SYMPOSIUM S
Applied Magnetic Field Effects on Materials Behavior

November 27 – 28, 2000

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*Invited paper
When the magnetization force were nearly equal to the gravitational one, bubbles were observed to levitate if they were in microgravity environments. Furthermore, we numerically simulated the natural convection arising from the depletion of protein concentration around a growing protein crystal when an upward magnetization force acts on the crystals and obtained the following results: when magnetic gradient B(H/dz) = 685T/m is applied, the maximum flow velocity is reduced by about 50% and the velocity in the vicinity of the crystal is reduced by about 30%. When B(H/dz) = 370T/m, the upward magnetization force damp completely. Recentrifugation method was applied to the formation of protein crystals. When an upward magnetization force (50% of gravitational one) was applied, this was segregated from the mother solutions as seen from the integrations of X-ray diffraction data than those grown in the absence of the magnetic field. On the other hand, when a downward force was applied, the crystal quality was made for worse.

During the early development of vertebrates many complex structures like cell membranes form and remain, and others, like the microtubule arrays comprising the mitotic apparatus, disappear after fulfilling their role. Developmental success can depend critically on the microtubule properties and how, when, where they are fabricated. We are investigating the use of high static magnetic fields as an in vivo tool for studying processes and the mechanical properties of structures of the developing frog embryo, Xenopus laevis. The presence of the magnetic fields applied to the embryos is exerted forces comparable to gravity, using existing high magnetic field solenoids. I will compare the levitated state to an ideal low gravity state and discuss how large inhomogeneous magnetic fields might be used to probe gravitationally sensitive phenomena in biological systems. Also, I will discuss two well defined types of magnetic field induced anomalies in the early development of the embryos that depend systemically on applied magnetic field strength and orientation. First, the early cell cleavages tend to align with a magnetic field. Second, magnetic fields greater than 0.5 Tesla applied to an embryo during its first three cleavages can lead to severe gasterulation abnormalities much later in development. I will describe our efforts to determine which of the internal structures are influenced by the magnetic field.

A variety of new research opportunities are now obtainable with magnetic levitation techniques [1]. One unique possibility involves long-term (> 1 - 10 min., < 12 hrs.), low gravity (< 1 = 100 m/s², g = 9.8 m/s²). Earth-based environments that may be utilized to provide experiments for the Space Shuttle Station. Transgenic Arabidopsis thaliana plants, engineered with a stress response reporter gene, were magnetically levitated for 2.8 hrs., and the results suggest the presence of significant levels of stress that are similar to those observed on parabolic flights. Control experiments placed in strong, homogeneous magnetic fields, also indicated significant level of stress response. Additional studies have been performed in homogeneous magnetic fields up to 10 T, and the results indicate an increase in the stress response above 8 T. These preliminary results suggest magnetic fields in excess of 17 T may influence certain aspects of gene regulation. Thus, the possibility exists to use magnetic fields to investigate the effects of stress conditions that operate in this range, such as magnetic resonance imaging (MRI) devices [2], may not reflect native circumstances. Our results and future directions will be described.

Supported, in part, by the NSF through the In-House Research Program of the NIH/NIH.

Application of a field has been observed to cause very large macroscopic strains in ferromagnetic shape-memory alloys in two ways. The first is by dipolar-field-induced transformation from austenite to martensite. The field-induced shift in the martensitic transformation temperature is of order 1 degree per Tesla, consistent with the Clausius-Clapeyron equation. The second method of using a field to produce large strains is by field-induced twin boundaries within the tetragonal martensitic state. This causes a nearly 90° reorientation of the c axis. In either case, strains of order 1/4 are produced; for Ni-Mn-Ga SMAs, this amounts to 6% strain in 0.1 Tesla and for Nb-Cu-Al Ti SMAs 1.8\% in 1 Tesla. In the case of field-induced twin-boundary motion, the presence of mobile twins reduces the modulus nearly 10\% to about 20 GPa from that of the determined martensite (about 2 GPa). The 6\% deformation measured in martensitic Ni-Mn-Ga alloys using a proximity sensor is confirmed to be due to twin-boundary motion by high-speed videos taken during compression loading as well as during application of a field.

2:00 PM *S8.2* GRAIN BOUNDARY DYNAMICS IN HIGH MAGNETIC FIELDS. Dmitri A. Medvedev, Gunter Gosele, Inst of Physical Metallurgy and Metal Physics, Aachen Univ of Technology, Aachen, GERMANY; Lunar S. Shvindlerman, Inst of Solid State Physics, Russian Academy of Sciences, Chernogolovka, RUSSIA.

The movement of grain boundaries is one of the fundamental mechanisms of microstructure evolution during heat treatment of metallic materials. Therefore, control of grain boundary motion means control of microstructure evolution, which is a key for the design of advanced materials. Grain boundary motion can be affected by a magnetic field, if the anisotropy of the magnetic susceptibility generates a gradient of the magnetic free energy. In contrast to curvature-driven boundary motion, a magnetic driving force also acts on flat boundaries so that the motion of crystallographically fully defined boundaries can be investigated, and the true grain boundary mobility can be determined. By appropriate positioning and repositioning of the specimen in the magnetic field the grain boundary gradient can be changed and even inverted for the same boundary.

