. The coupling between the piezomagnetic phase of CoFe2O4 and piezoelectric phase of BiTaO3 is discussed in this paper. This work is supported by the NSF/MRSEC under contract No. DMR-0648008.

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

Magnetic oxide materials exhibit a wide range of electronic properties with 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 PbSrMnO3. 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 micrometer and nanoscale and current-perpendicular-to-plane magnetotransport measurements. We will discuss magnetic and magnetotransport measurements of exchange-bias bilayers, GMR multilayers, and magnetic tunnel junctions.
11:00 AM FF4.5
Spin-polarized quasiparticles injection in 
La$_2$Sr$_3$MnO$_{6-δ}$/SrTiO$_3$/Nb heterostructure devices, 
L. Fratila$^1$, I. Maurin$^1$, C. Dubardieu$^1$ and J.C. Villégier$^1$; 
$^1$Laboratoire des Matériaux et du Genie Physique - INPG-CNRS, 
Saint Martin d'Hères, France; $^2$LCF-DRFMC/SPSMS-CEA, 
Grenoble, France.

The effect of spin-polarized quasiparticles injection from a ferromagnetic electrode into a conventional superconductor was investigated in La$_2$Sr$_3$MnO$_{6-δ}$/SrTiO$_3$/Nb heterostructures. The ferromagnetic La$_2$Sr$_3$MnO$_{6-δ}$/SrTiO$_3$ thin barrier (38 nm) and the SrTiO$_3$ substrate were grown epitaxially by pulsed- ..

SESSION FF5: Magnetoresistance/Spintronics
Chair: Leonid Levchuk
Tuesday, December 2, 2003
Commonwealth (Sheraton)

1:30 PM #FF5.1
Magnetoresponse by Injection and Transfer of Spin: 
Experiments and Theory, Albert Ferré$^1$, Pierre Boulin$^1$, Vincent 
Cros$^1$, Jean-Marie George$^1$, Julie Grollier$^1$, Henri Jaffrezic$^1$, 
Giancarlo Fami$^2$ and Amir Hranitzky$^2$; $^1$Université Paris XI, 
France; $^2$Physics Department, University of Zagreb, Zagreb, Croatia; 
$^3$Laboratoire de Photocéramique et 
Nonlinearities, CNRS, Marne-la-Vallée, France.

Słonczewski (and also Berger) predicted in 1995 that the magnetoresistance 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 have been put forward to understand 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 approach, we used the current-induced magnetic 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 experimental data on palladium devices. The model is based on a self-consistently calculated theory of the longitudinal and transverse parts of the spin current throughout the multilayer structure in the limit of quasiperiodic interlayer spin transfer. Theoretical results on magnetic layers are derived from the transverse component of the spin current injected into each layer. I will compare our results for the trilayer 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 palladium 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 perpendicular layer of the SV. This current-induced magnetic switching requires smaller current densities than the magnetization reversal in palladium and is therefore promising for applications.

2:00 PM FF5.2
Current-Driven Magnetization Dynamics at High Magnetic Fields in Co/Cu/Co Nanopillars, Barbare Oezyilmaz$^1$, Mariano 
Zimmer$^2$, Andrew D Kent$^3$, Jonathan Z Sun$^4$, Michael J Rooks$^5$ and 
Roger H Koch$^6$; $^1$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 been shown to have different effects in magnetic nanostructures. We have studied spin-transfer torques in the same field perpendicular configuration in both Co/Cu/Co and 
Cu/Cu/Co pillar devices at 4.2 K and 300 K. In this geometry for fields greater than the demagnetizing field field 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-mask metal process, which enables the production of large arrays of templates ideal for systematic variation of thickness and composition of the magnetic and nonmagnetic layers Co/Cu. Our spin-transfer torque (STT) measurements in large magnetic fields (>15T) 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 

2:15 PM FF5.3
Energy Deposition Effects on Giant Magnetoresistance 
Spin-Valve Multilayer Materials, David Zox, Romney Katti, 
Daniel S. Reed, Gordy A. Shaw and Hasan Kaskanli; 
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 is of increased interest for 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 deposition energy was increased, SV material sheet resistance increased and SV GMR coefficient decreased, while switching field (Hc), remanency field (Hr), and exchange field (Hex) 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 deposition energy was induced within a single film and did not require intermixing or 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 permeability is attributed to the increased scattering 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 Svet; SFI Lab, Dept. of 
Physics, Trinity College, Dublin, Ireland.

