SYMPOSIUM U
Ferromagnetic Materials
April 17 – 20, 2001

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magnetic features and present high mechanical strength and hardness. Ferromagnetic resonance (FMR) investigations on some amorphous magnetic ribbons (Fe, Mo) were performed using a JES-MX3X spectrometer, operating in the X-band. No significant effects on the FMR line shape due to the skin effect were observed. The FMR spectra were fitted by a superposition of 2-3 Lorentzian lines, reflecting the presence of an incoherent crystalline phase within the amorphous material. Although the splitting of the resonance line in several components has been ascribed to the presence of magnetic domains [1], the external magnetic field should be sufficiently large to suppose that the sample behaves as a single domain. However, the large number of defects usually present in these amorphous materials may pin the magnetization [2], causing the splitting of the resonance line. The angular dependence of FMR spectra, for the out of plane configuration (the external magnetic field is normal to the plane of the sample) is reported. The dependence of the resonance line position and of the resonance line width on the angle between the external magnetic field and the plane of the ribbon is discussed. The data are analyzed using a thermodynamic approach that takes into account the viscous evolution of the magnetization in the external magnetic field, through the Landau (Gilbert) damping vector. The main conclusion is that the angular dependence of the spectra is ascribed to the shape anisotropy.

References:

10:30 AM #UL6
MAGNETIC CORRELATIONS AND MAGNETIZATION PROCESSES IN NANOSTRUCTURED FERROMAGNETS.
Jörg F. Löffler, California Institute of Technology, W.M. Keck Laboratory, Pasadena, CA

In nanostuctured ferromagnets, the macroscopic magnetic properties arise from a subtle interplay of microscopic parameters like grain size, intergrain coupling, and anisotropy. As a certain grain size above the onset of superparamagnetism, isolated nanoparticles can be magnetically hard, whereas the same material can turn magnetically soft in the case of intergrain coupling. The relevant correlations determining the macroscopic properties, such as coercivity, occur on length scales of the order of the grain size. In order to resolve the grain size dependence of these correlations, we have performed magnetic small-angle neutron scattering on nanostuctured Fe, Co, and Ni. For small grain sizes we find magnetic correlations extending over several grains, whereas for large grains the correlation length is proportional to the grain size. The crossover between these two regimes is determined by the bulk domain-wall width of the respective material. In Fe, the correlation length shows a minimum at grain sizes of around 30 nm, where the coercive field has a maximum. In order to explain these observations, we propose a generalization of the random-magneton model, which includes reduced intergrain coupling and allows for domain-wall formation within grains. Magnetization configurations in coupled grains are discussed analytically. Our model allows us to predict the domain size distribution, exchange constants, exchange anisotropies, and anisotropy constants, in good agreement with the experimental data.
The evolution of magnetic correlations in increasing magnetic fields was also studied and can be described by the switching of correlated domains via a modified Stoner-Wohlfarth model.

11:45 AM U1.9

A STUDY ON THE MOVCD MECHANISM OF INVERSE SPINEL COPPER FERRITE THIN FILMS. Yangsheng Chang, Hsinhsin Tsai, Mingyung Chen, Menghui Lee Lightwave Inst. of Tech., Dept. of Chemical Engineering, Guanshan, Taiwan, TAIWAN ROC.

Spinel ferrites (MFeO4) are soft magnetic ceramics, with inverse spinel crystalline structure. For high frequency wireless communication, which is operated at several GBps due to the large resistivity of spinel ferrites, energy loss caused by induced eddy current will be reduced. As future development of ferrite process will be emphasized on thin film, integration within one chip, and compatibility to microfabrication technology; further, soft magnetic thin films should be low stress, fine grain, and thin domain wall. All these goals can be met by using MOVCD, and controlling process parameters such as deposition temperature, and supersaturation ratio. In this project, we have used a horizontal cold wall CVD reactor, using metal acetylacetonates, Cu2(H2O)4, Fe(C2H4O2)3, and O2 as reactants, and deposited CuFeO4 thin films at 760 torr; 420°C. As revealed by AES/XPS/XRD results, the CuFeO4 grains are [111]. Few a Fe2O3 and CuO crystallites were observed at lower deposition temperature. SQUID indicated that films were ferrimagnetic, with low coercive field (<10 Oe), saturation magnetization [Ms], 3.14 emu/g, and remanence magnetization [Mr], 0.16 emu/g. XTEM showed that deposited CuFeO4 crystallites were faceted polyhedrons. The grain size increased sharply as deposition temperature increased. Arhenius equation was used to estimate the activation energy. En, for grain growth. As the derived En being above 25 kcal/mole, grain growth was suggested as surface reaction controlled. A gas dynamics model, adapted from molecular beam epitaxy [MBE] theory, considering precursor vapor impingement flux, was used to interpret correlation between CVD film composition and gas pressure. Using the two terms, after 250 h partial pressure. After comparing the experimental data, we suggested to put precursor desorption rate into the gas dynamics model, to achieve more realistic results.

SESSION U2: HARD BULK MAGNETS

Tuesday, April 17, 2001

Golden Gate B3 (Marriott)

1:30 PM U2.1

EFFECT OF COMPOSITION AND PROCESSING ON THE MICROSTRUCTURE AND MAGNETIC PROPERTIES OF 217 HIGH TEMPERATURE MAGNETS. George C. Hadjipanayis, Department of Physics and Astronomy, Univ of Delaware, Newark, DE.

The Sm2(Co1-xFe_x)17, magnets represent a complicated system with four compositional variables (x, y, v, z) and five heat treatment variables (TB, TA, TA, T4, T1, dT/dt). The homogenized Sm2(CoFe2) magnets have a featureless microstructure. A cell-hexalinear microstructure develops after 24 h aging at 800°C, but the coercivity increases only after a subsequent slow cooling to 400°C. During cooling, diffusion takes place and Cu is concentrated in the 15 nm cell boundaries and Fe in the 2-17 nm cell boundaries. This distorts the magnetic properties of the 1.7 phase and causes domain wall pinning/nucleation at the cell boundaries. Higher ratio z leads to larger spheres as expected due to the larger amount of the 2.17 phase. For a fixed Cu content, this translates to a larger amount of Cu 15 nm cell boundary, and therefore, to a higher coercivity. Magnets without Cu but with Zr have a lamellar and a cell-like microstructure. In Zr free samples, however, a larger amount of Cu is needed to form the cellular microstructure. This cellular microstructure is unstable with prolonged isothermal aging. A uniform and stable cell/lamella microstructure is only observed in alloys containing both Cu and Zr. A higher aging temperature 60°C also leads to larger cells and higher coercivity because of the remagnetization explained earlier. The results of these studies clearly show that the amount of Cu in the 15 nm cell boundaries controls both the coercivity and its temperature dependence leading to a positive and negative temperature coefficients of coercivity in low and high Cu content alloys, respectively.

This work is supported by the Air Force Office of Scientific Research under Grant No. MURI F49620-98-1-0410.

2:00 PM U2.2

PARTITIONING DURING CRYSTALLIZATION AND ITS EFFECTS ON MAGNETIC PROPERTIES IN RARE EARTH PERMANENT MAGNETS. J.E. Skold and B.B. Koppes, Dept. of MSE, University of Utah, Salt Lake City, UT; J.A. Horton, J. Bentley, Oak Ridge National Laboratory, Oak Ridge, TN; D.J. Brumbaugh, Idaho National Engineering and Environmental Laboratory, Idaho Falls, ID.

Nonmagnetic permanent magnets are routinely produced by annealing overgrown melt spun ribbons. The nanocrystalline structure is formed upon devitrification of the mostly amorphous precursor. It is desirable to have a uniformly glassy material so that devitrification results in a homogenous microstructure. This often requires alloying additions to improve the 'quenchability'. Additionally, alloying additions are also used to alter the crystallization process to produce smaller grain sizes. The results are most often a complicated multicomponent alloy. The magnetic properties of nanoscale permanent magnets are strongly influenced by microstructural features that affect intergranular exchange interactions, including grain size and the character of the grain boundary. The alloying elements may aid in refining the grain size, segregation to the grain boundaries may occur, which would inhibit intergranular exchange interactions. We have studied the devitrification process in several Nd-Fe-B-based alloys in order to understand the microstructural evolution and the resultant effects on the magnetic properties. Analytical electron microscopy has been used to examine the chemical profile across growing crystallites in three alloys, Nd-Fe-B, Nd-Fe-B-Ti-C, and Nd-Fe-P Dy-Co. The segregation of Ti to the crystal/amorphous interface was observed in the Ti-bearing alloys. These alloys also showed a depletion of Fe at the interface, while the ternary alloy displayed a uniform composition across the crystal/amorphous interface. The scale of the crystallites in the partially crystallized materials also depended on alloy composition, indicating significant differences in the nucleation and growth characteristics. Vest differences in the transformation kinetics were also observed, again indicating differences in the nucleation and growth characteristics. The effect of these differences in microstructural formation on the magnetic properties, especially with respect to intergranular exchange interactions as determined from recoil measurements, will also be discussed.

2:15 PM U2.3

EFFECT OF IRON SUBSTITUTION ON THE HIGH-TEMPERATURE PROPERTIES OF Sm2(Co,Cu,Ti)17 PERMANENT MAGNETS. J. Zhou, R. Skomska, and D.J. Sellmyer, Dept of Physics and Astronomy and Ctr for Mag Research and Analysis, Univ of Nebraska, Lincoln, NE; W. Tang and G. Ladovics, Dept of Physics and Astronomy, Univ of Delaware, DE.
Recently, distributed Sm-Co permanent magnets have attracted renewed attention to their interesting high-temperature coercivity [1]. Our presentation deals with the effect of iron substitutions on the magnetic properties of the materials. X-ray diffraction shows that the inverted Sm(Fe,Co,Cu,Ti)z materials (z = 7.0 - 7.6) are two-phase magnets, consisting of 1.5 and 2.17T high coercivity phases. The high content affects both the coercivity and the magnetization. Depending on composition and heat treatment, some samples show a positive temperature coefficient of the coercivity in the temperature range from 25°C to 550°C. This effect is due to the room-temperature coercivity. For example, the room-temperature coercivity of SmCo$_5$Cu$_{13}$-0.4Cu$_{13}$Ti$_{60}$ is 9.6 kOe, as compared to 7.6 kOe for Sm$_5$Co$_{13}$Cu$_{13}$T$_{60}$. At high temperatures, the addition of Fe has a decreasing effect on the coercivity, which is 10.0 kOe at 500°C for Sm$_5$Co$_{13}$Cu$_{13}$T$_{60}$. The room-temperature magnetization increases on iron substitution, from 78 emu/g for Sm$_5$Co$_{13}$Cu$_{13}$T$_{60}$ to 82 emu/g for Sm$_5$Co$_{13}$Cu$_{13}$Fe$_{13}$T$_{60}$. Removing some of the Ti by Fe yield an increase in the mean square of the magnetic moment, which is proportional to the coercivity. The observed temperature dependence is attributed to the preferential dumbell-plate occupancy of the Fe atoms. Since Ti has a similar preference for the dumbell sites, the magnetic properties are a nonlinear function of the Fe and Ti concentrations.