This allows for the first time to study symmetry effects of boundary dynamics. We will report in detail results obtained on Bi crystals. Crystallographically defined grain boundaries in Bi were fabricated and subjected to a high magnetic field. The grain boundary moved under the action of a magnetic driving force. The mobility of symmetrical and asymmetrical $90^\circ \times 112\,^\circ$ tilt grain boundaries was investigated. The driving force for grain boundary motion was due to the anisotropy of the magnetic susceptibility of Bi parallel and perpendicular to the trigonal axis. The boundary velocity increased proportionally with driving force. Owing to the known driving force the absolute value of grain boundary mobility could be determined. The grain boundary mobility was found to depend strongly on grain boundary inclination. The mobility of the asymmetrical grain boundary was found to depend on the direction of motion.

Implications for materials processing will be discussed.

2:30 PM **S8.3** SELF-ALIGNMENT AND FUNCTIONAL CONTROL OF MATERIALS THROUGH SOLID/SOLID PHASE TRANSFORMATIONS IN HIGH MAGNETIC FIELD. Hideyuki Ohtsuka, Yu Xu, Hiroshi Wada, Tsukuba Magnet Lab., National Research Institute for Metals, Tsukuba, Ibaraki, JAPAN.

Structural and functional control of materials through solid-solid phase transformations in a high magnetic field is summarized. As for the structural control, effects of high magnetic field on diffusional transformation behavior and transformed structure in Fe-based alloys have been investigated. The specimens used in this study are Fe-0.4C (mass\%) and Fe-1.5Mn-0.1Co-0.05Nb for ferrite transformation, and Fe-13Mn-1.8Cr and Fe-0.8C for pearlite transformation. Ferrite, pearlite and bainite transformation are all accelerated by a magnetic field. The acceleration of ferrite transformation is due to (1) increase of nucleation rate, (2) increase of growth rate at some temperature range and (3) decrease of austenite grain size by magnetic field, and the effect of (1) is the dominant factor. The Fe-C phase diagram was calculated under various magnetic fields using the susceptibility of ferrite and austenite at high temperatures, and by the Weiss's theory and it was found that (1) A3 temperature, (2) carbon content of ferrite and (3) eutectoid carbon content are all increased by magnetic field. The direction of lamella of pearlite observed on the specimen surface was affected slightly by a magnetic field. Effects of high magnetic field on transformed structure in austenite ferrite transformation were studied and it was found that aligned structure along the direction of applied magnetic field is formed in austenite to ferrite transformation. As for the functional control, the martensitic transformation in Ni-Mn-Ga alloy and iron-nitride is briefly mentioned.

SESSION S2: MAGNETIC ANNEALING
Chair: Robert Tournier
Monday Afternoon, November 27, 2000
Room 308 (Hynes)


Perhaps the ultimate magnetic field-induced effect in a material would be to cause such a dramatic change in its structure by application of a field that one or more of its physical properties were altered in a way achievable by no other means. This has now been demonstrated in certain shape memory alloys (SMAs) that are also ferromagnetic.

3:30 P M S 2.4
UNIAXIAL ANISOTROPY CHARACTERISTICS OF THE SPUN-CASTED FeTaN/Ti FILMS WITH MAGNETIC FILLED ANNEALING Jong-Hun Jeong, Seok Bae, Sung-Ryong Ryu, Seong-Eui Nam, Hyung-June Kim, Hong-Kuk Univ, Seoul, KOREA.

Characteristics of magnetic anisotropy in the soft magnetic thin films is an important factor for the application of magnetic thin film devices such as thin film recording heads and film inductors. We investigated the evolution of uniaxial anisotropy of soft magnetic FeTaN/Ti bilayers as a function of magnetic field annealing conditions. Ti underlayer was found to be important for obtaining the films with large anisotropy field (HK). The deposited films were amorphous, and subsequently crystallized to a monocrystalline structure leading to the outcome of soft magnetism during post-deposition annealing at 400°C and for during the subsequent anisotropy rotation annealing at low temperature of 50°C -300°C. The maximum HK value of 13 Oe could be obtained after crystallization of FeTaN/Ti bilayer. Subsequently longitudinal magnetic field shows little effects on the HK value up to the annealing temperature 400°C. On the other hand, consecutive transverse magnetic fields lead to the complete 90° rotation processes were carried out. An atomic model to explain the evolution of HK was also suggested.

3:45 P M S 2.5
HIGH TEMPERATURE MAGNETIC TEXTURING OF PERMUTITE-DOPED MATERIALS: L. Waidner 2, C. Borschak 1, and H. Garret 3,1. FAMU-FSU College of Engineering and MARTECH, National High Magnetic Field Laboratory; 2 Center for Nonlinear and Non-equilibrium Aero-Sciences, Tallahassee, FL.

Heat treatment under magnetic field has received a lot of attention in the past decade. This method of engineering new materials is very important for industrial applications. Here we present the results of heat treatment performed on a permunite matrix material. A field of 15 Tesla was applied both parallel and perpendicular to the sample. The recrystallization texture was studied by X-ray diffraction. Surface characterization was performed in an environmental scanning electron microscope (ESEM). The relationship of microstructure orientation and the applied field will be discussed.

