SYMPOSIUM S

Applied Magnetic Field Effects on Materials Behavior

November 27 – 28, 2000

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* Invited paper

SESSION S1: MAGNETIC LEVITATION

Chair: John B. Vander Sande
Monday Morning, November 27, 2000
Room 308 (Hynes)

8:30 AM *S1.1
HYDRODYNAMICS IN HIGH MAGNETIC FIELDS. E. Beaugnon, D. Fabregue, C. Douarche, V. Blangy, R. Tournier CNRS-CRETA Cristallographie, Grenoble, FRANCE.

Diamagnetic substances can be levitated by strong magnetic field gradients, thus simulating zero gravity conditions, with in addition the possibility to achieve a stable levitation without any contact. Taking advantage of this effect, we describe a new technique to measure the surface tension of liquids. A liquid droplet maintained in levitation is excited by means of air bursts, and the surface tension can be derived from the resonance frequency. However the residual forces that help maintaining the droplet in a stable position may modify the rest shape and the resonance frequency. Numerical calculations have been performed to evaluate both effects. When the free surface of a pool of water is submitted to a strong non homogeneous magnetic field, a large decrease of the height can be measured in the region of maximum field although the maximum force may be below the one required for levitation [N. Hirota et al, Jap. J. of Appl. Phys., 34, 8 (1995) L991]. If this so-called "Moses effect" is associated with the flow of a liquid in an open air duct, the reduction of the height induces a local increase of the speed: this, in turn, can strongly enhance the height reduction and both simple theoretical predictions and experimental results will be presented.

9:00 AM *S1.2
MAGNETIC FIELD EFFECT ON PHYSICOCHEMICAL PROCESSES AND THE MAGNETO-ARCHIMEDES LEVITATION. Noriyuki Hirota, Yasuhiro Ikezoe, Hiromichi Uetake, Tohru Kaihatsu, and Koichi Kitazawa, Univ of Tokyo, Dept of Applied Chemistry, Tokyo, JAPAN; Jun Nakagawa, TDK Co Ltd, Chiba, JAPAN.

Owing to recent remarkable progress of superconducting magnets, the study of magnetic field effects on dia- or para-magnetic substances, i.e., non-magnetic substances, and some processes that include such materials have received considerable interest because the influence of the magnetic field is enhanced to the clearly observable level. We have been investigating the magnetic field effect on some physicochemical processes such as oxygen dissolution into water, vaporization of water and so on. Under magnetic fields up to 10 T, the equilibrium concentration of paramagnetic oxygen gas was not changed, whereas the dissolution rate was significantly accelerated. The vaporization of water was enhanced under the non-uniform magnetic field. The mechanisms of these phenomena were found based on the magnetically induced convection due to the non-uniformity of magnetic susceptibility in the system. The observations above seem to have a great significance, because some chemical, metallurgical, and biological processes that include oxygen dissolution or vaporization may be affected by the magnetic fields via these mechanisms. We also have been investigating about the utilization of the magnetic levitation. We have succeeded in the levitation of non-magnetic materials by using an ordinary 10 T superconducting magnet with the aid of pressurized oxygen gas (the magneto-Archimedes levitation). The mechanism of this magneto-Archimedes levitation and the application of this technique to the separation of powders will be discussed in this presentation.

9:30 AM *S1.3
NEW METHOD TO DAMP NATURAL CONVECTION AND ITS APPLICATION TO PROTEIN CRYSTAL GROWTH. Nobuko I. Wakayama, Jianwei Qi, Chengwen Zhong, National Institute of Materials and Chemical Research (Core Research for Evolutional Science and Technology, Japan Science and Technology Corporation), Tsukuba, JAPAN; Mitsuo Ataka, National Institute of Bioscience and Human Technology (CREST, JST), Tsukuba, JAPAN; Tsukasa Kiyoshi, Hitoshi Wada, National Research Institute for Metals (CREST, JST), Tsukuba, JAPAN; S.X. Lin, Research Center of CHUL, Quebec, CANADA.