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2:30 PM #12.6
NANOCRYSTALLINE AND NANOSTRUCTURED HIGH-PERFORMANCE PERMANENT MAGNETS. Dagmar Goll, Wilfried Sigle, Helmut Trommler, Max-Planck-Institut für Metallschorschung, Stuttgart, GERMANY; George C. Hadjipanayis, University of Delaware, Newark, DE.

High-performance permanent magnets [1] are based on compounds with outstanding intrinsic magnetic properties as well as on optimized microstructural formations. This correlation is demonstrated for two types of RE-TM magnets: (i) RE$_2$Fe$_{17}$Ba [2], which is currently regarded to be the highest performance pm material at all and which is well-suited for the newly developed polymer bonded magnets, (ii) Sm$_2$(Co$_{17}$Fe$_{5}$Zr)$_7$, which supplies the highest maximum energy products (BH) max at elevated temperatures (higher which RE$_2$Fe$_{17}$Ba is no longer viable) therefore being well-suited for high-temperature applications. On the basis of the ternary RE-Fe$_x$B phase diagram three types of nanocrystalline prs have been tailored: (a) Magnets with RE excess where the hard magnetic RE$_2$Fe$_{17}$Ba grains are separated by a paramagnetic RE-rich intergranular film limiting the remanence to J$_r$ = 0.5 J$_s$ [saturation polarization J$_s$ = approx 1.6 T], (b) Sciodometric magnets, where the hard magnetic grains are exchange coupled leading to an enhancement of the remanence (J$_r$ > 0.5 J$_s$) and therefore of (BH)$_{max}$, (c) Composite magnets with stoichiometric Fe in which the remanence enhancement is highly effective by exchange hardening of small soft magnetic Fe grains. Sm$_2$(Co$_{17}$Fe$_{5}$Zr)$_7$ magnets are characterized by a complicated nanostructure which develops during a complex annealing procedure. One finds Fe-rich gyroids 2.17 cells of a body-centered cubic lattice oriented perpendicularly to the c-axis is superimposed on the crystalline structure. By using high-resolution dispersive X-ray fluorescence (XRF) and the chemical compositions of the three phases involved and their continuous change between the different phases have been determined for various stages of the complex annealing procedure and correlated with the intrinsic magnetic properties clarifying the coercivity mechanism of this material system and the evolution of its characteristic microstructural and magnetic properties unambiguously.

3:30 PM #2.5
Nd$_x$Fe$_y$B MAGNETS - AN UPDATE. V. Pancheshchnik,Magnequench, Inc., Anderson, IN.

The Nd$_x$Fe$_y$B market is a significant growing fraction of the total permanent magnet market, and has experienced the fastest growth of any permanent magnet industry. The processing of these magnets has been carried out by two different methods. One is the conventional powder sintering process, and the other is the rapid solidification process. The sintering process produces only fully dense isotropic magnets. The rapid solidification process makes both bonded and fully dense isotropic and anisotropic magnets. The wide range of applications for bonded magnets includes computer storage devices, automotive applications, office automation products, consumer electronics, and hand held power tools. The fully dense magnets find applications in cranking motors, sensors, voice coil motors, speakers, inducers, generators, etc. Continuing advances in Nd$_x$Fe$_y$B magnets are expected to increase the demand for these magnets in various applications. The technological developments in Nd$_x$Fe$_y$B magnets and their applications will be discussed.

4:00 PM #2.6
SPATIAL DEPENDENCE OF AMORPHOUS CHARACTER IN CAST Nd$_x$Fe$_y$Al$_z$ FERROMAGNETIC ALLOYS. N.H. Dao, V.H. Ky, N.Y. Phuc, Institute for Materials Science, NCSR, Hanoi, VIETNAM; N. Chau, N.H. Luong, C.X. Huu, Center for Materials Science, Department of Physics, Hanoi National University, Hanoi, VIETNAM; L.H. Lewis, Energy Sciences and Technology Dept., Brookhaven National Laboratory, Upton, NY; R.W. McCullum, Ames Laboratory, USDOE and Department of MS&E, Iowa State University, Ames, IA.

Bulk magnetic glasses (BMG) of composition Nd$_x$Fe$_y$Al$_z$ are of interest due to their reported appreciable coercivity (up to 0.4 T) at room temperature. Reported differences in the coercivities of different forms of the BMG (i.e., melt-spinning rods vs. cast rods) naturally suggest that the solidification conditions, and attendant amorphous state, cannot significantly influence the magnetic properties. An understanding of the factors which control the magnetic properties of BMG alloys, detailed x-ray diffraction and magnetization studies were systematically performed on regions of suction-cast rods made from Nd$_x$Fe$_y$Co$_{z}$Al$_{1-x}$ prepared in three different routes: Fe and Al were combined and Nd added in later; Nd and Fe were combined and Al alloyed in later; and four elements (Nd, Fe, Al and 10% Co) were alloyed simultaneously. The suction-cast rods were of height $y_a$ ~ 60 mm, width $y_b$ ~ 10 mm and thickness $y_c$ ~ 1 or 3 mm. It was found that the structural and magnetic hysteresis character vary strongly with the depth along the thickness [$y$]. In all rods the outermost layer shows a magnetic feature within the amorphous matrix. With increasing depth $x$ the amorphous fraction first increases ($0 < x < 1/4x_w$) and then decreases ($1/4x_w < x < 1/2x_w$). While the amorphous/crystalline matrix ratio depends very little along the $x$ position, the magnetic hysteresis exhibits a significant dependence on location within the rods. These results indicate that the extent of crystallization and the accompanying magnetic properties are very sensitive to the temperature inhomogeneities present during the casting process.

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Support from the East Asia and Pacific Program of the Division of the International Programs, N.S.F., is gratefully acknowledged.

4:15 PM #2.7
INVESTIGATIONS ON THE MAGNETIC PROPERTIES OF HIGH-COERCIVITY (Nd$_x$Fe$_y$Co)$_z$Al$_{1-x}$ BULK AMORPHOUS ALLOYS. Maria Chirici, Nicolaia Lupu, National Institute of Research and Development for Technical Physics, Iasi, ROMANIA; Akira Takeuchi, Akiko Inoue, Institute for Materials Research, Tohoku University, Sendai, JAPAN.

Bulk and melt-spin amorphous Nd$_x$Fe$_y$Co$_z$Al$_{1-x}$ alloys were investigated by the magnetization measurements using a VSM magnetometer in the temperature range 80-810 K and external fields up to 1.6 T. The coercive fields amount to 0.4 T at room temperature for bulk amorphous alloy with 0.5, and are nearly 0.05 T for amorphous melt-spin ribbons of the same compositions. The increase of $x$ results in the increase of the coercive field of the melt-spin amorphous ribbons up to 0.35 T. The temperature dependence of the observed coercivity shows a maximum at around 150 K. The large coercive field values for the melt-spin and bulk Nd$_x$Fe$_y$Co$_z$Al$_{1-x}$ amorphous alloys as well as their cooling rate dependence appear to arise from the very small magnetic clusters embedded in the amorphous matrix. The relevant temperature treatments reveal the presence of bifurcation of the zero-field-cooled (M$_{2FC}$) and field-cooled (M$_{FC}$) magnetization curves for amorphous ribbons in all ranges of thickness and bulk amorphous rods. The presence of one pronounced cusp on (M$_{2FC}$) curves and its displacement towards lower temperatures with samples' thickness (i.e., coercivity increase) indicate the coexistence of two types of magnetic order: microscopic short-range spin-glass-like order in the amorphous bulk and macroscopic long-range ferromagnetic order. Both magnetic clusters' structure and amorphous matrix are very sensitive to composition, temperature, and preparation conditions and suffer different magnetic transitions. Details about the micromagnetic structure of Nd$_x$Fe$_y$Co$_z$Al$_{1-x}$ amorphous alloys will be discussed.

4:30 PM #2.8
THE COERCIVITY - REMANENCE TRADEOFF IN NANOCRYSTALLINE PERMANENT MAGNETS. Laura H. Lewis and David C. Crew, Materials and Chemical Sciences Division, Energy Sciences and Technology Dept., Brookhaven National Laboratory, Upton, NY.

The energy product (BH)$_{max}$ is a figure of merit quantifying the
maximum amount of useful work that can be performed by the magnet. The energy product is determined by the magnetic remanence and coercivity which, in extrinsic properties, are determined by the magnets' microstructure. Thus, in principle, magnetic material microstructures may be tailored to obtain defined parameters to produce optimal permanent magnets. However, as asserted by the eponymous Murph, "Nature favors the broadest microstructure". While there is still much undeveloped potential in nanomagnetic materials, with relevant length scales on the order of 100 Å, accumulating evidence strongly suggests that maximum remanence and magnetic coercivity can be mutually exclusive in nanocrystalline magnetic materials. Diverse experimental and computational results obtained from nanocrystalline Ni$_2$Fe$_2$B$_2$-based magnets produced by melt-spinning techniques and subjected to various degrees of thermal treatment confirm this. Inclusion of the above-mentioned results obtained from temperature-dependent magnetic measure, magnetic force microscopy and simple micromagnetic modelling will be reviewed and summarized. The result of some of the most promising materials design routes to sidestep the inherent performance limitations of the magnetic structures.

Research performed at Brookhaven National Laboratory under the auspices of the U.S. Dept. of Energy, Division of Materials Sciences, Office of Basic Energy Sciences under contract No.

DE-AC02-88CH10886.

**SESSION U3/T4: JOINT SESSION ON HIGH-FIELD MAGNETO-RESISTANCE MATERIALS**

**Wednesday Morning, April 18, 2001**

Golden Gate B3 (Merrill)

8:30 AM *U3.3/T4.1* ATOIC AND NANENGINEERED FERRITE SYSTEMS NEW HORIZONS IN LOW DIMENSIONS. Y.G. Harris, NWS Research Laboratory, Washington, DC.