(5 nm) Cr/[x nm] MgO/[30 nm] magnetic (Fe$_3$O$_4$)/ 
MgO (100) substrate [1≤x≤5 nm], as well as (5 nm) Cr/[5 nm] MgO/MgO 

(5 nm) Cr/[x nm] MgO/[30 nm] magnetic (Fe$_3$O$_4$)/ 
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 measurements. The influence of the magnetic 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 noticeable decrease is observed on the R(T) curve when the MgO layer thickness \( T_{\text{MgO}} \) is less than 3 nm. This results from the electrical coupling between the Cr film and magnetostatic layer through the pinholes in the MgO layer. The MR of the Cr film in the Cr/MgO/magnetic structure shown is a reversal of the sign of the MR Cr film in a Cr/MgO/MgO structure. This reversal of the MR sign was observed even when \( T_{\text{MgO}} \) 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 disturbed by the exchange coupling. Such areas in the Cr film are thought to contribute to the negative MR.

2:45 PM FFS 5
Accurate and realistic ab initio theory of spin-dependent interfacial scattering. Ivan Dzyaloshinskii and Tomasz Ariez; Physics, Cornell University, Ithaca, New York.

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

3:30 PM FFS 6
Increased Gilbert Damping in Spin-valve and Magnetic Tunnel Junction Devices. Lisbeth Larsen1,2, Waister Eyckmann1,2, Roel Wijn1,3,4,5,6, G. Hennig7,8,9,10,11,12, and J. De Boeck1,2,3,4,5,6, IMEC, Leuven, Belgium; 2ESAT/KA/LEUEN, Leuven, Belgium.

The Gilbert damping parameter \( \alpha \) 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 \( \alpha \). We systematically study \( \alpha \) in \( \text{NiFe}_{20} \) 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 Gaussian pulses. From these experiments three major conclusions are drawn: 1) The Gilbert damping parameter is strongly enhanced over the bulk value in ferromagnetic \( \text{NiFe}_{20} \) films thinner than 10 nm 2) The Gilbert damping parameter in thin film \( \text{NiFe}_{20} \) (5 nm) is increased when adding Ta and Cu as a seed or capping layer and modeling the data using Tserkovnikov’s model 3) Results in reasonable scattering parameter values of 0.29 for Ta and 0.09 for Cu. 3) The non-locality of spin transfer is proven by the observed \( \alpha \) for a \( \text{NiFe}_{20} \) (5nm)/Cu/2nm/Ta(5nm) layer stack with no direct interface between Ta and \( \text{NiFe}_{20} \).

4:00 PM FFS 8
Ferromagnetic Interactions in Manganese doped Cadmium Selenide Nanodot Particles. Donny Stromberg 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 Mn-doped II-VI materials, where magnetic, antiferromagnetic, and spin glass behavior has been observed. Although the ferromagnetic behavior arises in metal-doped quantum dot, by coupling to vacancies and intrinsic charge carriers. Manganese doped Cadmium Selenide has been 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 is due to a pinning effect in the intrinsic environment.

4:15 PM FFS 8
Half-metallic ferromagnetism and structural stability of zinblende phases of transition-metal pnictides and chalcogenides. Bang-Gui Liu1, Le-Bao Xie1, Yong-Qiong Xu2, and Daidu G Pettifer3; 1Institute of Physics, Chinese Academy of Sciences, Beijing, China; 2Department of Materials, University of Oxford, Oxford, United Kingdom.