Producing protein crystals of adequate size and quality is often the "bottleneck" for three-dimensional X-ray structure analysis of protein molecule. Recent crystallization experiments conducted on spaceshuttle have indicated that crystals grown in microgravity may be larger and yield diffraction data of significantly higher resolutions than the best crystals grown on Earth. Since an obvious difference between the space- and Earth- based experiments is the magnitude of gravity and buoyancy, we will report a new method for controlling vertical acceleration and the application to the formation of protein crystals. Magnetization force caused by a magnetic field gradient is a body force, and it is possible to control vertical acceleration continuously from normal gravity to microgravity by applying an upward magnetization force on fluids. We verified this method experimentally by generating bubbles and observing their behavior. When the magnetization force were nearly equal to the gravitational one, bubbles were observed to behave as 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 solution and obtained the following results: when a magnetic field gradient $B(dB/dz)=-685T^2/m$ is applied, the maximum flow velocity is reduced by about 50% and the velocity in the vicinity of the crystal is reduced by about 24%. When $B(dB/dz)=-1370T^2/m$, the upward magnetization force damps convection completely. Recently, this method was applied to the formation of protein crystals. When an upward magnetization force (30% of gravitational one) was applied, the crystals segregated from the solution showed higher resolutions 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.

10:30 AM *S1.4
MAGNETIC FIELD MANIPULATION OF FROG EMBRYOS. James M. Valles, Jr., Kevin Lin, Eric Galburt, W.B. Jordan, Sarah Wasserman, Juliet Liu, Dept. of Physics, Brown University, Providence, RI; James M. Denegre, Kimberly L. Mowry, Dept. of Molecular Biology, Cell Biology, and Biochemistry, Brown University, Providence, RI.

During the early development of vertebrates many complex structures like cell membranes form and remain, and others, like the microtubule arrays composing the mitotic apparatus, disappear after fulfilling their role. Developmental success can depend critically on the materials properties of these structures and how, when and 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 present in the early development of frog embryos of the species Xenopus laevis. Even though the materials composing the embryos are diamagnetic, presently available magnetic fields are strong enough to exert a magnetic force on an embryo comparable to its weight. Moreover, since the embryos are relatively large (1.2 mm diameter), structures within them, like the mitotic apparatus are large enough that it is expected to align in a magnetic field. I will describe how we achieved Magnetic Field Gradient Levitation of the embryos, i.e. 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 specimens. Also, I will describe two well defined types of magnetic field induced anomalies in the early development of the embryos that depend systematically 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 gastrulation abnormalities much later in development. I will describe our efforts to determine which of the internal structures are influenced by the magnetic field.

11:00 AM *S1.5
TRANSGENIC PLANT STRESS RESPONSE IN STRONG MAGNETIC FIELDS AND IN MAGNETIC LEVITATION (LOW GRAVITY) ENVIRONMENTS. A.N. Morgan, B.C. Watson, J. Yowtak, M.W. Meisel, Dept. Physics and NHMFL, Univ. Florida, Gainesville, FL; J.S. Brooks, Dept. Physics and NHMFL, Florida State Univ., Tallahassee, FL; A.-L. Paul, R.J. Ferl, Dept. Horticultural Sciences and Biotechnology Program, Univ. Florida, Gainesville, FL.

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 ($< 1 - 100$ milli-g, $g = 9.8$ m/s^2), Earth-based environments that may be utilized to prepare experiments for the Space Shuttle/Station. Transgenic *Arabidopsis thaliana* plants, engineered with a stress response reporter gene, were magnetically levitated for 2.3 hrs., and the results suggest the presence of significant levels of stress that are similar to those observed on parabolic flights. Control specimens, which were placed in strong, homogeneous magnetic fields, also indicated significant levels of stress response. Additional studies have been performed in homogenous magnetic fields up to 30 T, and the results indicate an increase in the stress response above ≈ 17 T. These preliminary results suggest magnetic fields in excess of 17 T may influence certain aspects of gene regulation. Thus, the possibility exists that *in vivo* gene expression data collected from instruments 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 NHMFL.
[1] J.S. Brooks *et al., J. Appl. Phys.* **87** (2000) 6194.

[2] *National Magnetic Resonance Collaboratorium*, a Report by the Committee for High Field NMR: A New Millennium Resource, August 1998, http://www.magnet.fsu.edu/science/programs/cimar/nmrc/index.html.

11:30 AM S1.6
GLASS MICRO-SPHERES FORMED UNDER HIGH MAGNETIC FIELD. Naoyuki Kitamura, Masaki Makihara, Osaka National Research Institute, Dept of Optical Materials, Osaka, JAPAN; Takayuki Sato, Miho Hamai, Iwao Mogi, Satoshi Awaji, Kazuo Watanabe, Mitsuhiro Motokawa, Tohoku Univ, Institute for Materials Research, Sendai, JAPAN.