Spinel ferrites are attractive materials for high frequency (1 MHz ≤ f ≤ 500 MHz) applications where low core losses are essential. Further, these materials are the only low-loss magnetic materials available for microwave frequency (f ≥ 1 GHz) applications. An essential property of these ferrites is the very low core losses that limit eddy current losses and other forms of conduction loss. Other attractive properties are their high permeability, low anisotropy fields, low FM linewidths, etc. However, their ferrimagnetic nature limits their intrinsic magnetization. This has the effect of limiting the power loads and efforts to reduce component size at the MHz frequencies, and their broadband utility at the microwave. In recent years, trends in ferrite research have involved processing of ferrite nanoparticles for core fabrication for MHz frequencies, and films for monolithic magnetic integrated circuits for noncircuital microwave devices. In both cases the ferrites are processed in low dimensional forms, i.e., thin film form, for high coupling and uniformity. This discussion will address the challenges associated with the nanoscale materials, as well as nanoengineering of composites designed to overcome the intrinsic limitations of ferrite systems.

9:00 AM U3.2/T4.2 DIRECT AND REAL-TIME OBSERVATION OF SUB-MICRON DOMAINS IN MAGNETICALLY BIASED STRONTIUM FERRITE PERMANENT MAGNETS BY ROOM TEMPERATURE SCANNING MICRO-HALL PROBE MICROSCOPY. A. Sundley, N. Ikeda, Tokai Univ, Dept of Electrical Engineering, JAPAN; H. Masaeda, Thei Kogyo Ltd, Tokyo, JAPAN; A. Oral, Bilkent Univ, Dept of Physics, TURKEY; S.J. Bending, Univ. of Bath, Dept of Physics, UNITED KINGDOM.

The development of ferromagnetic materials for high performance permanent magnets requires a fundamental understanding of the behavior of magnetic domains in external bias fields. We have developed a new room temperature scanning micro-Hall probe microscope (RT-SHMP) system for such purposes and will report on the imaging of domain movement in ferromagnetic materials (SFM) in external bias fields. The RT-SHMP system enables the highly sensitive, extremely fast, non-invasive, and quantitative measurement of local surface magnetic fields on the micron-scale. A 0.8 × 0.8 μm GaAs:AlAs diode (300 μm thick) with sensitivity of 0.3 μV/G and field sensitivity of 0.4 μV/μT with an integrated STM tip for precise vertical positioning was used as a magnetic field sensor. External bias fields (Hex) of up to 30000 Oe were applied in steps of 400 Oe parallel to the easy and hard axes of carefully polished 400 μm thick thermally demagnetized Sr ferrite permanent magnets (Hex=2870 Oe).

10:30 AM U3.6/T4.4 CRITICAL-STATE PHASE CONTROLS IN COLOSOAL MAGNETORESISTANCE MATERIALS. Y. Tokura, Tsunoshi Kimura, Department of Applied Physics, University of Tokyo, Tokyo, JAPAN; and Joint Research Center for Atom Technology (JR-CAT) and Correlated Electron Research Center (CERC), Tsuchuba, JAPAN.

Control of electronic parameters via modifications of composition, structure, and lattice strain in perovskite-type manganite oxides...
produces novel magnetoelectric properties, including colossal magnetoresistance (CMR). Close interplay among spin, charge, orbital, and lattice degrees of freedom produces rich and complex electronic/magnetic/orbital phases. With use of order-disorder phenomena in the charge and orbital sectors, unconventional phase control is also possible, such as photo- and current-induced insulator-metal transition for magneto-ferromagnetic transitions. Recent results of such an study on single crystals and thin films of CMR oxides are presented.

11:00 AM U3.7/T4.7
THE INFLUENCE OF SINGLE GRAIN BOUNDARY JUNCTIONS ON THE MAGNETORESISTANCE IN GRANULAR PEROVSKITE MANGANITE FILMS. Robert Gunnarsson, Zdzislaw Ivanov, Chalmers University of Technology, Department of Microelectronics and Nano Science, Göteborg, SWEDEN; Roland Mathieu, Peter Seelind, Dept of Materials Science, Uppsala Univ, Uppsala, SWEDEN.

We have examined single grain boundary junctions (GBJs) as well as GBJ arrays in Sr-doped (33%) lanthanum manganite thin films. The films were deposited by pulsed laser deposition (PLD) on symmetric b-cristals with 88.8 ± 18.4° and 45° misorientation angles. Microbridges, with a width of a few hundred nanometers and crossing the artificial grain boundary of the b-cristal, were patterned by Ar-ion milling through a resistive mask. Magnetoresistance and noise measurements were performed in a wide range of temperatures and magnetic fields. The measurements on single GBJ reveal a switching, i.e., steps in the magnetoresistance near the coercive field. We show that the switching originates from the magnetic domain structure at the boundary of the b-cristal interface. With a multi-domain model the magnetoresistive behaviour of a single junction can be described. The noise measurements show that the grain boundary noise, which has a Debye-Lorentzian frequency-dependence, is identical to the normal 1/f noise seen in bulk perovskite manganites.

11:15 AM #U3.8/T4.8
ANISOTROPIC MAGNETOCALORIC EFFECT IN NANO STRUCTURED MAGNETIC CLUSTERS. X.X. Zhang, Department of Physics, The Hong Kong University of Science and Technology, Clear Water Bay, Kowloon, Hong Kong, CHINA.

We have systematically studied the magnetic entropy change, DSM (H,T), in the Fe8 molecular crystals in a wide temperature range. Since the Fe8 crystals are composed of a huge number of (Avogadro constant) identical, non-interacting, aligned, anisotropic magnetic clusters with spin 29μB, it is a model system for the study of the fundamental properties of the nanostructured magnetic materials. The isothermal magnetization curves have been measured at different temperatures below the applied magnetic field and the magnetic easy axes of the clusters. The observed temperature and field dependence of the magnetic entropy change or magnetocaloric effect (MCE) have been obtained. It is found that the magnetic entropy change, a very important role in the determination of the magnetocaloric effect. The maximum and minimum MCE are observed when the applied magnetic fields are parallel and perpendicular to the easy axes, respectively, in the whole temperature range. The magnetic entropy change and other properties of a system composed of anisotropic magnetic clusters have been obtained by the numerical methods in order to illustrate the magnetic anisotropy effect.

11:45 AM U3.9/T4.0
NANOSCALE MAGNETIC DOMAIN STRUCTURE IN COLLOIDAL MAGNETORESISTANCE MATERIALS ISLANDS. Yun Wu and Yuri Suzuki, Department of MS&E, Cornell University, Ithaca, NY.

The doped perovskite manganites have received an enormous amount of attention recently because they exhibit colossal magnetoresistance (CMR) and may be hightemperature superconductors. However, the magnetic properties of these compounds are extremely sensitive to lattice strain and thus to structural distortion. As a result, many groups have studied partially and fully strained CMR films. We have chosen to study the effects of strain in CMR islands where we can tune the strain through variation of island aspect ratio. We have fabricated sub-micron sized islands of La0.5Sr0.5MnO3. Magnetization loops indicate a characteristic field that reflects anisotropic magnetic fields. We have used magnetic force microscopy to image the magnetic domain states of this family of islands in zero field after saturation in different directions. The stripe magnetic domain states that we observe are a result of the competition among shape anisotropy, strain anisotropy, magnetocrystalline anisotropy and magnetostatic energies. The evolution of domains in a magnetic field reveals the importance of shape anisotropy as well as magnetostriiction in determining the micromagnetics in such small CMR structures. Our understanding of the micromagnetics provides a foundation for the analysis and implementation of thin film magnetoresistive devices made of this class of materials.

SESSION U4: MAGNETIC NANOPARTICLES, NANOFLIES AND ARRAYS
Wednesday Afternoon, April 18, 2001
Golden Gate B3 (Marriott)

1:30 PM #U4.1
FIELD-INDUCED 3D AND 2D CRYSTALS OF FERROMAGNETICALLY COATED MICROSPHERES. Ping Shen, Weijia Wen, Liyong Zheng, C.T. Chan, Wing Yim Tam, HKUST, Dept. of Physics, Clear Water Bay, Kowloon, Hong Kong, CHINA.

We have fabricated uniformized, ferromagnetically coated microspheres ranging from 1-50 microns in diameter, each consisting of a glassy core with an outer Ni layer of adjustable thickness. An additional insulating coating of SiO2 or PZT is optional. The magnetic moment of each microsphere is easily tunable by controlling the Ni coating thickness. By dispersing the magnetic spheres in liquid, we show that the electric and/or magnetic field(s) can induce 3D crystalline arrangements of the microspheres. In addition, 2D magnetic colloidal crystals are formed by floating the microspheres on a liquid meniscus. Under a magnetic field, the balance between the repulsive magnetic interaction and the attractive interaction, due to the weight of the particles projected along the surface tangent, yields not only the triangular lattice with a variable lattice constant, but also all the other planar crystal symmetries such as the oblique, centered-rectangular, and square lattices. By using two different sized magnetic microspheres, local formations of 2D quasiequilibriums with fivefold symmetry were also observed.

2:00 PM U4.2
AC SUSCEPTIBILITY OF MONODISPERSE IRON NANO PARTICLES. Keith D. Humfeld, Anit K. Giri, and Sara A. Majetic, Physics Dept., Carnegie Mellon University, Pittsburgh, PA; Eugene L. Venturini, Sandia National Laboratories, Albuquerque, NM.

We have synthesized highly monodisperse, oxidized iron nanoparticles and measured their susceptibility as a function of frequency and temperature. 7 nm Fe nanoparticles were prepared using water-free inverse micelles, and via thermal decomposition of iron pentacarbonyl in an organic solvent. A 0.1 vol.% solution was sealed in an ampoule to facilitate the study of the magnetic properties of non-interacting mononanoparticles. The sample was frozen to prevent free rotation of the particles. The real and imaginary parts of the susceptibility were measured between 0.1 and 1000 Hz for temperatures between 10 and 500 K. The monodisperse applied field had an amplitude of 5 Oe. The peak in the imaginary part of the susceptibility χ''(f) for a given temperature was designated as the characteristic frequency, f0. χ''(f0) for different temperatures was normalized to a single curve by plotting it as a function of f/f0. The real part of the susceptibility χ'(f) could not be normalized to a single curve due to the temperature dependence of the magnetization, M(T) ≈ M0HV/kT. However the χ'/(f) scaled to a single curve when plotted as a function of f/f0. While in mononanoparticles ln(f0) increased slowly and linearly with temperature T, for the nanoparticles ln(f0) rose linearly with ln(T), and changed dramatically over a small temperature range. Though the nanoparticles are monodisperse, they may have differing energy barriers for coherent rotation due to weak interparticle interactions and varying orientations of the easy axes. To differentiate these effects, and to better understand the reasons for the temperature dependence of f0, magnetic viscosity is measured for monodispersely aligned and unaligned samples. The magnetic viscosity S as per M(t) = Me - S ln(t). The aligned particles exhibit a narrow distribution of energy barriers.