4:00 P M S 2.6
EFFECT OF MAGNETIC FIELD ON THE FORMATION OF VARIANT STRUCTURE OF EQUATOMIC FePd, Kawasaki Trinaks, Tsutau Yoshikazu, Masahiro Keita, Dept of M&E, Kyoto Univ, Kyoto, JAPAN, Kazuo Watanabe, Inst for Materials Research, Tohoku Univ, Sendai, JAPAN.

The alloys of FePd, FePt and CoPt undergo an order / disorder (fcc) transformation. In general, three kinds of ordered variants which exist in fcc-disordered matrix are formed in the ordering process. In the absence of any external fields, these variants are expected to be formed with an equal probability. Since the L1o phase exhibit high uniaxial anisotropy anisotropy with the easy axis parallel to the c-axis, application of a magnetic field is expected to modify the relative population of these variants. Single crystals of ordered variants were ordered at various temperatures in magnetic fields up to 10 T. The direction of the magnetic field is set to the c-axis of a crystallographic direction to make the variant with the c-axis parallel to the magnetic field as the most energetically favored one. When the temperature of ordering treatment is higher than 780 K, a significant change in the variant structure is observed, a mono-variant structure of an L1o ordered phase is formed under a magnetic field of appropriate strength. The necessary conditions for the formation of the mono-variant structure are the ordering process by nucleation and growth process (the heat treatment temperature must be higher than the spinodal ordering temperature), and the magnetic-crystalline anisotropy energy is sufficient large to change the nucleation rates of different variants.

4:15 P M S 2.7
SOFT MAGNETIC PROPERTIES OF FeTaN/M [M = Ti, Ni, Cr, AND Co] BILAYER FILMS Seok Bae, Jong-Hun Jeong, Choong-Sik Kim, Seong-Eui Nam, Hyung-June Kim, Hong-Kik Univ, Seoul, KOREA.

Recently, many worker have reported the FeTaN nanocrystalline films show good soft magnetic properties as well as high magnetization saturation. For practical application of these films for various magnetic devices, easy control of magnetic anisotropy is important. We previously reported that addition of Ti underlayer in conjunction with magnetic field annealing enhances the film uniaxial anisotropy of FeTaN films. However, detailed mechanism for the enhancement has not been reported. Here, to further investigate the effect of underlayers, we compared the magnetic properties of FeTaN/M (M = Ti, Ni, Cr, and Co) bilayer films with magnetic and non-magnetic field annealing, and correlate them with film stresses and crystallographic texture of α-Fe phases. While Ti and Cr underlayers improve the soft magnetic properties and increase the HK compared with FeTaN/M films, Co and Ni show the opposite trends. Ti underlayer gives best magnetic properties, i.e., highest saturation magnetization and lowest coercivity. Also, Ti leads to the highest anisotropy field (HK) up to 13 Oe. We found that changes of magnetic properties are closely related to the residual tensile stresses. That is, magnetic field annealing always increases the residual tensile stresses compared with non-magnetic field annealing. Furthermore, the HK is decreased as residual tensile stresses of FeTaN/M films are also discussed with emphasis of ferromagnetic resonance limited frequency dependency.

SESSION S3 POSTER SESSION
PARTICLE SUSPENSION IN A DC OR AC MAGNETIC FIELD Chair: Eric Benaglia
Monday Evening, November 27, 2000
8:00 PM
Exhibition Hall D (Hynes)

S3.1 BEHAVIOR OF MICRO-OBJECTS IN SOLUTION UNDER THE INFLUENCE OF MULTIPOLAR SYSTEMS OF ALTERNATING MAGNETIC FIELDS AND ELECTRIC CURRENTS Andrew Z. Zaum, Warren E. Collins, Don O. Henderson, Fisk Univ, Physics Dept, Nashville, TN.

Creation and application of multipolar systems of alternating electromagnetic fields are the parts of the new direction, called multipolar technology. Multipolar technologies provide wide spectrum of new approaches and applications in crystal growth, biophysics, particle alignment and others. We have studied the behavior of various micro-objects (glass beads, metal powder, and living microorganisms) inside multipolar systems, having various symmetry. Experimentally the multipolar system, having symmetrical 'star' configuration, was created as a number of solenoids or electrodes, powered by 3-cascade system of coupled transformers, working at frequencies 15 Hz - 30 kHz. Micro-objects, suspended in the solution, were placed in the zone inside of multipolar system. We have studied patterns and quasi-crystals, created by alignment of micro-objects under different parameters: concentration of solution, frequency and amplitude of field or current, spatial system balance. In the case of living microorganisms, besides pattern formation experiments indicated significant increase of mitosis or gas production (200%) and more inside 5 and 4-polar systems, while in 3 and 2-polar systems population of microorganisms was decreased and solution became sterile. Obtained results and possible mechanisms are presented.

S3.2 MEASUREMENT OF MAGNETIC SUSCEPTIBILITIES OF A PARTICLE IN A LIQUID PHASE UNDER THE MAGNETIC FIELD GRADIENT IN THE SUPERCONDUCTING MAGNET Kenji Shinohara 1,2, Kunihiro Hishimoto 3, Yoichi Aogaki 1

1National Research Laboratory for Magnetic Science, Japan Science and Technology Corp., Saitama, JAPAN; 2RCAST-The University of Tokyo, Tokyo, JAPAN.