Half-metallic ferromagnets, especially those that 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 temperatures. Although zinblende phases of MnAs, CrAs and CrSb have been fabricated as epitaxial monolayers or ultrathin films, it has been not possible to grow the zinblende 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 is highly desirable. We predict that the zinblende phases of MnP and CrSb are excellent half-metallic ferromagnets by using accurate density-functional method. Furthermore, we studied systematically all zinblende phases of transition-metal pnictides and chalcogenides, and hereby found the zinblende phases of FeP, CoP and CrP 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 Pettifer, Phys. Rev. B 86, 184435 (2012). [2] B-G Liu, Phys. Rev. B 67, 172411 (2003). [3] W-H Xie, Y-Q Xu, B-G Liu, and D G Pettifer, Phys Rev Lett. (accepted 2003).

4:30 PM FFS 10
Fabrication and controlled magnetic properties of Ni/ZnO nanorod heterostructures. Sang Wook Jung1, Gyu-Chul Yi3 and Miyoung Kim2; 1Materials Science and Engineering, POSTECH, Pohang, Kyungbuk, South Korea; 2Samsung 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 offers new functionality in memory devices, detectors, and light-emitting sources. Hence, fabrication of magnetic-semiconductor nanorod heterostructures.
heterostructures is of particular interest in nanoscale spintronics. Controlled growth of nanoscale magnetic layers on a single nanorod would enable high-speed data processing as magnetic materials. Before magnetic material is 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/2D heptacene nanoscale 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. Aided by Park et al. The synthesis of ZnO nanorods by MOVPE results in a preferentially oriented nanorod growth direction along the c-axis of ZnO, normal to the substrate surface. Since no metal nanoparticles were employed as a catalyst, no metal nanoscale clusters are observed on the tips of the nanorods. Using this method, several magnetic nanorod heterostructures including Fe, Co, Ni, and NiFe were easily fabricated on vertically-aligned ZnO nanorods. Furthermore, we investigated magnetic properties of Ni/Fe-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
Chair: 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.
Hyunjoo Shin, Ayakashi Manoami, and Mahinder 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 Ms is measured against temperature T from 5 K to 350 K in magnetic field H up to ±5 K Oe. 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 case at T = 210, 185, 134, 142 and 158 K for the D = 5.1, 7.0, 8.1, 11.8 and 15.8 nm respectively. This anomaly of M vs. D can be understood if nanosize increases rapidly with decrease in D, perhaps due to increase in surface anisotropy. For T > Tm, M varies approximately as 1/D as reported by others [1], and M vs H at different T is shown as expected behavior of (M vs. H) expected for superparamagnetic. However, there are several deviations from the Langevin behavior (possibly due to anisotropy) with macroscopic magnetic moment M = 5000 µemu/particle. For T < Tm, large coercive force exchange bias field Hc are observed, dependent on D. These results will be discussed in terms of multiaxial anisotropy of magnetic materials in nanoparticles of NiFe for D ≤ 10 nm reported recently [2]. [1] Work supported by the U.S. Air Force Office of Scientific Research [2]. Richardson et al., J. Appl. Phys. 20, 9877 (1991); Mikolajczyk et al., J. Appl. Phys. 81, 5561 (1997); [3] R. H. Kodama and A. E. Berkowitz, Phys. Rev. B 59, 3031 (1999).

8:30 AM #FF6.2
Magnetic Spectacles From Nanostructures.
Karine Chesnel1, M. Belkhayou2, G. van der Laan2, G. Bessiere2, A. Marty2 and F. Livet3
1ALS, LBL, Berkeley, California; 2DRFMC, CEA-Grenoble, Grenoble, France; 3RSS, Daresbury, United Kingdom; 4LTPCM, Saint Martin d’A, France.