2:15 PM U4.3
SYNTHESIS OF NANO COLLOIDAL MAGNETIC PARTICLES AND MAGNETIC NANOCRYSTAL SUPERLATTICES. Michael Hellinga, Nelly Salval, Michael Giersig, HMI, Dept of Solar Energie Science, Berlin, GERMANY.

The preparation of low-dimensional well ordered layers of nanocrystalline, size-controlled, and monodisperse magnetic particles are of interest to a wide range of technological applications such as memory devices. It is known that the deposition of monodisperse non-aggregated colloids may lead to self-assembled layers and superlattices. The quality of ordering of magnetic particles can be improved using a magnetic field during the deposition. i.e. during the solvent evaporation. To make the preparation of well ordered layers of nanocrystalline particles attractive for technological applications it is necessary to find easy ways for the preparation of non-aggregated,
monodisperse colloids as well as for the preparation of wellordered layers (considering the necessity of different properties to apply different deposition techniques). Our aim is to develop simple and cheap synthesis routes to prepare nanocrystalline particles in solution which can be easily modified to get non-aggregated, site-controlled, and monodisperse colloids in water as well as in hydrophobic solvents. We are also interested in alloying and coat the nanocrystalline particles with noble metals to change their magnetic properties, to preserve the particles for oxidation and to control the distance between the particles of a well ordered deposited layer. We will report here some results to monodisperse magnetic particles in hydrophobic solutions, their nanostructuring and the preparation of more-dimensional ordered nanocrystalline layers using a magnetophoretic deposition technique. Actual successes and problems will be discussed.

2:30 P.M. U4.4
MAGNETIC NANO PARTICLE ARRAYS. Dorothy Farrell, Sara Matson, Amit K. Giri, Keith Humfeld, Maleh Tsamis, Satoshi Yamamuro, Carnegie Mellon University, Dept of Physics, Pittsburgh, PA.

Solvent evaporation from suspensions of surfactant coated 4-12 nm Fe or FePt particles in hexane can cause self-assembly of the particles into mono- and multilayer arrays. The particles are formed by dissolving acetylacetonate in toluene in the presence of a reducing agent and heating. Iron pentacarbonyl is added at elevated temperature, and the molar ratio of Fe to Pt determines whether FePt or Pt seed coated Fe is formed. Surfactants are added to the system to coat the particles, which are then washed and dispersed in hexane. When the suspension dries on a solid surface, the hexane evaporates and the suspension forms a thin film. Solvent evaporation from the film gives rise to capillary forces, which bring the particles together. These forces and particle interactions balance, resulting in monolayer array formation. Solvent flows into the array from the rest of the suspension to replace the evaporated hexane, carrying more particles with it. These particles are added to the growing crystal edge; when the contact angle between solvent and crystal surpasses a critical angle, multilayers of varying structure and orientation are formed.

Transmission electron microscopy images are used to quantify and explain the lattice structures. The structures should have unique magnetic properties. TEM reveals the coercive and magnetization behavior of the arrays, while Lorentz mode TEM reveals the magnetic structure. Unfortunately, the as-formed FePt particles have a face centered cubic internal structure, and are only weakly magnetic. The arrays can be annealed, however, to transform the particles to the higher anisotropy tetragonal phase. For both the Fe and FePt arrays, the magnetic properties can be enhanced by crystallographic alignment of the particles. Growing and annealing the arrays in high magnetic fields is a promising venue for this alignment that we are pursuing.

2:45 P.M. U4.5
LOW TEMPERATURE STUDY OF MAGNETIZATION REVERSAL AND MAGNETIC ANISOTROPY IN Fe, Ni, and Co NANOGRAPHS. Michael Kroll, Physics Department, Trinity College Dublin, IRELAND; Jos de Jong, Fernando Luís, Peter Paulus, Kamerlingh Onnes Laboratory, Universiteit Leiden, THE NETHERLANDS; Günther Schmid, Institut für Anorganische Chemie, Universität Essen, GERMANY.

Iron, Nickel and Cobalt nanowires are prepared by an AC plating procedure using nanoporous anodic membranes as a matrix material. The pore diameter and therefore the diameter of the wires can be easily controlled within a range of 5 to 200 nm. A study of the magnetic reversal mechanism for iron and Nickel nanowires with diameters down to 5 nm, i.e. smaller than the domain wall width, is presented. The coercive field at 5 K is a factor of three lower than the prediction for rotation in unison. We also observe that the activation energy associated with the magnetic reversal process is much lower than the cross-section of the wires and nearly independent of the wire length. From the temperature dependence of the coercive field and the magnetic viscosity we can conclude that magnetization reversal takes place via nucleation of a small magnetic domain, probably at the end of the wire, followed by the movement of the domain wall. For Cobalt wires, we observe a different behavior that is dominated by the competition between the shape anisotropy and the temperature dependent magnetocrystalline anisotropy, which competes partially due to a competition between hcp-Co and fcc-Co. The amount of fcc-Co increases with decreasing wire diameter causing a different magnetic behavior. Structural studies (EXAFS, WAXS) support this statement.

3:30 P.M. U4.6
STABILITY OF MAGNETIC STATES IN PATTERNED MATERIALS. Mary Parodi-Herzach, George Washington University, Dept of ECE, Washington, DC.

The interest in regular two-dimensional arrays of small magnetic particles is motivated by their potential as the next generation high density magnetic recording medium. The stability of a 2D patterned magnetic system is an important practical problem with interesting fundamental aspects. The elements of a 2D array are single domain particles, allowing by incoherent rotation, and interacting magnetostatically. The stability of the magnetic state of the elements and the system is determined by material parameters, shape and size, statistics, and reversal mode. The role of the shape and size in switching and incoherent rotation depends on the details of the switching fields is one of the determining factors in the stability of the system. Another factor is the interaction between elements. Its mean value depends on the total magnetization of the system, however, its statistical deviation depends not only on the statistical geometry of the array, but also depends on the total magnetization of the system. This means, that for a 2D magnetic recording medium, the stability of the recorded information depends on the information itself. The stability magnetization reversal depends on the details of the magnetization process. The magnetization process in film and bulk materials involves both low energy barrier domain wall motion and high energy rotational processes. However, the thermal stability of single domain particles, switching by rotation, is much higher than for a continuous medium with a much broader switching barrier distribution, ranging from the domain wall motion coherency up to the micromagnetic process. Experimental data for a model 2D square array of single crystalline, strongly uniaxial, single domain garnet particles illustrate the effects on stability of shape, statistics, and magnetization process.

4:00 P.M. U4.7
SYNTHESIS AND SELF-ASSEMBLY OF FILMS CONTAINING FeCO nanoparticles. Jing Chen, DaWei Zhang and David E. Nikles, University of Alabama at Tuscaloosa, AL.

Fe4Co nanoparticles were synthesized by simultaneous chemical reduction of platinum acetylacetonate and cobalt acetylacetonate and thermal decomposition of the product. As prepared the particles had a disordered face-centered cubic lattice within an average diameter of 3 nm and were superparamagnetic. The particles were dispersed in a hydrocarbon solvent and painted onto a silicon coated Cu TEM grid. After drying, the particles assembled into parallel arrays of chains. The particles were deposited onto a single crystal Si (100) substrate and annealed at 700°C for 30 minutes. The particles transformed to the face-centered tetragonal phase with the [111] direction oriented in the plane of the film. The film became ferromagnetic with an in-plane coercivity of 8700 Oe and a squareness of 0.75.

4:15 P.M. U4.8
EFFECT OF SUBSTRATE ON THE SELF-ASSEMBLY OF FePt NANO PARTICLES. Min Chen, DaWei Zhang and David E. Nikles, Center for Materials for Information Technology, The University of Alabama, Tuscaloosa, Tuscaloosa, AL.

Spherical Fe48Pt52 nanoparticles were synthesized by simultaneous chemical reduction of platinum acetylacetonate and thermal decomposition of iron acetylacetonate. As prepared the particles had a disordered face-centered cubic lattice with an average diameter of 3 nm and a peak intensity of less than 5% for particles with a tetragonal phase. The particles were dispersed in a 50/50 mixture of hexane and octane and deposited onto different substrates. When deposited onto a carbon-coated Cu TEM grid, the particles assembled into the form of hexagonal two-dimensional arrays. When deposited onto a silicon coated Cu TEM grid the particles formed a square, closed-packed two-dimensional array. The particles were deposited onto a single crystal Si (100) substrate and annealed at 700°C for 30 minutes. After annealing the particles transformed to the face-centered tetragonal phase with the [111] planes oriented in the plane of the film. The film became ferromagnetic with an in-plane coercivity greater than 11,000 Oe and a squareness of 0.70.

4:30 P.M. U4.9
DOMAIN WALL STRUCTURE IN EPITAXIALLY GROWN MAGNETIC WIRES AND DOTS. K. Onoda, J. Pregenau, L. Budil, C. Bork, IPCOM (1051 7600 CLEVELAND, OH).

Advances in materials growth and characterization have, over the past ten years, made possible the investigation of basic physical processes in novel artificial materials. These materials are artificial in the sense that the geometry and composition are controlled during growth on micrometer and nanometer length scales. This results in macroscopic behavior that can be dramatically different from that of a material in its bulk form. Magnetic order and magnetic order reversal processes have been extensively studied since the turn of the century have now to be
The results on domain structure in submicron magnetic dots, rings and wires presented here exemplify current state of the art in detecting and imaging technologies. Equally important, the reported results of intricate domains in submicronic magnetic structures demonstrate the potential for precise control of micromagnetic behavior in patterned materials. For instance, the recent observation of a domain wall magnetization effect in magnetic nanowires exhibiting a head to head wall structure was recently interpreted in terms of spin dependent scattering and spin accumulation at the domain walls. In this interpretation, the domain wall can be treated as a crucial nanoscale feature of the domain wall structure a primary concern. Here, a detailed examination of the domain wall structure is presented in epitaxial Co nanowires which form perfect model systems for such investigations. Wires made from polycrystalline material have been epitaxially grown to 8 to 10 nm thick Co films. We have established experimentally the boundaries between the ground states and the metastable states which strongly depend on the lateral width and height of the nanomaterial structure. We have furthermore demonstrated that exchange anisotropy configurations induced following specific magnetization histories.