A new method for the measurement of the magnetic susceptibilities of particles in liquid phase and related to their separation was proposed. It is well known that the magnetic force is induced even on the non-magnetic materials with paramagnetism or diamagnetism under high magnetic gradient, whereas a flowing liquid drag them by the hydrodynamic force. Therefore, by balancing the magnetic forces acting on such particles with hydrodynamic forces, according to the difference of their susceptibilities, we can precisely determine the magnetic susceptibilities of the particles and also separate each other without any direct contact. In this paper, the formulation of this method is firstly presented. Then, the experimental result for a polystyrene micro-sphere is compared with the value obtained from the data in the literature.

S3.3 CONSOLIDATION OF WC/Co COMPOSITES IN THE MAGNETIC FIELD AT MICROWAVE FREQUENCY. Jing Cheng, Rastum Roy, and Dinesh Agrawal, Materials Research Laboratory, Pennsylvania State University, University Park, PA.

During the past decades, in the microwave processing of materials research area, all authors have just dealt with the microwave-materials interaction as due to the dielectric losses of
materials in the microwave electric field. Using a fine-tuned single mode microwave cavity, the microwave energy can be separated into two physical fields, a pump and a probe magnetic field. By this means we have been able to prove conclusively that in many materials the magnetic losses are more important than the electric losses. In this study, a small WC/Co powder compact sample was located in the pure microwave magnetic field and heated up to 1400°C in an inert atmosphere. It was found that the magnetic field, not the electric field, is the main energy source to heat the WC/Co composite at low temperatures in the microwave processing. The considerable slowing of the grain growth of the WC/Co samples in the pure microwave magnetic field were studied and compared with that of conventionally processed samples.

S3.4 TURBULENT TRANSITION IN ELECTROMAGNETICALLY LEVITATED DROPLETS: R.W. Hyers, NASA Marshall Space Flight Center, Microgravity Materials Science, Huntsville, AL; B. Abeles, Tufts University Department of Medical Engineering, Medford, MA; C. Trapani, D.M. Meson, Massachusetts Institute of Technology, Dept. of Materials Science and Engineering, Cambridge, MA.

Electromagnetic levitation (EML) is an important tool in materials research. Because a sample can be processed without contact with a container, experiments may be performed on high temperature, highly reactive, and undersaturated liquid metals. Many of these experiments are affected by fluid flow in the sample, driven by the electromagnetic positioning force. Despite the importance of convection in these experiments, the transition to turbulence is not well understood in this system. However, we have observed a transition from laminar to turbulent flow in droplets in the course of microwaving experiments in TEMPOS on the Space Shuttle [STS-94]. The transition occurs repeatedly and over a narrow range of conditions. These experimental observations are compared with two competing theories about the transition to turbulence. Also, the results of a particle tracking study of the instabilities leading up to the transition to turbulence are presented.

S3.5 DAMPING OF THERMAL CONVECTION IN NONCONDUCTING AND LOWCONDUCTING FLUIDS BY APPLICATION OF A STATIC MAGNETIC FIELD: Nobuko I. Watanabe, Ji-Soo Qi, Chengwen Zhong, Dept of Physical Chemistry, National Institute of Materials and Chemical Research (Core Research for Evolutional Science and Technology, Japan Science and Technology Corporation), Tsukuba, JAPAN.

Lorentz force caused by external magnetic fields has been widely used to damp convection of molten semiconductor materials. However, this method cannot be applied to electrically nonconducting or low-conducting fluids which Lorentz force does not exert, for example, melts of inorganic oxides, organic solvents and aqueous solution of proteins. In the present study, we will report a new method for damping convection in such material by applying a magnetic field gradient. Magnetization force caused by a magnetic field gradient is a body force and is proportional to density. Therefore, it is possible to damp convection by applying an upward magnetization force. Most materials are magnetic and require magnetization measurement on them. For evaluating this method, first, we numerically simulated thermal convection (R=33734) in pure water which is diamagnetic and nonconducting. When B=1/T²/m, convection was damped and the maximum velocity was decreased by about 50%. Thermal convection was damped with increasing B=1/T²/m. Numerical simulation was also conducted in a lowconducting fluid (25% NaCl aqueous solution, 21 Ohm·m⁻¹) when B=1/T²/m was 573 T²/m, and the contribution from magnetization force to damp convection was larger than that from Lorenz force. Furthermore, we numerically simulated thermal convection (R=33734) in a paramagnetic fluid (30% Gd(NO₃)₃ aqueous solution) on which magnetic attractive forces act on it. Therein, magnetic buoyancy was originated from the density difference but also the magnetic susceptibility difference, and the contribution from the latter was larger than that from the former. Therefore, it is possible to damp convection by applying a small value of B=1/T²/m. The visualization experiments of these phenomena will be also reported.

S3.6 MAGNETIC FIELD PROCESSING OF A NICKEL SUPERALOY: Robert F. Tournier, Sylvain Rakotosorain'no, Laboratoire de Cristallographie, Consortium de Recherches pour l'Emergence de Techniques Avancées, Centre National de la Recherche Scientifique, Grenoble, FRANCE.