The recent development of Resonant Magnetic Scattering (XRS) in the soft X-ray range provides increasing opportunities to study magnetic order and magnetic domains in nanoscale, 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 nanoscale scale. Moreover, the use of coherently high and 2D detection techniques remarkable small patterns that are related to the local magnetic topology. Magnetic spectacles have been recorded in a reflection geometry on two types of systems with perpendicular magnetic anisotropy: thin epitaxial Fe/Pd films with well-defined lines gaps covered by Co/Pt multilayer [2]. The resulted images from Fe/Pd layers exhibit magnetic spectacles with a strong contrast intensity, 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 reconstructions of the magnetic domains. Indeed, in Co/Pt independent of Co/Pt, the scattering pattern presents a series of sharp peaks related to the grating periodicity. In some specific demagnetized state, remarkable magnetic satellites appear in between the structural peaks, evidencing a magnetic texture to antiferromagnetic order [2]. This source 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 switching and switching mechanisms. In comparison, 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 et al., Science 284, 2166 (1999) [2] K Chesnel et al., Phys. Rev. B 66, 204445 (2002) [3] K Chesnel et al., Phys. Rev. B 66, 174404 (2002)

9:00 AM FF6.3
Unusual Magnetic Anisotropy of Monatom Magnetic Co-wire at the Pt(111) Surface: Step-Edge. Peter Oppeneer1, Alexander B. Shick2 and Prasanta Mohanty2
1Leibniz Institute for Solid State and Materials Research, Dresden, Germany; 2Institute of Physics, Prague, Czech Republic.

Recently, a very unusual magnetic behavior was reported by Gnanadella et al. [1] for monatomic Co-wires grown on the Pt(997) step-edge. The easy magnetization axis was found to rotate away from the step normal, pointing towards the step edge. In angle resolved photoemission measurements [2], an enhancement of the Co 3d orbital magnetic moment Mr ~ 0.7 µB as compared to the Co bulk Mr value of 0.14 µB 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 magnetic Crystalline anisotropy energy (MAE) and orbital magnetic moment Mr for simple super-cells modeling the Co-wire on the Pt-step-edge. We find that the lowering of magnetic symmetry permits the non-collinear 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) for the configuration in the plane perpendicular to the step-edge 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:Mr (~0.3-0.5 µB, depending on the choice of Co-atom and the size of the super-cell), which is still somewhat smaller than observed in the experiment. Finally, we relate our computed MAE and Mr results to the microscopic features of the Co-wire electronic structure. [1] P. Gnanadella et al., Nature 416, 301 (2002).

9:15 AM FF6.4

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-magnetized nanomagnetic nanoparticle films [1]. Magnetic nanowire array buried in self-organized porous alumina nanohole 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 alumina was sputtered on Si, and two steps modification of Al2O3 [2] was carried out at the mode value of 20 V with 0.15 M sulfuric acid. Finally Co wires of 30nm in diameter with various heights from 20 to 500nm were electroplated with AC current of 1 kHz. We evaluated aspect ratio (AR, a ratio of height to diameter) dependence of M-H hysteresis 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. However, Hc rapidly increased to Co/M as 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[001] axis (i.e., the direction perpendicular to the substrate) axis was rather perpendicular. We also carried out micro magnetic simulation based on LLG equation for M-H property of a single Co wire with various aspect ratios, and these results suggest that magnetic anisotropy is different from the perpendicular axis against substrate plane. The Hc increases critically when Co wire aspect ratio

9:30 AM FF6.5
FMRI Study of Square Arrays of Thin-Film Permalloy Rings of Variable Inner Diameter. Lieu Er Eric De Long1, Dylan Byron Watkins1, Wenwei Xu2, John D. Ketterson1, Venkat Chandrashekhar1, and V. V. Varadan3, 1Physics and Astronomy, University of Kentucky, Lexington, Kentucky; 2Physics and Astronomy, Northwestern University, Evanston, Illinois; 3Electrical 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 spin-ferromagnetic resonance (FMRI) spectra of square arrays of permalloy rings of thickness 35 nm, spacing s = 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 presented 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 $10^{-11}$ A/m Hz/s² has been obtained by a moderate gain of the 2DEG. With this improved sensitivity we performed magnetostatic 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/c=15 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 nanoarches, as well as various theoretical models. The work was supported by NSF-DMR grant #0072356 and DARPA through ONR grants N-00014-94-1-0964 and MDA-972-02-1-0002.