SESSION 15: MAGNETIC MICRO- AND MACROSCOPIC PROPERTIES

Thursday, April 19, 2001
Golden Gate B3 (Merritt)

8:30 AM #15.1
THE ROLE OF DISORDER IN NANOSTRUCTURED MAGNETIC ALLOYS. Dimitra L. Leslie-Pelecky, L. Yue, R. Sabirianov, E. Kirkpatrick, University of Tennessee. - Lincoln, Department of Physics & Astronomy and Center for Materials Research & Analysis, Lincoln, NE; Paul Shi, Department of Physics, University of Northern Iowa, Cedar Falls, IA; T. Pekarek, Department of Natural Sciences, University of North Florida, Jacksonville, FL.

Low-energy, randomly oriented crystalline regions in a nanostructured system interact with each other through non-crystalline interphase regions. Atoms in the interphase - which can comprise as much as 50% of the sample when the grain size is on the order of 5 nm - experience a different strain and stress field than the bulk matrix. Understanding the effect of different types of structural disorder on the magnetic properties of ferromagnetic alloys is critical to our ability to produce materials for specific applications. This talk will focus on the effects of disorder in three magnetic systems. SmCo5, a hard magnetic material, can be made harder via mechanical milling. The factor-of-two change in coercivity with as little as two hours of milling is shown by aging studies to be due to defects and not simply grain size. The metastable Ni5Fe phase predicted by Linear-Muñoz-Tin-Oriental calculations to be nonferromagnetic, however, mechanically alloyed Ni3Co:18 70°C coercivity at room temperature. Subsequent LEFT calculations demonstrated that locally disordered Ni regions can indeed support ferromagnetism. Crystalline GdAl15 is a ferromagnet with a Curie temperature of ~175 K, while amorphous GdAl15 is a spin glass with a freezing temperature of ~16 K. Nanocrystallized GdAl15 has spin-glass-like features, but with a freezing temperature of ~65 K. The effects of structural disorder on the nature of the magnetic ground state have been investigated using linear and nonlinear susceptibility measurements. Scaling theory is used to determine the magnetic phase diagram as a function of the order of the alloy.

9:00 AM #15.2

The AC magnetic properties of quenched FeCo nanocomposites are explained quantitatively in terms of the random anisotropy mode with two types of exchange coupled regions. These nanocomposites were formed by the composition of monodisperse but in many cases unaggregated nanoparticles, which have a thin core-shell structure. We have used transmission electron microscopy and magnetic measurements to determine the size and shape of the FeCo particles. The measurements of the permeability, coercivity, and power loss have suggested that there are two distinct components contributing to the AC magnetic properties of these composites. One component is an exchange-coupled component, characterized by a low coercivity and a high permeability. The other component is a disordered component, characterized by a high coercivity and a low permeability. The measurements of the magnetic properties of these composites are consistent with the model of exchange coupling described above.

9:15 AM #15.3
ELECTROCHEMICAL DEPOSITION OF FeCo ALLOYS AND FeCo/TiO2 NANOCOMPOSITES. Ingrid Sino, P.M. Vereecken, P.C. Severns, R.C. Cummarsan, John Hopkins Univ., Dept. of MSE, Baltimore, MD; C. Liu, Johns Hopkins Univ., Dept. of Physics and Astronomy, Baltimore, MD.

Iron-cobalt alloys near the equiatomic composition have superior soft magnetic properties with a very high saturation magnetization (31 kG), high D.C. permeability, low D.C. coercivity and low A.C. core loss. The ability to produce soft magnetic materials in thin film form has many technological applications, such as hard disk drives, microactuators and microinductors. Electrochemical deposition is an important processing technology for microfabrication due to its low cost, high yield, low energy requirements, and capability for generating high-aspect-ratio features. However, electrochemical deposition of FeCo alloys is problematic due to the low solubility of Fe and Co. We have successfully produced high quality Fe6Mo30Co15 films from an aqueous sulfamate electrolyte with a rotating disk electrode. Samples (7 mm in diameter and about 25 µm in thickness) were deposited at constant current densities between 0.6 and 4.0 mA/cm2 and at a temperature of 50°C. Knop hardness, magnetic hysteresis loops, resistivity, microstructure, and composition of these films were characterized. A saturation magnetization of 21 to 22 kG is typical for these as-deposited films. Bulk FeCo alloys are primarily used in the manufacture of rotor and stator laminations in motors and generators for aircraft power generation applications. The lower magnetic properties of these alloys, including low yield strength, low creep resistance and poor ductility, have hampered their use in technological applications. We have utilized electrochemical codeposition from an electrolyte containing a suspension of TiO2 particles (25 mm in diameter) to produce oxide dispersion strengthened FeCo/TiO2 nanocomposites. Large grain sizes of about 10 µm were observed for all these FeCo/TiO2 films. An average hardness enhancement of 50% was observed for the electrodeposited FeCo/TiO2 (1 to 2 vol % particles) nanocomposites compared to cast FeCo alloys with similar grain sizes. Magnetic properties were slightly degraded due to the incorporation of nanoparticles.

9:30 AM #15.4
HIGH STRENGTH MAGNETIC COMPOSITES. A. Goren, M.M. Corte-Real, R.H. Yu, and John Q. Xiao, University of Delaware, Department of Physics and Astronomy, Newark, DE; L. Ren, Azer P nar, A.M. Mature, University of Delaware, Department of Mechanical Engineering, Newark, DE.

There has been an increasing demand in high temperature soft magnetic materials with much lower microwave losses than existing commercial materials such as FeCo alloys. We have designed new exchange-coupled composites by reinforcing FeCo alloys with high strength tungsten or carbon fibers. Several methods including electrodeposition, sputter infiltration, and high pressure compaction were employed to achieve bulk alloys. In general, as-deposited composites show a relatively high Hc and low magnetic permeability, because of induced strain during the fabrication. After appropriate thermal annealing, the composites show good soft magnetic properties comparable to bulk commercial alloys. However, the saturation induction is reduced due to nonmagnetic fiber inclusions. The composites also show significant enhancements in yield strength and tensile strength that increase linearly with fiber volume fraction as seen in other common composite materials. In addition, a near-zero creep is observed at 600°C under a stress of 600 MPa. The mechanical properties can be further improved by co-depositing soft magnet and Al2O3 nanocenter core fiber reinforced FeCo/TiO2 composites, where the anisotropy was observed between Hc and the volume fraction of Al2O3 particles. The hardness of the composites nearly doubled with about 10% vol. concentration of Al2O3 particles. The square root relationship has also been observed between the hardness and Al2O3 particle concentration.

9:45 AM #15.5
MAGNETIC PROPERTIES OF TRANSITION METAL-NITRIDE NANOCOMPOSITES. Richard A. Fyg, R.D. Shek, National Institute of Standards and Technology, Gaithersburg, MD; S.

The experimental cutoff frequencies. Together they are used to obtain the temperature dependence of K_{c} and V_{c}. The exchange coupled volumes are calculated as smaller than the grain sizes and the small regions are associated with the cutoff frequencies, and currently limit the useful frequency range of the nanocomposites. At lower frequencies a second type of exchange coupled region dominates. Here the magnetic K_{c} is estimated from the lower temperature coercivity and saturation magnetization, to within a temperature-independent constant a. Using the random anisotropy model with K_{c}, V_{c}, and K_{s}, the exchange coupled region V can be estimated. The Lorentz microscope shows a variation in cut-off frequency with particle size, suggesting a μ0μ0. This dimension is comparable to the diameter of the particles used to form the nanocomposite.
Uppuluri, and L. Balogh, University of Michigan, Center for Biologic Nanotechnology, Ann Arbor, MI.

Magnetic nanocomposites have been successfully prepared by encapsulating nanosized entities of iron, cobalt, and nickel compounds in hydrophobic poly(aminoamine) (PAMAM) dendrimer hosts. Problems related to the instability of nanocomposites shown that after subfractionation of the diamagnetic polymer background, at 300 K all samples exhibited paramagnetic behavior, with susceptibilities of 1.14, 1.08, and 0.70 x 10⁻⁴ m³/kg for Fe, Co, and Ni-containing samples respectively. The temperature dependence for T<100 K is typical paramagnetic behavior, with the susceptibility increasing for decreasing temperature. Curie-Weiss (1/M vs. T) graphs displayed a linear behavior at high temperatures, with temperature increases to about 5 K (Fe), 6 K (Co), and 0 K (Ni). Negative deviations from Curie-Weiss behavior occurred at T<175 K for the Fe and T<25 K for the Co samples, which indicated the susceptibility increased at a faster rate with decreasing temperature than the Weiss molecular field model would dictate. Magnetic moments calculated from the high temperature Curie constant indicated that Fe, Co, and Ni possessed effective moments of 4.4, 4.4, and 2.9 μB under the assumption that these species were present in metallic form. The negative intercepts and the fact that these moments are larger than those expected for metallic transition metals is indicative that these species are probably present in an oxidized form. The low temperature behavior showed curved isotherms with an approach to saturation at 76, 132, and 123 m³/kg (i.e., emag) at 5 K and 5 T for Fe, Co, and Ni respectively at fields >30 Koe indicating either superparamagnetic or soft ferromagnetic behavior. Detailed structural characterization of the nanogold is presently under investigation.


10:30 AM *U5.6
FERROMAGNETIC AND SUPERPARAMAGNETIC PARTICLE COMPOSITES STRUCTURED BY UNIAXIAL AND BIAXIAL FIELD POLING
James E. Martin, Judy Odinek, Eugene Venturini; Richard A. Anderson, Sandia National Laboratories Albuquerque, NM.

We will discuss the synthesis and properties of mixed composites of ferromagnetic and superparamagnetic materials. Theformer we refer to as Field-Structured Composites (FSCs), and these consist of ferromagnetic particles suspended in a polymeric resin and structured into chain-like or plate-like aggregates by applied uniaxial or biaxial fields. The formation of chains in a uniaxial field is familiar, and occurs because of induced dipolar interactions. The formation of sheets in a biaxial field, such as a rotating field, is less familiar, and occurs because of negative induced dipolar interactions. FSCs exhibit highly anisotropic magnetic, optical and transport properties, and are promising materials for such applications as actuators, chemical sensors, and current-limiting thermostats. Recently, we have begun to investigate the properties of structured composites of superparamagnetic microspheres and ferromagnetic particles, using the technique of Direct Poling of Nanostructured Composites (DPNs), to emphasize the persistent particle dipole. Uniaxial DPNs are easily made in a static applied field, but producing biaxial composites in a rotating field is more challenging, due to the high field frequencies and the complex geometry of the materials. The work is mainly accomplished by designing an audio frequency, resonant Biaxial Helmoltze Coil that employs a fractal capacitor bank essentially continuously tuned over three decades of capacitance. The strong collective dipolar interactions in DPNs significantly alter their magnetism, producing anisotropic susceptibilities, shifts in the blocking temperature, and shifts of the structure dependence of the AC susceptibility. Finally, the strength of these materials and their magnetic properties are accounted for by simple Langevin dynamics codes.