Upward force in a gradient of magnetic field realizes a quasi-microgravity. Glass sphere prepared by levitation methods is great interest because of producing high purity materials without any containers at ambient temperature. We have produced glass micro-spheres by the evaporation-condensation process under high magnetic field gradient. Na_2O-$2TeO_2$ glass was evaporated by CO_2 laser irradiation for a few seconds in a hybrid magnet. Thermal convection of glass cloud was suppressed under magnetic force of -0.8G. Size of the sphere produced under the magnetic force was about 500nm at most. This size is one half as compared with the sphere produced without magnetic field. Sodium content was 20-30 at.% in the microsphere produced under high field, while it was less than 10 at.% in that produced under zero magnetic field. Sodium content at surface of the laser irradiated glass decreased with increasing magnetic field. It is deduced that the magnetic force assists the evaporation of sodium oxide from glassy melts.

11:45 AM S1.7
ELECTROMAGNETIC-MELTING AND ALLOYS PROCESSING IN A VERTICAL MAGNETIC FORCE. Robert F. Tournier, Sylvain Rakotoarison, Laboratoire de Cristallographie, Consortium de Recherches pour l'Emergence de Techniques Avancees, Centre National de la Recherche Scientifique, Grenoble, FRANCE.

Conducting paramagnetic liquids can be levitated by combining electromagnetic and magnetic vertical forces as already shown for some transition metals and alloys by using a cold crucible and an inductive heating. The centrifugal and horizontal magnetic force is easily compensated by the radial electromagnetic force which is produced by heating the sample with an inductive coil. The magnetic liquids levitate in relatively low BdB/dz due to their high paramagnetic susceptibility. Some recent examples of magnetic processing will be given to enlighten some experimental difficulties related to processing in a magnetic force opposed to the gravity. A magnetic force can produce magnetic phase separation. Consequently, a levitation processing is difficult to control during crystallization because of the susceptibility difference between solid and liquid phases. Cooling a magnetic liquid in a cold crucible tends to push the cooled liquid from the bottom to the top and to create magnetic convection in competition with convection braking in a magnetic field. This effect is due to a magnetic force increase when the liquid temperature decreases. It is easier to texture conducting materials in a magnetic force which is added to the gravity because natural convection is not only reduced by electromagnetic braking but also by an acting magnetic force. It is also possible to damp convection in a conducting liquid by only using a homogenous magnetic field which brakes radial motion. Marangoni convection also appears as being damped in such conditions. The most exciting perspective of magnetic processing is that convection is suppressed in a magnetic liquid having a temperature dependent susceptibility by using much smaller magnetic forces than the levitation force.

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

1:30 PM *S2.1
MAGNETIC-FIELD-INDUCED STRUCTURE AND PROPERTY CHANGES IN FERROMAGNETIC SHAPE-MEMORY ALLOYS. R.C. O'Handley, S.M. Allen, M. Marioni, C.P. Henry, M. Richard, P.G. Tello, and K.A. Lee, Department of Materials Science and Engineering, Massachusetts Institute of Technology, Cambridge MA; and S.J. Murray, Mide Technology, Cambridge MA.

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. 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 adiabatic, 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 magnetic field to produce large strains is by field-induced motion of twin boundaries within the tetragonal martensitic state. This causes a nearly 90° reorientation of the c axis. In either case, strains of order 1 - c/a are produced; for Ni-Mn-Ga SMAs, this amounts to a 6% strain in 0.4 Tesla and for Fe-Pd SMAs, a 0.5% strain in 1.2 Tesla. In the case of field-induced twin-boundary motion, the presence of mobile twins reduces the modulus nearly 100-fold to about 20 MPa from that of the detwinned 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 *S2.2
GRAIN BOUNDARY DYNAMICS IN HIGH MAGNETIC FIELDS. Dmitri A. Molodov, Guenter Gottstein, Inst of Physical Metallurgy and Metal Physics, Aachen Univ of Technology, Aachen, GERMANY; Lasar 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 micstructure 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 energy gradient can be changed and even inverted for the same boundary. This allows for the first time to study asymmetry effects of boundary dynamics. We will report in detail results obtained on Bi bicrystals. 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 $90° < 112 >$ 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 *S2.3
STRUCTURAL AND FUNCTIONAL CONTROL OF MATERIALS THROUGH SOLID/SOLID PHASE TRANSFORMATIONS IN HIGH MAGNETIC FIELD. Hideyuki Ohtsuka, Ya Xu, Hitoshi 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 a 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-0.1C-0.05Nb for ferrite transformation, and Fe-13Mn-1.0C and Fe-0.8C for pearlite transformation. Ferrite, pearlite and bainite transformations 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 a 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 to 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 NiMnGa alloy and iron-nitride is briefly mentioned.