10:15 AM *FF6.7
MRS MEDAL AWARD TALK PRESENTATION
Exchange Biased Nanostructures. Ivan K. Schuller1, Igor V. Roshchin1, J. Ekenenmayer2,1, O. Petrenko1, ZP Li2, CL Li2, M Viret2 and K Liu3, 1Physics Department, University of California, San Diego, La Jolla, California; 2Abteilung Festkörperphysik, Universitats-Ulm, Ulm, Germany; 3Physics Department, University of California, Davis, Davis, California.

Magnetic nanostructures are receiving increasing attention in recent years, mainly because of the interesting phenomenon of exchange bias which 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 novel phenomena arise; the reversal mode of the ferromagnet changes considerably, the superparamagnetic transition temperature is affected and there is a noticeable change in the macroscopic 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 AFSOR, 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. Leondard Spinal1, Cosmin Radu1, Alexandru Stancu2, Yukiko Kubota3, Gheorghe Ia2 and Dieter Weller3, 1AMRI & Physics, University of New Orleans, New Orleans, LA; 2Physics, Al. I. Cuza University, Iasi, Romania; 3Siagnetic Research, Pittsburgh, Pennsylvania.

As discovered in 1957 by Meikjohn 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 potential to grant for high-density magnetic 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, in susceptibility, ferromagnetic resonance and Brillouin 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/A阜 coupled systems and allows a proper decomposition of EA from the experimentally measured TS signal. The TS signal was measured using a sensitive method based on a tunnelling magnetoresistance technique [3]. The materials considered in our study is a IrMn 12 nm / FeCo 50 nm multilayer with Cu 4 nm seedlayer deposited on a glass substrate [4]. The sample was fabricated with a commercial dcasc magnetic field system, University of M12 [1]. W.H. Meikjohn and D. Weller, "Spin Structure of a Ni / Cu / Ni Film," Phys. Rev. B, 102 (1957) 1413. [2] H. Xi et al., Phys. Rev. B, 60 (1999) 14837. [3] L. Spini et al., IEEE Trans. Mag., 37 (2001) 2188. [4] H.S. Jung and W.D. Doyle, IEEE Trans. Mag., 39, 679 (2003).

11:00 AM FF6.9

Spatter deposited, Ni-Mn thin films used in giant magnetoresistive (GMR) spin valves are found to not 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 LiO phase. The LiO phase is the thermodynamically stable configuration, but favorable kinetics for the transformation were only found above 300°C. The amorphous to ferromagnetic LiO phase transformation was studied by X-ray diffraction, transmission electron microscopy (TEM), and differential scanning calorimetry (DSC). The nucleation and growth conditions were determined and an exothermic transformation enthalpy of 7.24 kJ/mol of atoms was determined.

11:15 AM FF6.10
Ultrathin Fe Films on the Vicinal Pt(001) Surface: The Role of Steps for Growth and Magnetic Properties. Tseyon Lee1, Axel Enders1, Klaua Kuhnke1, Diego Repetto1, Jan Honold1, Cesare Grassi2, S. R. Krishnamurthy3, Marco Veronesi4, Carlo Carbone1 and Klaus Kern4, 1Max-Planck-Institute for Solid State Research, Stuttgart, Germany; 2Institute of Structure of the Matter, National Research Council, Trieste, Italy; 3International Center for Theoretical Physics, Trieste, Italy.

A stepped Pt(001) substrate is employed in 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(001) under ultrahigh vacuum are investigated by thermal desorption spectroscopy (TDS), 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, on Fe wedge films of 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 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.

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 inhomogeneous 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].