The AMI nickel superalloy which has been used for magnetic processing mainly contains 63.3% weight of nickel, 7.4% of chromium, 8.2% of tantalum, 6.4% of cobalt, 5.7% of tungsten, 5.2% of aluminum and 3.3% of other elements. This alloy type is used by aeronautic industry in turbine vanes. Cylindrical samples have been previously melted and cast into a mold and by using a heated furnace before processing in an other resistance furnace and an alumina crucible submitted to a vertical magnetic field. The dendritic growth appears under moderate thermal gradients in the e 100 s privileged crystallographic directions. Heat treatments are made in the homogenous temperature furnace zone or in a thermal gradient applying or not a 5Tshal homogeneous magnetic field. The sample is fully melted during a 100 minutes temperature at 1360°C after a 410°C holding rate. The thermal treatment is realized in the temperature interval 1360-1280°C during a 50°C/h cooling rate. The microstructure study shows that dendrites have no specific orientation inside each sample which has been processed without applying any magnetic field and controlled thermal gradient. On the contrary, the dendrites are oriented along the 5 Tesla applied magnetic field even if no thermal gradient is simultaneously applied along the magnetic field direction. The magnetic field appears as being an efficient tool to grow large crystals and to orient the dendrite microstructure along it.

S3.7 THE DOMINANT ROLE OF H FIELD LOSSES IN VARIOUS MATERIALS INTERACTIONS: N. M. Moskovskii, D.T. Zimmerman, P.H. Cutler, Department of Physics, J. Cheng, R. Roy, D. Agrawal, Materiel Research Laboratory, The Pennsylvania State University, Univ. Park, PA.

Theorists have generally ignored the role of the H field in microwave interactions with dielectric materials and metals [see, however, I.D. Landau and E. M. Lifshitz, Electrodynamics of Continuous Media (Pergamon Press, New York, 1960, p. 104)]. Yet, experimentalists have made little effort to study the separate contributions of the E and H field with most of the reported work to date dozens experiments in a multimode cavity. Recently Cheng, Roy, and Agrawal [J. Chen et al., submitted to J. Appl. Phys. (Comm.), 2000] demonstrated, for the first time, using a single mode cavity configuration, that the separated energy densities, associated with the E and H fields, have radically different magnetic field characteristics in ceramics, semiconductors and metals. Using these unexpected experimental observations, we present some preliminary theoretical results to explain the data.

S3.8 A NOVEL DIAGNOSTIC TECHNIQUE TO MONITOR THE FABRICATION PROCESS OF NiOBiO/COPPER RESONANT CAVITIES BY FLUX-GATE MAGNETOMETRY: Massimo Vincenzii, Adele Rucci, Istituto Nazionale di Fisica della Materia, Naples, ITALY; Vincenzo Palmieri, Fabrizio Stinniello, Istituto Nazionale di Fisica Nucleare, Legnaro, Padova, ITALY.

The buffered chemical polishing is a standard procedure applied in several laboratories in order to etch Niobium/Copper resonators for particle accelerators. Even though the chemical polishing is only one of the many steps of the fabrication process, it is of great importance for having a high quality resonator. Hence, although the process parameters are carefully monitored, frequently this polishing is just applied as a cookery recipe, and not as a result of an optimization of the process parameters. In addition to that, the Niobium chemistry is a topic only marginally covered by literature so far. Flux gate magnetometry is herein proposed as a novel diagnostic technique of the ongoing corrosion due to the buffered chemical polishing of Cu/Nb superconductive wires. The detection of the magnetic field induced by the motion of the ions involved in the chemical process enables to detect the dynamics of the reaction from the men outside the resonator and, whenever the environmental magnetic noise is screened, it is very sensitive to the parameters of the process. In particular the preliminary results we present herein confirm the possibility to investigate in an non-invasive and contactless method the corrosion of a copper cavities due to the chemical polishing. Moreover the diagnostic technique in monitoring the electro polishing process of the copper cavities used as substrate for the successive step of Niobium sputtering. The technique is contactless, non intrusive and enables the measurements of the magnetic field in the range of pico-Tesla.

S3.9 THE PARAMAGNETIC INSULATING TO FERROMAGNETIC METALLIC TRANSITION IN OPTIMALLY DOPED La_2-xCo_xMo_3O_8 AND ITS DEPENDENCE ON OXYGEN MASS: J.P. Jurek, Guoxun Zhang, Univ. of Alberta, Dept of Physics, Edmonton, AB, CANADA; J. J. Podlesn, J.J. Ambrose College, Dept of Physics, Amherst, MA; C. Maresce, CEA Grenoble, FRANCE; R.A. Fisher and N.E. Phillips, LBL and Univ of California-Berkeley, Berkeley, CA.

We have investigated the paramagnetic to ferromagnetic metallic transition in the optimally doped colossal magnetoresistance (CMR) oxide.