11:40 AM U5.7
NON-COMPACT COMPOSITE WITH NON-SPHERICAL GRANULES: LOGARITHMIC FIELD DEPENDENCE OF GIANT MAGNETORESISTANCE
E. Meilikhov, Russian Research Center Kurchatov Institute, Moscow, RUSSIA; B. Roquet, Laboratoire de Physique de la Matiere Condensee de Toulouse, Toulouse, FRANCE.

In the present paper, we consider the giant magnetoresistance of the nanocomposite Fe₃O₄/SiO₂—i.e., which is the granular ferromagnetic metal in the insulating matrix with x>0.6 (this corresponds to the state close to the percolation transition metal-insulator). Experiments show that at high enough magnetic fields, the resistance of the system depends logarithmically on the magnetic field. Such a dependence does not fall into the framework of the known theory of the giant magnetoresistance of ferromagnetic nanocomposites. We relate this unusual feature to the fact that the “traditional” theory is applied to systems with spherical granules, while real nanocomposites consist most commonly of non-spherical ones. Moreover, as a rule, there are granules of diverse non-sphericity in the system — from strongly prolate to the strongly oblate ones. This paper examines the giant magnetoresistance of such a system in terms of a simple model where the non-ordinary semi-logarithmic magnetic field dependence of nanocomposite magnetoresistance is related to the non-spherical particle distribution over their shapes.

11:15 AM *U5.8
SYNTHETIC AND PROPERTIES OF HYBRID HIGH-TEMPERATURE NONSTRUCTURED MAGNETS
D.J. Sellmyer, J. Zhou, H. Tang, R. Skomski, Behlen Lab of Physics and CEE for Materials Research and Analysis, Univ of Nebraska, Lincoln, NE.

We report studies of novel Sm-Co-based microstructured magnets with excellent high-temperature properties. Two classes of materials have been synthesized. The first is Sm-Co/Cu-Ti hybrid magnets which are two-phase mixtures of 2-17% Ti-Co magnets support a Sm-Co-Cu inter-granular region [1]. The typical dimensions of the main and boundary phases are 70 nm and 10 nm, respectively. A positive temperature dependence of the coercivity Hc observed with maxima in the 400-500°C range. Hc values at 125 Koe at 500°C have been the highest known values at this high temperature. A theoretical model involving wall pinning provides a qualitative understanding of the unusual Hc(T) behavior. The second class of material is reported in mechanically milled Sm/Co/Zr/magnet with grain sizes in the 10-20 nm region and with the ordered TiCo₂Zr structure [2]. The Zr stabilizes and refines the nanostructure leading to Hc values up to 21 Koe and [Hc] values up to 15 Koe at room temperature. Magnetic properties provided enhanced hard magnetic properties through the use of amorphous intergranular exchange coupling.

Research supported by DOE under grant DE-FG03-88ER45573, DMR/ARO under grant DAAH04-98-1-0298, and AFOSR under grant F49620-98-1-0098.


SESSION I/6.Y7. JOINT SESSION
MAGNETIC PROPERTIES OF NANOMATERIALS
Chairs: James E. Hutchinson and Franciska Groen
Thursday Afternoon, April 19, 2001
Metropolitan II (Argenta)

1:30 PM *U6.1/Y7.1
MAGNETISM IN THE NANOTECHNOLOGY WORLD
Robert D. Shull, Magnetic Materials Group, National Institute of Standards and Technology, Gaithersburg, MD.

The National Nanotechnology Initiative (NNI) in the United States this year has caused renewed attention to the area of nanometer length-scale materials and devices, even引起了 the question of the "Is there really a magnet in this activity?". Here, a description will be presented of the properties and applications of magnetic materials possessing nanometer-thick films, particles, or crystals of a magnetic material intrinsically mixed with nonmagnetic or semiconducting materials. Such nanoscale morphology has been found to result in novel magnetic behavior. Why does this occur and how will it impact your present and future lives? Particular attention will be devoted to the fabrication and use of magnetic "micromagnets" for magnetic recording. In this application, use is made of a novel phenomenon called the "Giant Magnetoresistance (GMR) Effect" which provides strong magnetic switching behavior for magnetic recording. This technique, in addition to being an important component of magnetic structures and applications also pioneered at NIST. As a result of this presentation, it should become obvious what makes magnetism a particularly special case for nanotechnology excitement.

2:00 PM U6.2/Y7.2
SUPERPARAMAGNETISM AND MICROSTRUCTURAL PROPERTIES OF CARBON ENCAPSULATED Ni NANO-PARTICLE ASSEMBLIES
Xiaobin Cheng Sun, J.A. Toledo, Prog.
Superparamagnetism is a unique and important feature of magnetic nanoparticles. Novel carbon encapsulated Ni nanoparticles offer us great opportunities for studying the mechanism of superparamagnetic properties.

Carbon encapsulated Ni nanoparticles were synthesized by modified seed-discharge reactor under methane atmosphere. The presence of carbon encapsulation was identified by HR-TEM lattice imaging, nanodiffraction, and Mössbauer spectroscopy. A cores-shell nanocrystal typically has 16.3 nm with spherical shape, neither gaps nor intermediate phases were observed between the outer carbon layers and the core metallic Ni nanocrystals. The intimate and contiguous carbon fringes around these Ni nanocrystal particles is good evidence for complete encapsulation by carbon shell layers.

Superparamagnetic properties studies for an assembly of carbon encapsulated in nanoparticles using DVM (VSM) magnetometer. The field-cooled (FC) and zero-field-cooled (ZFC) magnetization measurements display a divergence below the blocking temperature at a certain applied magnetic field. The blocking temperature $T_B$ is an interfacial interaction. This work deals with novel $g$ values of magnetic and structural phase transitions in iron oxide nanocrystal systems induced by interface and strain effects. New nanostructures systems composed of sfs, gamma-iron oxide nanocrystals with sizes of 25-50 nm were synthesized by solid-state chemical reaction. The systems were loaded by shear stress (250 grade) under high pressure (up to 20 Kbar) as well as by the stresses combined with polymerization in acrylamide. The nanostructures were found to compose of nanocrystals that interact with each other and matrix. The magnetic properties of systems were determined by intercluster interaction, by density of defects in clusters and by intercluster strain. We observed new type of magnetic phase transition: jump-like first order magnetization transition at which the magnetic relaxation and magnetic order disappeared by jump with temperature at $T_{c}=120-300 K$ (for the bulk is ~900K). The studied nanostructures showed collective transition into the unusual twin structure just above the Morin temperature, $T_m$, typical of a ferric oxide. The values of $T_m$ were found to vary from 120 to 260K depending on intercluster interaction. An action of shear stress under high pressure leads to phase transition and the character of magnetic phase transition (first or second order phase transition) depending on the presence or absence of polymeric matrix. For nanocrystals of 25-50 nm in size the character of magnetic phase transitions and variation of the Curie or Neel points were treated and explained by the thermodynamic model of magnetic phase transition with regard for intercluster strain effects, intercluster interaction and density of defects.

2:30 PM U6.4/Y7.4

**PRODUCTION OF MAGNETIC-ORDERED SPIN SYSTEMS BY THE FORMATION OF TWO-DIMENSIONAL OXIDE NANOSTRUCTURES OF VARIOUS TOPOLOGY ON THE SILICA SURFACE.** Vladimir M. Smirnov, Igor V. Maren, S. Petersburg State University, Dep. of Chemistry, S. Petersburg, RUSSIA.

Theoretical bases and experimental data confirmed a possibility of a synthesis of ordered spin systems are discussed. A possibility of a synthesis of ordered spin systems is confirmed. Chemical designing of specific steric arrangement of surface atoms in the matrix of two-dimensional nanocrystals is considered as the base of the procedure. In the instance of oxide nanostructures we evaluate a possibility to use the resources of modern precision synthesis for the dissolving the production problem of solid chemical compounds with various steric distribution of atomic groups in high order artificial substance like oxide superlattices. The phenomenon of two-dimensional ferromagnetism which was discovered by us is discussed.

Two-dimensional magnetization area is supposed to arise from magnetization of certain amount of $Fe^{3+}$ - $O_2^-$ groups on the surface of magnetic support. Problems of production of high ordered spin systems are considered in the relation to magnetic properties of two samples series: i) two-dimensional oxide nanostructures containing in the plane of two-dimensional nanocrystal structure various element-oxygen monolayers with their designed ratio ($Fe^{3+}$, $O$ and $Fe^{2+}$, $O$, $Fe^{3+}$, $O$, $Ni^{2+}$, $O$, $Fe^{3+}$, $O$, $Ni^{2+}$, $O$ and $Ti^{4+}$, $O$ etc.); ii) two-dimensional oxide nanostructures containing alternating element-oxygen monolayers of various chemical composition ($Fe^{3+}$, $O$ and $Fe^{3+}$, $O$, $Fe^{3+}$, $O$, $Ni^{2+}$, $O$, $Fe^{3+}$, $O$, $Ni^{2+}$, $O$, $Fe^{3+}$, $O$, $Ti^{4+}$, $O$ etc.), the monolayers are deposited in the designed order.

The data obtained confirm a possibility to control/directly the ordered spin states (states of magnetic moments) with given oxide nanostructures. Work is supported by RFBR (RUSSIA) under the Grant No. 99-03-32301.

2:45 PM U6.5/Y7.5

**NANOCLUSTERS IN METAL NANO NEEDLES MADE BY NON-AQUEOUS ELECTRODEPOSITION.** C.S. Yang, A. Sokolov, J.R. Jennings, J. Redpenning, B. Doudin Dept. of Physics and Astronomy, Dept. of Chemistry, University of Nevada Lincoln, Lincoln, NE.

This research investigates the synthesis and properties of magnetic materials made by electrodeposition in non-aqueous solvents. Very little is known on this synthesis method, mostly because aqueous deposition is easy. However, the deposition process has been found to be of primordial importance when plating over a thin oxide for the purpose of making tunnel junction by electrochemical methods. Our initial research concentrates on the magnetic properties of nanometer-sized wires, of diameters down to 30 nm, obtained by template synthesis in filtering membranes. Wires have the ideal needle-type geometry for which the shape contribution of the magnetic micromotors is dominant. Our results show surprisingly small crystallite size when using different solvents. Wires of Co plated on an ethylene glycol solvent show properties similar to those observed with aqueous solutions. However, a decrease in magnetization and coercive force for the other solvents is evident. Electron microscopy studies show that the crystallite size is not exceed 3 nm for the DMF produced Co, and even lower for the acetonitrile bath.