3:30 PM S2.4
UNIAXIAL ANISOTROPY CHARACTERISTICS OF THE SPUTTERED FeTaN/Ti FILMS WITH MAGNETIC FILED ANNEALING. Jong-Han Jeong, Seok Bae, Sung-Ryong Ryu, Seoung-Eui Nam, Hyoung-June Kim, Hong-Ik 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 bilayer films 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 nanocrystalline structure leading to the outcome of soft magnetism during post-deposition annealing at 400°C and /or 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 field-annealing. Subsequent 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°C rotation processes were carried out. An atomic model to explain the evolution of Hk was also suggested.

3:45 PM S2.5
HIGH TEMPERATURE MAGNETIC TEXTURING OF FERRITE-DOPED MATERIALS. L. Meda[1,2], C. Bacaltchuk[1], and H. Garmestani[1,2]; [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 treated ferrite-doped strontium materials. 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 PM S2.6
EFFECT OF MAGNETIC FIELD ON THE FORMATION OF VARIANT STRUCTURE OF EQUIATOMIC FePd. Katsushi Tanaka, Tetsu Ichitsubo, Masahiro Koiwa, Dept of MS&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 ($L1_0$) / disorder (fcc) transformation. In general, three kinds of ordered variants which posess the c-axis along either of $< 100 >$ directions of the fcc disordered matrixare 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 $L1_0$ ordered phase exhibit high uniaxial magnetocrystalline anisotropy with the easy axis parallel to the c-axis, application of a magnetic field is expected to modify a relative population of three variants. Single crystals of disordered FePd were ordered at various temperatures under the magnetic fields up to 10 T. The direction of the magnetic field is set to the $< 001 >$ crystallographic direction so that the variant with the c-axis parallel to the magnetic field is the most energetically favored one. When the temperature of the ordering treatment is higher than 780 K, a significant change in the variant structure is observed; a mono-variant structure of an $L1_0$ 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 proceeds by nucleation and growth process (the heat treatment temperature must be higher than the spinodal ordering temperature), and the magnetocrystalline anisotropy energy is sufficiently large to change the nucleation rates of different variants.

4:15 PM S2.7
SOFT MAGNETIC PROPERTIES OF FeTaN/M(M=Ti, Ni, Cr, AND Co) BILAYER FILMS. Seok Bae, Jong-Han Jeong, Choong-Sik Kim, Seoung-Eui Nam, Hyuong-June Kim, Hong-Ik Univ, Seoul, KOREA.

Recently, many worker have reported that FeTaN nanocrystalline films shows 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 had not been reported. Here, to further investigate the effects of underlayers, we compared the magnetic properties of FeTaN/M(M=Ti, Ni, Cr, and Co) bilayer films with magnetic and/or 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 without underlayer, 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 with residual 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 increases. The increase of tensile stress by field annealing can be explained in terms of magnetoelastic effects as well as crytallographic texture of α-Fe. High frequency characteristics of FeTaN/M films were also discussed with an emphasis of ferromagnetic-resonance-limited frequency dependency.

SESSION S3: POSTER SESSION
PARTICLE SUSPENSION IN A DC OR AC MAGNETIC FIELD
Chair: Eric Beaugnon
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. Andrey I. Zavalin, Warren E. Collins, Don O. Henderson, Fisk Univ, Physics Dept, Nashville, TN.

Creation and application of multipolar systems of alternating electromagnetic fields and electric currents 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 2-cascade system of coupled transformers, working at frequencies 15 Hz - 30 kHz. Micro-objects, suspended in 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 6- polar systems, while in 2- and 4-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], Kazuhito Hashimoto[2], Ryoichi Aogaki[1]. [1]National Research Laboratory for Magnetic Science, Japan Science and Technology Corp., Saitama, JAPAN; [2]RCAST-The University of Tokyo, Tokyo, JAPAN.