SESSION FF7: Magnetic Clusters and Molecular Magnets

Chair: Marcus Grismitch Wednesday Afternoon, December 3, 2018

1:30 PM *EFF.1 Magnetic Phase of Nanostructured Metallic Particles, J. Escrig, P. Landrovo, D. Larrea, D. Abkic, J. D. Albuquerque e Castro, P. Vargas, and A. Mendez. Universidad Tecnica Federico Santa Maria, Valparaíso, Region Metropolitana, Chile; *Physics Dept. Universidad Tecnica Federico Santa Maria, Valparaíso, Region Metropolitana, Chile; *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 present work is defining 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 *EFF.2 Magnetization Reversal In Patterned Magnetic...
magnetism in the framework of the pair model that was proposed by Neel to characterize surface magnetism. This model, although partly phenomenological, can help us understand the nature of spins and the effects due to incomplete shells of atoms. We will present calculations based on numerical simulations of the structure of relaxed isospectral cobalt clusters and compare the results with magnetization measurements on deposited clusters.

3:30 PM FF7.5
Jason Thomas Harland, Janine Musfeldt, and Ted Barns.1,2
1Department of Physics and Astronomy, University of Tennessee, Knoxville, Tennessee 37996-1200; 2Department of Chemistry, University of Tennessee, Knoxville, Tennessee.

Using a new neighbor antiferromagnetic exchange Hamiltonian, 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.
Moming Sircar,1 Lucian Constantin Danîescu2, and Mihaela Valanu1.
1Physics, Duquesne University, Pittsburgh, Pennsylvania; 2Materials 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 a series of nanocomposites of cobalt substituted spring magnets: Nd11Fe80.6Co2.5Si8 annealed for 3 min at 650, 700, 750 C, Nd10.5Fe78.4Co5Si3.8 annealed for 3 min at 650, 700, 750, and 775 C, and Nd10Fe76.5Co7.5Si5.6 annealed for 3 min at 650, 700, and 750 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 increasing 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 magnetic field with decreasing 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 Fullerenol Nanomaterial. Frank J. Owens,2 Zafar Iqbal2, Lyubov Belya3, and K.V. Rao3.
1Army Research & Engineering Center, Picatinny, New Jersey; 2Chemistry and Environmental Science, New Jersey Institute of Technology, Newark, New Jersey; 3Materials 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 298K, 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 Ramam data and molecular orbital calculations, will be discussed. Properties of inkjet 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. Janine L. Musfeldt,1 Jongwoo Choi, Roman Wosikowski, Andrei Sankov, Scott Oppenheimer, Randy Ashby, Mihail North, Nareesh Dalal, Arkady Eller, and Paul Kögler.1,2 Chemistry, University of Tennessee, Knoxville, Tennessee, 3Chemistry, Florida State University, Tallahassee, Florida.

Using a new neighbor antiferromagnetic exchange Hamiltonian, 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.

SESSION FF8: High Anisotropy Magnetic Nanostructures
Chair: 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. Toney2, Simone Racco3 and Shooung Sun,4 Hitachi San Jose Research Center, San Jose, California; 2Stanford Synchrotron Radiation Laboratory, SLAC, Menlo Park, California; 3IBM Almaden Research Center, San Jose, California; 4IBM TJ Watson Research Center, Yorktown Heights, New York.

Self-assembled FePt nanoparticles with diameters of 4 nm and a narrow size distribution σ < 5% are currently attracting considerable attention as potential data storage media [1-3]. It is well known that Co-deposited, FePt particles are not in the required chemically ordered, high anisotropy L10 phase and that annealing at T > 500°C is required to achieve L10 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 2.2nm. Upon annealing the particle size and magnetic moment increase significantly. Coercivity increases with annealing temperature from Hc = 2 kOe for annealing conditions of 300°C/30min to 26.2 kOe for 800°C/3mins. We conclude that a single mode of FePt nanoparticle arrays where annealing simply helps the formation of the L10 phase. While previous work on the disorder from the ordered phase to the ordered L10 phase does not describe all the thermodynamic processes. We present a model which provides a more complete description of the ordering process. [1] S. Sun, C.B. Murray, D. Weller, L. Eksa, A. Mozer, Science 287, 1989, [2] S. Sun, S. Anders, H.F. Himmel, J-U. Thiele, J.E. Baglin, T.Thomson, E.E. Fullerton, C.B. Murray, B.D. Terris, J. Am. Chem. Soc. 124, 3884, (2002)