Lao.2Co_xMo_3O_8 and its dependence on oxygen mass.
compound La_{0.65}Ca_{0.35}MnO_3, in closely matched oxygen isotope (^{16}O, ^{18}O) comparison samples. We present magnetoresistance and magnetization data below T_C and specific heat data in fields up to 5.5T. We find that the transition region can be characterized by various characteristic temperatures: (a) the first peak in the high temperature polaron condensation region, T_P; (b) the first transition temperature, T_C; (c) T_T and T_R are very close in zero field, but T_T moves increasingly above T_P with increasing field. No signature in C_P is noticeable at T_T, but T_T drops in a manner dependent on the onset of an anomaly in C_P. The rapid drop in C_P with increasing field, and relative orientation of the two transitions in the present work, it was determined that a magnetic field of 100Oe applied to a ferroic alloy containing twisted martensite plates may result in an increase in the martensite fraction. The final example deals with the conversion of magnetic energy into kinetic energy and the ability to drive a work piece into a die at very high velocities through an applied magnetic field. After this process, low stacking fault energy martensitic stainless steels exhibit very different properties than those seen in the unprocessed material. In this high strain-rates, a suppression of the martensite phase content, large numbers of deformation twins and a significant fraction of stacking faults and epsilon martensite are observed.

SESSION S4: MAGNETICALLY STRUCTURED MATERIALS
Chair: Ryochi Aogaki
Tuesday, November 28, 2000
Room 308 (Hynes)

8:30 AM *S4.1 PROCESSING OF POLYMERIC MATERIALS IN HIGH MAGNETIC FIELDS. Tatsuhisa Kimura, Tokyo Metropolitan Univ., Dept. of Applied Chemistry, Tokyo, JAPAN.

Recent work on magnetic field induced alignment of polymeric materials is presented. Magnetic processing of diamagnetic materials including polymers is based on the force acting through the magnetic field gradient and on the torque acting when the materials have diamagnetic anisotropy. These effects are small compared to the thermal energy and therefore usually difficult to observe. However, they may be studied when samples are immersed in a magnetic field and the interaction between the field and the magnetic moments of the material is large enough to provide a sufficient interaction with the volume. A typical value for the critical volume is the order of microns to submicrons, depending on the applied field strength and the anisotropic diamagnetic susceptibility of the material. We have observed that polymeric fibers align in liquid suspensions. The mechanism of the alignment is easily analyzed in terms of the balance of magnetic torque and hydrodynamic torque. The magnetic field induced alignment is not limited to solid anisotropic particles such as fibers and crystals but also is possible to systems undergoing self-organization. We have shown that crystalline polymers including poly(ethylene-2,6-naphthalate), isotactic polyisoprene, isotactic polypropylene, and poly(ethylene terephthalate) undergo magnetic alignment from the melt. The orientation starts to occur prior to the formation of crystallites, indicating that some ordered structures, most likely liquid-crystalline phase or conidiophore phase, are responsible for the magnetic orientation. In the case of the solid polystyrene, the anisotropic structures formed during phase transitions change their shape and size in the course of the transition, and hence the analysis of the orientation mechanism becomes difficult. One of advantages of the use of magnetic fields over the conventional methods is the wide range of choice of the direction of the alignment, even grade alignments. The use of magnetic field would provide a new means to control the orientation of polymeric materials.

9:00 AM *S4.2 APPLIED MAGNETIC FIELD EFFECTS ON THREE CLASSES OF MATERIALS. Paolo Frenner, John B. Vander Sande, MIT, Dept. of Materials Science and Engineering, Cambridge, MA.

In recent years, the recognition that a magnetic field induced structural change can be a useful tool for the design of materials with improved properties has emerged. In this context, there is a broad range of materials where the application of a magnetic field influences the nature of the processing-structure-properties relationships. This talk covers three areas where elevated magnetic fields are used to process materials: (a) in the development of high-T_c superconducting oxides, (b) in the preparation of high T_c superconducting oxides, and (c) in the preparation of high T_c superconducting oxides.
The Co and Ni salts of one T CNQ and two T CNQ-** molecules (Co(CNQ) and (Ni(CNQ)2) exhibited a ferromagnetic behavior albeit in very small saturation magnetization at room temperature. The spin-ordered structure and mechanism of this ferromagnetic behavior remain to be still elucidated. To get some information on this room-temperature ferromagnetism, the crystal growth of Co(CNQ) and (Ni(CNQ)2) salts from CH3CN/Et2O was performed under a static magnetic field of 5T at 298°C, and the optical, electrical, and magnetic properties of the obtained crystals of Co(CNQ) and (Ni(CNQ)2) of H were compared with those of their corresponding crystals grown under a normal magnetic field of Co(CNQ)(IIT) and (Ni(CNQ)2(TCNQ))(IIT). These physical properties were remarkably different between Co(CNQ)(IIT) and Co(CNQ)(IIT,ST). The cause of the change in these physical properties induced by the application of magnetic field is discussed by taking account of their crystal structures. On the other hand, there was almost no difference in the optical, electrical, and magnetic properties between (Ni(CNQ)2(TCNQ))(IIT) and (Ni(CNQ)2(TCNQ))(ST).

11:00 AM 54.6
CONTROLLED MODIFICATION OF MATERIALS BY PULSED MAGNETIC FIELDS. Mark N. Levin, Voronezh State University, Voronezh, RUSSIA.