A new method for the measurement of the magnetic susceptibilities of particles in liquid phase and resultant 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 field gradient, whereas a flowing liquid drags 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. Jiping Cheng, Rustum 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, virtually 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 physically different fields, a pure electric field and a pure 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 microwave processing. The consolidation behavior and 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. Abedian, Tufts University, Dept of Mechanical Engineering, Medford, MA; G. Trapaga, D.M. Matson, Massachusetts Institute of Technology, Dept. of Matierials 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 undercooled 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 EML droplets in the course of microgravity experiments in TEMPUS on the Space Shuttle (STS-94). The transition occurs repeatably 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. Wakayama, Jianwei 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.

Lorenz force caused by external magnetic fields has been widely used to damp convection of molten semiconductor material. 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 diamagnetic and repulsive magnetization force acts on them. For evaluating this method, first, we numerically simulated thermal convection (Ra=33734) in pure water which is diamagnetic and nonconducting. When B(dB/dz) of magnetic field gradient is -573 T^2/m, convection was damped and the maximum velocity was decreased by about 50%. Thermal convection was damped with increasing B(dB/dz). Numerical simulation was also conducted in a lowconducting fluid (29% NaCl aqueous solution, 21 $Ohm^{-1}m^{-1}$) when B(dB/dz)=- 573 T^2/m, and the contribution from magnetization force to damp convection was larger than that from Lorenz force. Furthermore, we numerically simulated thermal convection (Ra=33734) in a paramagnetic fluid (30% Gd(NO3)3 aqueous solution) on which magnetic attractive forces acted 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(dB/dz), $5T^2$/m. The visualization experiments of these phenomena will be also reported.

S3.6

MAGNETIC FIELD PROCESSING OF A NICKEL SUPERALLOY. Robert F. Tournier, Sylvain Rakotoarison, Laboratoire de Cristallographie, Consortium de Recherches pour l'Emergence de Techniques Avancées, Centre National de la Recherche Scientifique, Grenoble, FRANCE.

The AM1 nickel superalloy which has been used for magnetic processing mainly contains 63.8 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 casted in a cold mold by using an inductive furnace before processing in an other resistance furnace and an alumina crucible submitted to a vertical magnetic field. The dentritic growth appears under moderate thermal gradients in the $< 100 >$ privileged crystallographic directions. Heat treatments are made in the homogenous temperature furnace zone or in a thermal gradient applying or not a 5 Tesla homogenous magnetic field. The sample is fully melted during a 90 minutes temperature at 1390°C after a 40°C/h heating rate. The alloys solidify 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 dentrite microstructure along it.

S3.7

THE DOMINANT ROLE OF H FIELD LOSSES IN VARIOUS MICROWAVE-MATERIALS INTERACTIONS. N.M. Miskovsky, D.T. Zimmerman, P.H. Cutler, Department of Physics; J. Cheng, R. Roy, D. Agrawal, Materials 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, L.D. Landau and E. M. Lifshitz, *Electrodynamics of Continuous Media* (Pergamon Press, New York, 1960), pp.303-4]. Likewise, experientialists have made little effort to study the separate contributions of the E and H field with most of the reported work to date describing experiments in a multimode cavity. Recently, Cheng, Roy and Agrawal [J. Cheng et al., submitted to J. Mat. Res. (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 absorption 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 NIOBIUM/COPPER RESONANT CAVITIES BY FLUX-GATE MAGNETOMETRY. Massimo Valentino, Adele Ruosi, Istituto Nazionale di Fisica della Materia, Naples, ITALY; Vincenzo Palmieri, Fabrizio Stivanello, 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 a step of crucial 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 optimisation 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 cavities. 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 area 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 a non-intrusive and contact less method the corrosion of a copper cavities due to the chemical polishing. Moreover the same diagnostic technique is proposed to monitoring the electro polishing process of the copper cavities used as substrate for the successive step of Niobium sputtering. The technique is contact less, 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 $La_{0.65}Ca_{0.35}MnO_3$ AND ITS DEPENDENCE ON OXYGEN MASS. J.P. Franck, Guanwen Zhang, Univ of Alberta, Dept of Physics, Edmonton, AB, CANADA; J.E. Gordon, Amherst College, Dept of Physics, Amherst, MA; C. Marcenat CEA-Grenoble, FRANCE; R.A. Fisher and N.E. Phillips, LBNL and Univ of California-Berkeley, Berkeley, CA.