8:30 AM FF8.2

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 determine suitable parameters for the design. The model is also supported by simulations of the self-organisation process, from which it follows that the nature of the interparticle interaction potential is obtained. A model of the intrinsic properties of FePt particles at the atomicistic level has also been developed, which correctly predicts the temperature variation of anisotropy and gives atomistic calculations of the magnetization reversal process, which shows the reversal mechanism to be non-uniform even for particle sizes as small...
9:00 AM FFS.3
Structural study of epitaxial L10 Ru-Pt magnetic thin films sputtered on Cu (001). Cheng-Jun Xin,1,2,4, Guang-Moog Chow1 and Jian-Ping Wang,2 1Department of Materials Science, National University of Singapore, Singapore, Singapore; 2Data Storage Institute, Singapore University of Electronic and Computer Engineering, The Center for Micromagnetics and Information Technologies (MINT), University of Minnesota, Minneapolis, Minnesota.


9:15 AM FFS.4
Oriented FePt Nanoparticles for Perpendicular Magnetic Recording, Zheng-Zhang Zhang, Takco Suzuki and Kyonghun Kang, ISMI, Toyota Technological Institute, Nagaoya, 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 nanoparticles 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/cm 3. 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 by co-sputtering the three deposition materials 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 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 9-10 11 erg/cm 3 by using well optimized film stack structure and annealing condition, double-layered perpendicular magnetic recording disk were prepared, where 400 nm FeCu film serves as a magnetic soft underlayer (SUL) and FePt/Ag or FePt/MgO bimodal layers as a magnetic recording layer. In order to magnetically decouple the SUL and recording layer and to induce the (001) texture in FePt films, the combined SO 2/MgO intermediate layers were employed. The disk recording property evaluation will also be presented.

9:30 AM FFS.5
Microscopic characterization of the degree of L12 order in FePt nanoparticles from the gas-phase, Bernd Rellinghaus,1 Olga Dmitrieva2 and Sonja Stuppert,2 1Institute of Combustion and Gasdynamics, University of Duisburg-Essen, Duisburg, Germany; 2Experimental Physics, AG Parke, University of Duisburg-Essen, Duisburg, Germany.

FePt 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 ≤ p ≤ 2 mbar and 298 K ≤ T ≤ 1273 K, respectively, in order to control the morphology and the crystal structure of the particles. High resolution transmission electron microscopy (HRTEM) shows that for FePt 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 L12 ordered face-centered tetragonal (fct) phase with increasing sintering temperature. Concurrently, the magnetic properties of the particles change from superparamagnetic to ferromagnetically blocked at room temperature (RT). However, the maximum measured coercive field of Hc(001) = 1.2 kOe and the maximum effective anisotropy constant of K_eff = 8·10 6 J/m 3 which are obtained for particles that have been sintered at the highest sintering temperatures of T_s = 1273 K is much higher than what is expected for fcc FePt. Furthermore, electron diffraction does hardly provide any evidence for the occurrence of the L12 superstructure. In order to characterize both the number of ordered particles and the degree of L12 order, spatially HRTEM studies and HREM simulations were performed. From these investigations, the fraction of ordered particles and their degree of order are determined to be 0.30 ≤ p ≤ 0.44 and 0.3 ≤ S ≤ 0.76, respectively. From this, the volume averaged order parameter p_S of the FePt L12 ensemble is determined to be 0.09 ≤ S ≤ 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 agreement with data for fct FePt reported in the literature. [1] S. Stuppert, B. Rellinghaus, M. Aetz, and E.F. Wassermann, J. Cryst. Growth 252 (2003) 444-450. [2] B. Rellinghaus, S. Stuppert, M. Aetz, 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 FFS.6
Magnetization Reversal in FePt Thin-Film Composites, David J. Sellmyer,1-4 Minglong Yan,1-4, Yingfan Xu,1-4, Arti Kulkarni1,2, Renat F. Shuiskyov1-2,1 and Ralph Skomski1,2 1Department of Physics and Astronomy, Univ. of Nebraska, Lincoln, Nebraska; 2Ctr Mnd Res & Ann, Univ. of Nebraska, Lincoln, Nebraska.