The comprehensive summary of our research of unique possibilities of pulsed magnetic fields (PMF) to modify structure and properties of semiconductors, polymers and proteins will be presented. The results were previously reported earlier[1]. It was shown that the PMF allow one to improve structure of semiconductor surfaces and to control defects in the crystals for low temperature gettering, 3-D banding, forming of sharp impurity profiles, detecting of latent defects etc. The short-term PMF actions cause the prolonged conformation change in bi-molecules and make it possible to increase or to suppress the catalytic activity of a lot of enzymes (peroxidase, lactate dehydrogenase, haemoglobin, collagen etc) by the proper PMF treatment. The effects of PMF on organic polymers are presented for the first time. The short-term PMF treatment of silicone polymers results in irreversible changes of temperatures of their phase transitions. Thus the PMF-induced shift of crystallization and melting temperatures achieves 25K for polymethylmethacrylate. According to our model concepts the startup mechanism of the PMF induced effects is an excitation of the chemical bonds in defect complexes of crystals by non-equilibrium population of their metastable electronic terms due to intermolecular transitions (Phys. Lett. A 1990, 160, p.386). The PMF act on spins of electrons and cause the electron transitions in the points of configuration-space, where the other interactions are weakened and the electron terms are close or cross each other. The PMF-induced conformation change in polymers and proteins are explained on the base of the well-known Landau-Zener model, modified to describe intersection of electronic terms due to Zeeman effect in the PMF. The quantitative theory is given (Ref. 1)

11:15 AM 54.7
ANISOTROPIC MAGNETISM OF PARTICLE COMPOSITES STRUCTURED BY UNIAXIAL AND BIAXIAL FIELDS. James E. Martin, Robert A. Anderson, Eugene Venturini, and Judy Odinsk, Sandia National Laboratories, Albuquerque, NM.

We have investigated the properties of field-structured composites (FSCs) consisting of magnetic particles in a polymeric host that have been structured into films or sheets by applied uniaxial or biaxial (e.g. rotating) magnetic fields. These FSCs have highly anisotropic magnetic properties, that for soft carbonyl iron particles are largely due to the strong local magnetic fields, which are several times larger than those of a random particle composite. These strong local fields greatly increase the permeability along the direction or plane of the structuring field, and alter the magnetization curves in ways that can be understood through self-consistent local field calculations on particle structures produced by Langevin dynamics simulations. In magnetically hard samarium cobalt particle composites particle alignment also occurs, and these effects combine to create an eight-fold remanence anisotropy, although the coercive field does not shift. Finally, we show that these changes in the magnetic properties should lead to significant magnetostriction along the structuring field, since this effect depends on terms quadratic in the permeability.

11:30 AM 54.8
Bi 2212 and Bi 2223 MAGNETIC SUSCEPTIBILITY AND MAGNETIC TEXTURING STUDIES AS A FUNCTION OF PARTIAL MELT AND OVERHEATING TEMPERATURES. Sylvie Payard, Daniel Bourgault, Robert Toerner, Lab de Cristallographie, CNETA, CNRS, Grenoble, FRANCE.

Application of the magnetic field during the electrodeposition of ferromagnetic material films and nanowires affects the crystalline structure, texture, morphology, growth as well as magnetic properties[1,2]. We have deposited the Cobalt and Nickel films on

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Bi 2212 and Bi 2223 can be textured by solidifying them in a magnetic field. The maximum plateau temperature Tp used for melting appears as being the most important parameter for texturing. It exists a temperature narrow range which leads to the highest critical current density and to the best orientation. Above it, a melt overhosting is detrimental for the critical current. A too low temperature used for the plateau leads to partial melting and partial texturing. This phenomenon has been already observed by processing YBCO in a magnetic field. In order to study this phenomenon in Bi 2212 and Bi 2223, the magnetic susceptibility is measured by applying a magnetic field on the material during processing in a field gradient. Me 0 powders are introduced in Bi 2212 in order to obtain a more viscous liquid which sets its size after melting and does not wet a too large crucible surface. Magnetic susceptibility measurements show that Bi 2212 is fully melted at T ≈ Tp. Then, the best texture is obtained when all model are free to orient in a magnetic field. Melting increases with time at a partial melting temperature. Consequently, the full melting can be obtained by increasing temperature or by time consuming at a partial melting constant temperature. This time dependence is related to oxygen losses which progressively reduce the melting temperature of the residual solid grains. It has been already shown that Bi 2223 melting is necessary to orient this material during solidification in a magnetic field. One purpose is to verify again by susceptibility measurements whether Bi 2223 is fully melted versus time at T ≈ Tp during the optimized magnetic texturing.

SESSION 55: SOLUTIONS AND ELECTRODEPOSITIONS IN A MAGNETIC FIELD
Chair: Paolo J. Ferraris
Tuesday Afternoon, November 28, 2000
Room 308 (Hyenas)

1:30 PM 55.1
MAGNETIC FIELD EFFECTS ON MORPHOLOGY OF ELECTRODEPOSITS. J M.D. Coey, Physics Department, Trinity College, Dublin, IRELAND.