We have investigated the paramagnetic to ferromagnetic metallic transition in the optimally doped colossal magneto-resistance(CMR) 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 in fields up to 5.5T and specific heat data in fields up to 6.5T. We find that the transition region can be characterized by various characteristic temperatures: (a) the first deviation from the high temperature small polaron conduction region, T^*; (b) the resistivity maximum, T_R; (c) the specific heat maximum, T_C. T^* and T_R are very close in zero field, but T^* moves increasingly above T_R with increasing field. No signature in C_P is noticeable at T^*, but T_R is characterized by the onset of an anomaly in C_P. The rapid drop in resistivity below T_R is associated with an increased entropy loss. The maximum in C_P, signaling a second order transition, is found close to the end of the steep resistivity decrease. The isotope effect in T_R, as measured by the isotope exponent α_0=-ΔlnT/Δlnm, is near 0.3 and independent of field to 5.5T. The isotopic dependence of T^* is similar to that of T_R. The isotope exponent for the second transition at T_C decreases approximately linearly with field from 0.3 (0T) to near zero in 6T. The different mass dependence of T_R and T_C show that the paramagnetic to ferromagnetic transition progresses in several steps, involving different processes with different characteristic oxygen mass dependencies. The second order transition at T_C occurs at 40 to 50% of the low temperature magnetization, it is likely a cooperative percolation transition.

SESSION S4: MAGNETICALLY STRUCTURED MATERIALS

Chair: Ryoichi Aogaki
Tuesday Morning, November 28, 2000
Room 308 (Hynes)

8:30 AM *S4.1
PROCESSING OF POLYMERIC MATERIALS IN HIGH MAGNETIC FIELDS. Tsunehisa 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 are visible for materials with a size large enough because the effects are proportional to the volume. A typical value for the critical volume is of 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 fine 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 polystyrene, isotactic polypropylene, and poly(ethylene terephthalate) undergo magnetic orientation during crystallization from the melt. The orientation starts to occur prior to the formation of crystallites, indicating that some ordered structures, most likely liquid-crystalline like phase or condis phase, are responsible for the magnetic orientation. In contrast to the case of solid fine particles, 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 means is a 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. Paulo Ferreira, 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 used as 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. In this talk three areas where elevated magnetic fields are used to process materials are discussed. The first example is related with the development of texture in high-Tc BSCCO superconducting oxides. BSCCO thick films and tapes with thickness greater than 20 microns have been studied after melt-processing under a 9 T magnetic field. Superconducting grains exhibit an anisotropic paramagnetic susceptibility in their normal state, and thus when placed in a magnetic field will minimize their magnetic energy when the axis of maximum susceptibility is aligned parallel to the field. With this thermodynamic principle in mind, the influence of an applied magnetic field on the nucleation and growth of superconducting grains from the liquid state, grain rotation in a peritectic liquid and interfacial phenomena have been investigated. A second example is the development of magnetically driven shape memory alloys. If two adjacent twin variants within the martensite phase have their easy axis of magnetization oriented at different angles with respect to the applied magnetic field, an extra thermodynamic driving force for the translation of the twin interfaces will arise. Reorientation of the twin structure is controlled by the strength and orientation of the magnetic field, and relative orientation between the twin variants. In the present work, it was determined that a magnetic field of 100 kOe applied to a ferrous alloy containing twinned martensite plates may result in stresses of about 35 MPa acting on twin dislocations. The final example deals with the conversion from 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 austenitic stainless steels exhibit very different properties than those deformed at low strain rates. At 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.

9:30 AM *S4.3
MAGNETIC TEXTURING OF DYSPROSIUM 123, DYSPROSIUM-DOPED BISMUTH-2212 and BISMUTH-2223. M. Ausloos, Ph. Vanderbemden, SUPRAS, University of Liege, BELGIUM; L. Tortet, G. Vacquier, LPCM, Universite de Provence, Marseille, FRANCE; A. Rulmont and R. Cloots, SUPRAS, University of Liege, BELGIUM.

This report discusses the crystal growth mechanism of 123 superconducting ceramics from optical micrographs made on DyBa2Cu3O7-d superconducting materials synthesized by peritectic recombination under a small magnetic field (0.6T). Because of the marked anisotropy in the crystal growth of so-called 123 crystals, like YBa2Cu3O7-d, which favors the growth in the CuO2 planes, the crystals tend to exhibit a plate geometry. The a-b planes properties are much enhanced. The report deals also with the elaboration of new synthesis processes for Bi-based superconducting ceramics doped with dysprosium. As a first achievement, magnetically (1.2T) melt-textured Dy-doped 2212 ceramics were obtained with strongly anisotropic electrical and magnetic properties and interesting microstructural features. The failure of synthesizing Dy-doped Bi-2223 under magnetic field will be discussed.