Particularly, FePt-based thin films for high-density magnetic recording are investigated experimentally and by theoretical calculations. The key question is how the real structural 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 Cu and Ag, and having 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 kinds of the hysteresis loop shape is dependent on the interaction between the magnetic grains increases through the matrix [3] or due to direct contact. As a consequence, the reversal mechanism changes from a local magnetic moment, 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 regime dependent threshold of the order of 0.1 KV, where the regime and the place 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 simulation code. A special feature of the hysteresis loop shape change not only on the packing fraction but also on the symmetry of the packing. For example, particles forming a square lattice yield smaller parameters in thin triangular lattices with equal net exchange per particle. This work is

10:30 AM FFS.7

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 ordering order determines the transformation. Magnetic ordering perpendicularly to the film plane was achieved, promoting the initial weak magnetic anisotropy to the highest values known for FePd films. Applications to ultrahigh density magnetic recording are suggested.

11:15 AM FFS.10
Nanocomposite Films of High K Magnetic Materials Prepared By Pulsed Filtered Vacuum Arc Deposition. Y. Yang, M. F. Bathias, S. C. Kim, C. Young, M. Li, Q.-Y. Ge, H. Chen, X. Li, Y. Zhang, and S.P. Wong. 1Electronic Engineering, Chinese University of Hong Kong, Shatin, Hong Kong; Physics, Chinese University of Hong Kong, Shatin, Hong Kong; Materials Science & Technology Research Center, Chinese University of Hong Kong, Shatin, Hong Kong.

Nanocomposite films consisting of high K magnetic grains embedded in non-magnetic matrices are of great interest for their potential applications in 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 well defined 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 a novel sample magnetometry. The temperature-time profile of the RTA process consisted of three regions, namely, a transient overheat region in the first 4-5 s for temperatures of 200°C to 400°C, 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 overheat 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_2 phase CoPt and FePt nanograins after appropriate annealing. For example, for the film with a particular composition of Fe_{50}Pt_{50}Co_{12}, the L1_2 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: CUHK071208E).

11:30 AM FFS.11

The effective spin Hamiltonian for 3d-5d (FePt, CoPt) bimetallic nanoparticles layered ferro-magnets have been investigated on the basis of the first-principles calculations for non-capture configurations [1] and site reached magnetic microcrystalline 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_{nm} and out of the 3d atom layers J_{nm}. For example, for the FePt the exchange length in the <001> direction (\xi_{\perp}) was found to be five times smaller than the <110> direction (\xi_{\parallel}), and it has been demonstrated that electronic degrees of freedom of the Pt can be effectively described within the Stoner model with intrinsic 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 anisotropy exchange and additional ferromagnetic isotropic exchange. The strength of this effective anisotropic exchange is found to be dependent on the Stoner parameter on the Pt site and via the value of the induced 5d/4d magnetic moment (for the FePt m_{5d} is about 0.36\mu B), the interaction parameter J_{\perp} which is about 2 meV for the FePt and the single-ion anisotropy D^{(1)} which is estimated to be about 1.6 meV. The investigation of the spin-orbit 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 ferromagnetism 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, 12930 (1992); [2] A. B. Shick and O. N. Mryasov, PRB. v. 67, 172407 (2003)

11:45 A.M. EPS 12
Composition Control of CoPt Nanoparticles by Chemical Reduction. Hongli Wang1, Yong Zhang1, Yuwen Zhao1, Michael John Borden1, Yunhe Huang2 and George Hadjipanayis1. 1Department of Physics, University of Delaware, Newark, Delaware; 2Center for Materials for Information Technology (Mint). The University of Alabama, Tuscaloosa, Alabama.

Recent interest in magnetic nanoparticles has been focused on ultrahigh 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 fct 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 992035 (1) Shouheng Sun et al. J. Phys. Chem. B 2003, 107, 5419-5425 To whom correspondence should be addressed. Email: hlwang@udel.edu