Non-aqueous plating offers a unique possibility to fabricate magnetic materials with very low crystallite dimensions. The decrease of the saturation magnetization is more likely due to an increasing number of Co surface atoms. A model of chain-of-sculpture becomes more accurate to explain the magnetic properties of lower crystallinity samples.

3:30 PM U6.6/Y7.6

**FROM NEAR-SURFACE AND INTERFACE MAGNETISM TO THE MAGNETISM IN SMALL PARTICLES.** P. Stahil, M. Ghasri, H. Huhn, Darmstadt University of Technology, Institute of Material Science, Darmstadt, GERMANY.

To understand magnetic phenomena in small particles not seen in bulk materials, especially in the vicinity of critical points, surface, interface, shape, volume and structural effects have to be taken into account. Experiments on different particle sizes in order to distinguish these effects have to start with infinite large particles, i.e. the near-surface region of single crystals and interfaces of layered structures. These nearsurface and interfaces generate a significant contribution to the magnetic properties of particles in the nanorange. From this it is clear that the experimental methods have to cope with this scaling with respect to depth resolution, magnetic and structural characterisation. This gives the field a largely interdisciplinary character, especially if one aims at applications as is the case for instance in magnetorenseism devices. Experiments on the near-surface magnetism of single crystals as well as on nanostructured materials will be presented, laying special attention on a surface-sensitive and depth resolved neutron scattering technique.

4:00 PM U6.7/Y7.7

**SIZE-DEPENDENCE OF MAGNETIC PROPERTIES OF BISMUTH FERRITE NANOPOWERS.** H. He, J. Li, Lanzhou Univ. Dept of Materials Science, Lanzhou, CHINA.

BFeO$_3$ is a magnetoelectric material in which antiferromagnetic and ferroelectric orderings coexist. BFeO$_3$ has a cycloidal spiral modulated magnetic structure with an abnormal long period of 62 nm. So it would be interesting if the crystal dimension decreases to nanometric scale, especially below 62 nm. BFeO$_3$ nanopowders with average grain sizes from 20 to 60 nm are supposed to be single-crystal particles and have narrow size distributions. The cell edge increases...
markedly and the axis angle deviates increasingly from 60° as the particle size decreases. The change of magnetic susceptibility with temperature is characteristic of antiferromagnetic ordering. However, its high magnitude is indicative of weak ferromagnetism. The magnetization and magnetic susceptibility increase with decreasing particle size. Møssbauer studies reveal that the spin ordering angles in the antiferromagnetic and ferrimagnetic phases are different. The magnetic structure in these particles is an uncompensated antiferromagnetic spin ordering. Therefore, as the particle size decreases, the lattice distortion, the spin canting, and the weak ferromagnetism of the BiFeO₃ nanoparticles increase.

4:15 P.M. #U6.8/VT.8
MAGNETIC BEHAVIOUR OF INTERACTING SUPERPARAMAGNETIC FERROFLUIDS. Wolfgang Voit, Royal Institute of Technology, Engineering Materials Physics Division, Stockholm, Sweden.

We present a magnetic study of ferrofluids containing superparamagnetic magnetite (Fe₃O₄) particles in a size range from 6 to 10 nm. The iron oxide particles were produced using a controlled co-precipitation technique, prepared with a deliberate oxidation of Fe₂⁺. After coating with sodium oleate or PVA, the nanoparticles were dispersed in a water-based solution forming a stable ferrofluid. The magnetic properties of ferrofluids with different particle concentration were studied using a superparamagnetic and magnetic susceptibility, and compared to the magnetic properties of the solid iron oxide nanoparticles. The measurements reveal a dependence of the blocking temperature on the particle concentration. In addition, the superparamagnetic and magnetic susceptibility of the ferrofluids show irregularities near the transition point from the frozen to the liquid state for ferrofluids, due to different relaxation mechanisms (Néel relaxation and Brownian relaxation). The AC susceptibility measurements in the frequency range from 1 Hz to 4 kHz complement this study. A correlation of the magnetic properties to the chemical environment around the particles is investigated. Recent results of these studies will be presented.

4:30 P.M. #U6.9/VT.9
MAGNETIC PROPERTIES OF SINGLE MOLECULE MAGNETS. Andrew D. Kent, Louis Bokhoven, Dept. of Physics and Marc Walker, Dept. of Chemistry, New York University.

Single molecule magnets (SMMs) are a new type of magnetic nanomaterial that consists of a core of strongly exchange-coupled transition metal ions with a large collective magnetic moment per molecule. These molecular magnets enable experimental studies of monodisperse ensembles of nmagnets with well-defined size, shape, chemical composition, and magnetic anisotropy. Such materials are of interest for the study of the interplay between classical and quantum effects in nanomagnets, as well as potential applications in quantum computing. This talk will present results of our recent magnetic studies of the crossover between thermal-activity dominated magnetization (classical) and quantum tunneling of the magnetization in the prototype SMM Mn₁₂₆acetate [1]. Some open questions in magnetic quantum tunneling in SMMs and perspectives for new SMM materials will also be discussed.


SESSION U7: MAGNETOSTRICATION
Friday Morning, April 29, 2001
Golden Gate B3 (Marriott)

8:30 A.M. #U7.1

Very large field-induced strains (ε ~ 6%) have been reported for Nb-Mn-Ga single-crystal ferromagnetic shape memory alloys (FSMAs) at room temperature [1]. While these materials show the conventional thermoelastic shape memory effect upon transformation to the high-temperature phase, the magnetostrictive induced strain occurs fully within the low-temperature, martensitic phase. Fields of 320 to 400 kA/m (4 to 5 kOe) are sufficient to produce the maximum strain under opposing stresses of order 1 MPa. The blocking stress (stress at which field-induced strain is zero) observed here is approximately 2 MPA but can be up to 10 MPa. These strains are not magnetostriuctive in origin but arise rather from field-induced motion of twin boundaries in the martensitic phase [2]. An effective magnetic field in the martensite phase has induced this motion. However, its high magnitude is indicative of weak ferromagnetism. The magnetization and magnetic susceptibility increase with decreasing particle size. Møssbauer studies reveal that the spin canting angles in the antiferromagnetic and ferrimagnetic phases are different. The magnetic structure in these particles is an uncompensated antiferromagnetic spin ordering. Therefore, as the particle size decreases, the lattice distortion, the spin canting, and the weak ferromagnetism of the BiFeO₃ nanoparticles increase.

9:00 A.M. #U7.2
S ועלים AC FIELD INDUCED MECHANICAL ROTATION IN MAGNETOSTRICTIVE AMORPHOUS Fe-Bi wires SUBJECTED TO THERMAL TREATMENT. V. Rupalo, A. Mitra and M. Vásquez, Instituto de Ciencia de Materiales de Madrid (C.S.I.C.) and Instituto de Magnetismo Aplicado UCM-RENFE, Madrid, Spain. National Metallurgical Laboratory, Jamshedpur, India.

An interesting new phenomenon has been recently observed in magnetostriactive amorphous and polycrystalline wires [1, 2]. It consists of the spontaneous rotation of the wires when submitted to an AC axial field. The rotation, observed at certain amplitudes and frequencies of the applied field, is believed to appear due to interactions between the eddy currents and magnetostriactive nanometric wave. In the present work rotational characteristics of amorphous Fe₇₆Si₁₆Bi₈ wires in their as-cast and heat-treated state has been investigated. The experimental results on the as-cast state indicate that the spontaneous rotation occurred at 5.5 kHz magnetizing frequency. At constant rotational speed the as-cast wire was at 8 kHz and observed at the magnetizing frequency of 2 kHz. In the 700 kHz annealed wire, the rotational speed increased and rotation of the wire was observed at more applied frequencies than the as-cast one. In fact it appeared to be a continuum with respect to the applied frequency with variation in rotational speed of the wire. The maximum rotational speed in annealed samples was at 8 kHz and observed at 2 kHz applied field. Applied magnetic field amplitude dependence of the rotational characteristic was also investigated using 1 kHz magnetizing field. Rotation of as-cast wire started at critical applied field of 0.3 kA/m and the speed was 3 kHz. Critical applied field decreased to 0.2 kA/m when the sample was annealed at 700 kHz. The change in rotational characteristics of the wires is due to the relaxation of quenched-in internal stresses by annealing.


9:15 A.M. #U7.3
EFFECTIVE MAGNETOSTRICATION OF NONCRYSTALLINE MAGNETIC MATERIALS: INDENTATION EFFECTS. W.-W. W. New, Department of M&E, Tsinghua University, Beijing, CHINA, G.J. Weng, Department of Mechanical and Aerospace Engineering, Rutgers University, New Brunswick, NJ.

Recently, nanocrystalline Fe-based alloys, such as FeZrBα, MnZr nanocrystalline alloys, consisting of nanocrystallized materials grown in their amorphous precursors, show excellent soft magnetic properties which are considered to be attributed to the absence (or very small value) of magnetostriction due to nanocrystalline structure. An effective-medium type method is developed for the effective magnetostriaction of nanocrystalline magnetic alloys based on the successful Green’s function technique. A more general, explicit relation for determining the effective magnetostriaction of nanocrystalline alloys is derived, and it recovers those previous Reuss-type approximations in the special cases. For illustration and comparison, calculations for the effective magnetostriaction of nanocrystalline Fe₅₀Zr₂₅B₂₅ alloy are given. The effective-medium type formula is more applicable to consider the interfacial effect.

9:30 A.M. #U7.4
OBSERVATION OF PATTERNS BY MAGNETIC FORCE MICROCOPY IN Fe-AlLOYS WITH SHAPE MEMORY EFFECT. M.N. da Silva, J.C. Gonzalez, North Carolina State University, Aeronic Instrumentation Facility, Raleigh, NC. Laboratorio de Nanociencia, Setor de Tecnologias de Materiais, CDTec, Av. José Candido da Silveira, Belo Horizonte-MG, BRAZIL.

In this work we make a study of the magnetic domain in a Fe₈₅Si₂₅N₂₅ stainless steel sample using the MFM technique. We
compared the patterns obtained by scanning the sample with three different coated tips: standard MMF, LM (low magnetization), and LC (low coercivity). The tip surface was varied in the range from 300 to 1000 nm in order to quantify the magnetic microstructure of the sample, using a simple domain model. This model showed that the average maximum frequency decreasing with the tip-surface separation, for the three tips using the same frequency calibration, is stronger for standard MMF and decrease for LM and LC tips. Using X-ray diffraction, we identified only two phases in the sample: y-phase (paramagnetic phase) and a magnetic phase, and that the patterns seen in MMF image are due to the sample's magnetic phase.