10:30 AM S4.4
ORIENTATION OF CRYSTALLINE POLYMERS INDUCED BY MAGNETIC ORIENTATION OF NUCLEATING AGENT. Takahiko Kawai, Ryota Iijima, Tsunehisa Kimura, Dept. of Applied Chemistry, Tokyo Metropolitan University, Tokyo, JAPAN; Yuzo Yamamoto, Dept. of Biological and Chemical Engineering, Gunma University, Gunma, JAPAN.

We have recently reported that several crystalline polymers undergo magnetic orientation during the heat treatment in a magnetic field. However, for some polymers, the orientation is limited to those with lower molecular weight. In this paper, we report a novel method that enables the magnetic orientation of high molecular weight polymers. In this method, the magnetic orientation of a nucleating agent (a low molecular weight organic crystal) is utilized, inducing the alignment of polymer chains due to the epitaxial growth of the polymer crystals on the nucleating agent. We investigated the magnetic alignment of a high molecular weight isotactic polypropylene (iPP) containing 2,6-naphthylene di(cyclohexyl amide) as a nucleating agent (NA). The powder of the NA was mixed with iPP at various mass fractions, and isothermal crystallization was carried out in the magnetic field of 6 tesla. The orientation of iPP crystals was observed for the samples containing NA as low as 0.05 wt%, but no orientation was observed for iPP alone. The orientation becomes higher with increase in NA amounts. Wide-angle x-ray analysis showed that the c-axis of iPP aligns perpendicular and the a-axis is tilted by 35.5° with respect to the magnetic field. The nucleating crystals were found to be aligned with the $< -104 >$ plane parallel and the $< 100 >$ plane tilted by 35.5° with respect to the magnetic field. This observation along with the orientation direction of the iPP crystal is consistent with our previous founding that the (330) plane of the iPP undergoes the epitaxial growth on the bc plane of the NA.

10:45 AM S4.5
OPTICAL, ELECTRICAL AND MAGNETIC PROPERTIES $Cs_2(TCNQ)_3$ AND $(NMe_4)_2(TCNQ)_3$ CRYSTALS GROWN UNDER MAGNETIC FIELD. Abdurrahman Hasanudin, Tohoku Univ, Inst for Mater Res, Sendai, JAPAN; Noritaka Kuroda, Kumamoto Univ, Fac of Engineering, Kumamoto, JAPAN; Toyonari Sugimoto, Kazumasa Ueda, Toshiji Tada, Osaka Pref Univ, Res Inst of Adv Sci & Tech, Osaka, JAPAN; Naoki Toyota, Hiroshi Uozaki, Tohoku Univ, Dept of Physics, Sendai, JAPAN.

The Cs and NMe_4 salts composed of one TCNQ and two $TCNQ^{-\bullet}$ molecules ($Cs_2(TCNQ)_3$ and $(NMe_4)_2(TCNQ)_3$) 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 not elucidated. To get some information on this room-temperature ferromagnetic behavior, the crystal growth of $Cs_2(TCNQ)_3$ and $(NMe_4)_2(TCNQ)_3$ salts from CH_3CN/Et_2O was performed under a static magnetic field of 5T at 20°C, and the optical, electrical and magnetic properties of the obtained crystals ($Cs_2(TCNQ)_3(5T)$ and $(NMe_4)_2(TCNQ)_3(5T)$) were compared with those of their corresponding crystals grown under a normal magnetic field (Cs_2 $(TCNQ)_3(0T)$ and $(NMe_4)_2$ $(TCNQ)_3(0T)$). These physical properties were remarkably different between $Cs_2(TCNQ)_3(0T)$ and $Cs_2(TCNQ)_3(5T)$. 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 $(NMe_4)_2(TCNQ)_3(0T)$ and $(NMe_4)_2(TCNQ)_3(5T)$.

11:00 AM S4.6
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 partly 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 islanding, forming of sharp impurity profiles, detecting of latent defects etc. The short-term PMF actions excite prolonged conformation changes in bio-molecules and make it possible to increase or to suppress the catalytic activity of a lot of enzymes (peroxidase, lactate dehydrogenase, lysozyme, collagenase etc) by the proper PMF treatment. The effects of the 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 achieve 25 K for polydimethylsiloxane. According to our model conceptions the start-up 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 intercombinational transitions (Phys. Lett. A 1999, 260, p.386). The PMF act on spins of electrons and cause the electron transitions in the points of configuration-spin space, where the other interactions are weakened and the electron terms are close or cross each other. The PMF-induced conformation changes 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: MRS Meet. Abstr. 1999 Fall AAA9, I7.34, K5.4; 1999 Spr. G2.9; 1997 Spr. E13.1; 1996 Spr. J13.13; 1995 Fall J8.8; 1994 Fall B1-2.16; 1993 Fall Cb1.12; 1993 Spr. M2-3.2.