Magnetic fields can be used during electrodeposition to enhance the deposition rate of magnetic or nonmagnetic species, and to modify the morphology of the electrodeposits. The effects are attributed to the Lorentz force jxB which creates a transverse flow that disrupts the depletion layer near the electrode. Here j is the current density and B is the magnetic flux density. The morphology of radially- or linearly-grown fractal electrodeposits are sensitive to magnetic fields when the Lorentz force becomes significant. Drastic effects are observed when the dimensionless ratio jB/dg ≈ 891, which is possible for reasonable current densities in fields of 3E4 tesla, d is the density. The effects are quite different in horizontal and vertical cells. Some of these results are simulated by a random-walker model.

2:00 PM 55.2
EFFECTS OF HIGH MAGNETIC FIELDS ON CHEMICAL AND PHYSICAL PROCESSES. Yoshihumi Tanimoto, Masao Fujwara, Yoshihisa Fujwara, Hiroshima Univ, Graduate School of Science, Hiroshima-Hiroshima, JAPAN.

We have researched the effects of magnetic fields (0-13 T) on a variety of chemical and physical processes. Magnetic field effects (MFEs) on photochemical reactions of organic compounds are interpreted in terms of quantum mechanical effects where conversion of electron spin states in short-lived reaction intermediates are affected by a magnetic field; MFEs on liquid-liquid red reactions under a magnetic field gradient are interpreted in terms of mechanical effects where a magnetic force induces convection of solution; MFEs on the crystal growth of organic and inorganic compounds are explained by the thermodynamic effects where a magnetic field can substitute the crystal growth.

In this paper, we shall present the recent work obtained in our group.

3:00 PM 55.3
Abstract Withdrawn

3:15 PM 55.4
INFLUENCE OF MAGNETIC FIELD ON THE ELECTRO- DEPOSITION OF THE FILMS AND NANOWIRES OF Cu AND Ni. H.R. Khan and K. Petrikowski, FEM, Materials Physics Department, Schenwiefs, Gmuend, GERMANY.

Application of the magnetic field during the electrodeposition of ferromagnetic metallic films and nanowires affects the crystalline structure, texture, morphology, growth as well as magnetic properties[1,2]. We have deposited the Cobalt and Nickel films on
copper substrates and nanowires into the self-assembled pores of anodic alumina under the influence of magnetic fields applied in different directions with respect to the ions motion between the electrodes upto 10 kOe. X-ray diffraction data shows the effect of magnetic field on the phase formation as well as texture. These changes subsequently affect the anisotropic magnetic properties. For example a f.c.c. phase Co deposited without field transforms to a h.c.p. phase when deposited under the influence of magnetic field. Similarly the nanowires of Co and Ni deposited under the influence of magnetic field show formation of different phases and textures and anisotropic magnetic properties. The pore filling is also enhanced by the application of magnetic field during the electrodeposition. The possibility to tailor the structural, morphological and magnetic properties of the ferromagnetic films and nanowires using a magnetic field will be discussed.


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3:30 PM S5.5
Dissolution Process of Copper Sulfate into Water in a Heterogeneous Vertical Magnetic Field.
Akiushi Sugiwara, Tokyo Metropolitan Univ, Dept of Industrial Chemistry, Tokyo, JAPAN & National Research Laboratory for Magnetic Science, Japan Science and Technology Corporation, Saitama, JAPAN; Shigeoishi Morigaki, Tokyo Metropolitan Univ, Dept of Industrial Chemistry, Tokyo, JAPAN; Ryosuke Aoki, National Research Laboratory for Magnetic Science, Japan Science and Technology Corporation, Saitama, JAPAN and Dept of Product Design, Polytechnic Univ, Kanagawa, JAPAN.

The dissolution process of copper sulfate into water in a heterogeneous magnetic field vertical to the interface was examined from the viewpoint of the self-organization process of the nonequilibrium fluctuations. In a heterogeneous magnetic field, a material receives a magnetic force proportional to the product of the magnetic susceptibility, the magnetic flux density B and its gradient (dB/dz).

As the reaction proceeds, a diffusion layer develops in the area of constant concentration because of the dependence of the susceptibility on the solute concentration. In the case of a vertical magnetic field, a magnetic force is applied to the diffusion layer to induce magnetic force fluctuation and the resultant concentration fluctuation of the solute, which self-organize numerous convection cells. The cell pattern was then observed from the morphology of the dissolved copper sulfate pentahydrate crystal. As a result, it was concluded that the size of the convection cell decreases with the magnetic flux density, so that the surface roughness also decreases.

3:45 PM S5.6
Visualization of the Micro-MHD Flow on the Copper Corrosion in Nitric Acid. Kenji Shinozawa1,2, Kazuho Hashimoto2, Ryosuke Aoki1, National Research Laboratory for Magnetic Science, Japan Science and Technology Corp., Saitama, JAPAN, 2RCAS-The University of Tokyo, Tokyo, JAPAN.

In the high magnetic fields, suppression effect of the copper corrosion in nitric acid was examined. A microscopic fluid motion accompanied with the micro-MHD flow was visualized, a pair of rotations appeared over the copper surface dipped in nitric acid under vertical magnetic field, which reflected the large-scale circulation of the electrolytic current. Each rotation revolved slowly about an axis, which was attributed to the difference of the distributions of the anodic and cathodic active points. These phenomena could be described with the micro-MHD effect and the fluctuation theory on the chemical dissolution of metals.