9:45 AM U7.5
TAILORED MAGNETIC PROPERTIES OF GLASS COATED MICROWIRES. Araceli P. Zhukov, Donostia International Physics Centre, San Sebastian, SPAIN; J. Gonzalez, Departamento de Fisica de Materiales, Facultad de Quimica, San Sebastian, SPAIN; V. Zhukov, J. M Blanco, Opto. Fisica Aplicada I, EUTIT, Univ. Pais Vasco, San Sebastian, SPAIN.

The Taylor-Ulitovski technique has been employed for fabrication of ferromagnetic amorphous and nanocrystalline metallic wires covered by an insulating glass coating with magnetic properties of great technological interest. A single and large Barkhausen jump is observed for Fe-rich microwires with positive magnetostriiction. Negative Co-rich magnetostriiction microwires exhibit almost un hysteretic behavior with an easy axis transverse to the wire axis. Enhanced magnetic softness (initial permeability to 14000) and Giant Magnetic-impedance effect (GMI) up to 140% at 10 MHz was observed in amorphous Co-based microwires with nearly zero magnetostriiction. After adequate heat treatments, the permeability of GMI and magnetic characteristics on external tensile stresses has been observed. The effect of conventional furnace and DC current annealing under DC axial magnetic field or without it on the magnetic properties of the coated microwires has been studied. The applied magnetic field (field annealing) can improve significantly such magnetic parameters as coercivity or magnetic permeability. Such phenomena can be interpreted considering the noticeable magnetic anisotropy induced by the combined effects of the applied magnetic field and internal stresses originated from the coating during the annealing. Upon heat treatment, FeSiBCoNi amorphous microwires devitrificate into nanocrystalline structure with enhanced magnetic softness. Such nanocrystallization process depends on internal stresses induced by the glass coating and on chemical composition. The magnetic bistability has been observed even after the second crystallization process in particular cases. The switching field can increase up to 5.5 kA/m for first or second crystallization processes. Hard magnetic microwires with coercivity up to 60 kA/m were also obtained as a result of decomposition of metastable phases in Co-Ni-Cu and Fe-Ni-Cu.

10:30 AM U7.6
MAGNETOSTRICTIVE MULTILAYERS FOR SENSOR AND ACTUATOR APPLICATIONS. Eckhard Quantiert, Markus Loehneder, Alfred Lustig, Michael Tews, Center of Advanced European Studies and Research, Bonn, GERMANY.

Magnetostriuctive thin films are an attractive class of materials to realize microactuators in miniature size. Since the possibility of wire-based, high frequency operation, simple design, and a cost-effective manufacturing technique using magnetron sputtering, an essential development is achieved with the preparation of layered thin film materials, which allow e.g. the control of the magnetic and electric properties as well as the microstructure in a wide range by combining different materials. In the case of micro-actuators e.g. for microfluidic devices, ultrasonic motors, or laser scanners, multilayers consisting of alternating layers with positive and negative magnetic anisotropy and nanocrystalline soft magnetic Fe-Co layers have a very high magnetization present a spring-magnet-type system which shows very high magnetostriiction energies at low fields. The thickness of these multilayers can be reduced as compared to single layer materials due to the increased magnetostriction and the reduced anisotropy while keeping relatively large values of the magnetostriction. In general, applications of these materials require a low defined uniaxial anisotropy, which can be obtained by a magnetic bias field during deposition or by annealing under a magnetic field. In the case of microsensors for mechanical quantities like torque the magnetostriuctive thin film material is used as core in a microtorque meter, where the combined use of magnetic and capacitive impedance effect. With either techniques it is possible to detect mechanical stresses over large distances by a radio-link, preferably at a frequency of 2.5 GHz. Co-Ni-Fe-Co multilayers were found to be a suitable candidate for magnetostrictive film material due to their high permeability, their high magnetic polarization, their small coercive field, and their high magnetic anisotropy resulting in a cut-off frequency in extent of 2.5 GHz. The magnetic properties (magnetization, magnetostriiction, permeability, ferromagnetic, c., of permeability) of both types of magnetostrictive multilayers will be discussed in view of possible applications as micro-actuators or sensors.

11:00 AM U7.7
DOMAIN STRUCTURE OF THICK AMORPHOUS MICROWIRES WITH NEARLY ZERO MAGNETOSTRICTION. Horii Chirico, Toshi-Adrian Oumi, National Institute of Research and Development for Military Physics, Iasi, ROUMANIA; M. Yokonobe, Institute of Technology, Dept. of Electrical Engineering, Kanda, JAPAN; Jiro Yamaski, Kyushu Institute of Technology, Dept. of Electrical Engineering, Tokara, JAPAN.

Near-zero magnetostrictive glass coated microwires (l = 1 x 10^7) are suitable materials for sensor applications. Samples with metallic core diameters below 25 µm exhibit a typical hysteresis loop with zero magnetostriction that was related to the magnetic structure of the domain wall with circumferential easy axis. The magnetic behavior of these microwires is changing drastically when the metallic core diameter increases over 25 µm, i.e., they display a bistable magnetic behavior at low fields, thus a one step magnetization reversal at a certain value of the applied field, called switching field. In this paper, results on the direct domain observation in nearly zero magnetostrictive Co84Fe12Si6 glass-coated microwires by means of Kerr microscopy are reported for the first time. Samples of different transverse dimensions, but with the metallic core diameter over 25 µm, and fixed length (7 cm), have been investigated. The effect of glaess removal on the domain structure has been also studied. AC hysteresis loop measurements have been employed to establish a relation between domain structure and magnetic behavior. Glass-coated microwires exhibit a single domain configuration with the magnetization pointing mostly to the wire axis. The domain structure does not change qualitatively with glass removal, but the parameters of the squared hysteresis loops are modified. The remanence to saturation ratio increases after glass removal, while the switching field decreases. For a microwire with the metallic core diameter of 34 µm and the glass thickness of 33.5 µm, the remanence to saturation ratio increases from 0.8 to 0.88 after glass removal, while the switching field decreases from 31.5 kOe to 27.7 kOe. The obtained results are of interest for sensor applications, and show that the metallic core diameter is a fundamental factor which contributes to important changes in the domain structure of such microwires.

11:15 AM U7.8
MAGNETIC SHAPE MEMORY EFFECTS INDUCED BY NANO SCALE COLUMNAR GRAIN. Yoshikazu Nishi, Hiroshi Yabe, Horu Hisa, Uchida, Yasuito Momma and Hirosh Uchida, Tokai University, Showa Campus, Hiratsuka, JAPAN.

Rapid vapor deposition often forms the oriented directional textures. In order to obtain giant magnetostrictive, a Fe-Ni-Co amorphous incoherent shape memory alloy were prepared by magnetron sputtering process to form the thin film of the fine nano scale columnar structure, which shows magnetostriiction of crystal orientation. The fine nano scale columnar grained 100 nm was observed by near edge x-ray photoemission. The reversible relationship was obtained between magnetostriction and applied magnetic field. Since the magnetostrictive susceptibility was higher than that of Tb0.6Dy0.2Fe0.2 thin film, the highest magnetostrictive susceptibility for this film was detected at low magnetic field at room temperature.

11:30 AM U7.9
X-RAY MAGNETIC LINEAR DICHROISM OF Fe-Ni-AlLOY S ON Cu(111). Tracey F. Johnson, S. Chiang, Y. Sato, J.D. Shne, J.A. Ganci, G.E. Huyler, X.D. Zhu, University of California Davis, Dept. of Physics, Davis, CA; D.P. Land, University of California, Davis, Dept. of Chemistry, Davis, CA; M. Horschter, J. G. Tobin, Lawrence Livermore National Laboratory, Livermore, S.A. Morton, University of Missouri, Rolla, MO.

We are studying single-layer synthesis of ultrathin metal films by controlling nanolayer level the composition and structure of these films, including the interfacial region. We have prepared Ni2Fe multilayers on Cu(111) in order to better understand the giant magnetostrictive (GMI) effect of Fe layers on Co-Ni multilayers with magnetic disk drive heads. Using Undulator Beamline 7.0 and the X-ray Microscopy Facility (7.0.1.2) at the Advanced Light Source, we have measured x-ray magnetic linear dichroism (XMD) signals for five different thin Ni70Fe30 multilayers on Cu(111) with Fe composition ranging from 34% to 76%. The Curie temperature for all of these samples was in the range -25°C to -130°C, which is considerably lower than we previously seen for such films deposited on Cu(100). Further work is in progress to understand how magnetic anisotropy is a function of film thickness in addition to composition. We also plan to
compare the XMD and SQUID measurements of the magnetic
moments of these alloy films.

11:45 AM UT. 30
INDUCED SPIN POLARIZATION IN ANTIMONY OVERLAYS.
Takashi Komesu, C.N. Bocar, Hae-Kyung Jeong, R. Skomski, P.A.
Dowben, University of Nebraska-Lincoln, NE; Delia Ristoiu, J.P.
Nozieres, CNRS, Laboratoire Louis Neel, Grenoble, FRANCE.

We have investigated the induced magnetization of paramagnetic Sb
overlays on the Heusler alloy NiMnSb. From combined X-ray
absorption spectroscopy (XAS) and spin-polarized inverse
photoemission spectroscopy (SPIES) [1], we can assign some of the
unoccupied states of the Heusler alloy NiMnSb. With increasing
thickness of the Sb overlay, there is a decline in the density of states
near the Fermi energy, as expected for a semimetal overlay on a
metallic substrate and explained in context of a spin-dependent
envelope-function approximation (SEFDA) [2]. While the Sb is
polarized by the ferromagnetic NiMnSb substrate, consistent with the
expectations of mean field theory, the polarization at the center of the
surface/overlay Brillouin zone cannot be easily related to the
induced magnetization. The NiMnSb acts as a magnetic perturbation
and induces a spin polarization in the semimetallic Sb overlay. Due
to the small numbers of carrier electrons and holes, the perturbation
propagates deep into the overlay and can be described by SEDFA
[2]. It is argued that the range of the injection depth decreases with
increasing temperature and obeys a 1/(T)^1/2 law at high
_temperatures, i.e. well above room temperature. In addition, the
magentic behavior of the overlay is mapped onto a
Gilbert-Landau theory whose parameters are both band-structure
and temperature dependent.
[1] Takashi Komesu, C.N. Bocar, Hae-Kyung Jeong, P.A. Dowben,
Delia Ristoiu, J.P. Nozieres, Shane Studler and Y.U. Idzerda, Physics
Dowben, Delia Ristoiu, and J.P. Nozieres, submitted to J. Appl. Phys.