11:15 AM S4.7
ANISOTROPIC MAGNETISM OF PARTICLE COMPOSITES STRUCTURED BY UNIAXIAL AND BIAXIAL FIELDS. James E. Martin, Robert A. Anderson, Eugene Venturini, and Judy Odinek, 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 chains 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 S4.8
Bi 2212 AND Bi 2223 MAGNETIC SUSCEPTIBILITY AND MAGNETIC TEXTURING STUDIES AS A FUNCTION OF PARTIAL MELTING AND OVERHEATING TEMPERATURES. Sybille Pavard, Daniel Bourgault, Robert Tournier, Lab de Cristallographie, CRETA, CNRS, Grenoble, FRANCE; Catherine Villard, CNRS, Centre de Recherches sur les Tres Basses Temperatures, CRETA, Grenoble, FRANCE.

Bi 2212 and Bi 223 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 overheating 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 force on the material during processing in a field gradient. MgO powders are introduced in Bi 2212 in order to obtain a more viscous liquid which save its size after melting and does not wet a too large crucible surface. Magnetic susceptibility shows that Bi 2212 is fully melted at T=Tp. Then, the best texture is obtained when all nuclei 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 S5: SOLUTIONS AND ELECTRODEPOSITIONS IN A MAGNETIC FIELD

Chair: Paulo J. Ferreira
Tuesday Afternoon, November 28, 2000
Room 308 (Hynes)

1:30 PM *S5.1
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 interferes with natural convection. Dramatic effects are observed when the dimensionless ratio jB/dg =89 1, which is possible for reasonable current densities in fields =BE 1 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 *S5.2
EFFECTS OF HIGH MAGNETIC FIELDS ON CHEMICAL AND PHYSICAL PROCESSES. Yoshifumi Tanimoto, Masao Fujiwara, Yoshihisa Fujiwara, Hiroshima Univ, Graduate School of Science, Higashi-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) can be classified into three groups: 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-solid redox reactions under a magnetic field gradient are ascribed to 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 anisotropic magnetic energy of a crystal leads its orientation. In this paper, we shall present the recent work obtained in our group.

3:00 PM S5.3
Abstract Withdrawn.

3:15 PM S5.4
INFLUENCE OF MAGNETIC FIELD ON THE ELECTRO-DEPOSITION OF THE FILMS AND NANOWIRES OF Co AND Ni. H.R. Khan and K. Petrikowski, FEM, Materials Physics Department, Schwaebisch Gmuend, GERMANY.

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 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 a 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.

1. H.R. Khan and K. Petrikowski, J. Magn. Magn. Mat. (In Press).
2. H.R. Khan and K. Petrikowski, Proc. 8^{th} European Magn. Mater. And Applications Conference 2000, Kyiv, Ukraine (In Press).

This work is supported by Bundesministerium für Wirtschaft through Arbeitsgemeinschaft industrieller Forschungsvereinigungen e.V. and grant no (AIF 11429 N).

3:30 PM S5.5

DISSOLUTION PROCESS OF COPPER SULFATE INTO WATER IN A HETEROGENEOUS VERTICAL MAGNETIC FIELD.

Atsushi Sugiyama, Tokyo Metropolitan Univ, Dept of Industrial Chemistry, Tokyo, JAPAN & National Research Laboratory for Magnetic Science, Japan Science and Technology Corporation, Saitama, JAPAN; Shigeyoshi Morisaki, Tokyo Metropolitan Univ, Dept of Industrial Chemistry, Tokyo, JAPAN; Ryoichi Aogaki, 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 changing susceptibility 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 Shinohara[1,2], Kazuhito Hashimoto[2], Ryoichi Aogaki[1]. [1]National Research Laboratory for Magnetic Science, Japan Science and Technology Corp., Saitama, JAPAN, [2]RCAST-The University of Tokyo, Tokyo, JAPAN.

In the high magnetic fields, suppression effect of the copper corrosion in nitric acid was examined. A macroscopic 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.