DAMAGE PROCESSES IN ADVANCED MATERIALS: Hydrogen and Corrosion Effects

Sponsored by: ASM International: Materials Science Critical Technology Sector, Structural Materials Division, Composite Materials Committee, Corrosion and Environmental Effects Committee, Physical Metallurgy Committee
Program Organizers: Russ H. Jones, Pacific Northwest Natl. Lab., Richland, WA 99352 USA; Richard Ricker, NIST, Materials Rm B254, Gaithersburg, MD 20899; Norman S. Stoloff, Rensselaer Polytechnic Inst., MS&E Dept., Troy, NY 12190-3590 USA

Thursday AM Room: Paris C
October 15, 1998 Location: O'Hare Hilton Hotel

Session Chairs: R. H. Jones, Pacific Northwest National Laboratory, Richland, WA 99352 USA; N. S. Stoloff, Rensselaer Polytechnic Institute, Troy, NY 12180-3590 USA

8:30 AM INVITED PAPER
DETERMINATION OF HYDROGEN EFFECTS ON INTERFACIAL FRACTURE USING THIN FILM TESTS: *N. R. Moody*[1]; D. Medlin[1]; S. Guthrie[1]; [1]Sandia National Laboratories, Livermore, CA 94550 USA

Although it is well-known that exposure to hydrogen and hydrogen producing environments can cause premature failure in many materials, experimental studies are inconclusive as to the mechanism controlling fracture. However, thin film testing provides a promising alternative for determining hydrogen effects on a local level. We have therefore employed nanoindentation and nanoscratch testing to determine how hydrogen affects deformation and fracture of thin tantalum nitride films and thin aluminum films on aluminum oxide substates. Tantalum nitride films are rigid films that fracture along the film-substrate interface. The aluminum films are ductile and show a great resistance to interfacial fracture. Both films exhibit a strong susceptibility to interfacial fracture and are accompanied by a significant decrease in interfacial fracture energy when exposed to hydrogen or moisture. We will present these results and discuss the relationship that exists between hydrogen and interfacial fracture in these thin film systems.

9:10 AM
MODELING AND QUANTIFICATION OF CORRODED SURFACES: *W. M. Mullins*[1]; [1]AFRL/MLLP-TMCI, Wright-Patterson, AFB, OH 45433 USA

The surface damage introduced by corrosion attack of surfaces is considered deleterious to long term structural integrity. As a result, the quantification of this damage represents an interest in the NDE community. Stochastic models for the chemical kinetics of general attack and intergranular/exfoliation corrosion are used to model the morphology of the surface as a function of time of exposure. Experimental results for corroded surfaces are presented which appear to agree with the model predictions. Stress analyses are performed for the surface morphologies in question to elucidate the relationship between fatigue-crack initiation and corrosion damage. Finally, discussions of the relationships between macroscopic measurements and predictions of residual service lifetime predictions are presented.

9:30 AM
THE EFFECT OF MICROSTRUCTURE AND COMPOSITION ON LOCAL CORROSION RESISTANCE OF NEWLY DEVELOPED NICKEL-FREE DUPLEX STAINLESS STEELS: *J. Wang*[1]; M. O. Speidel[1]; P. J. Uggowitzer[1]; [1]Institute of Metallurgy, ETH, Zentrum, Zurich CH-8092 Switzerland

Duplex stainless steels (DSS) with high nitrogen contents have some advantages, i.e., higher strength and corrosion resistance, more stable austenitic content in high temperatures. Due to high contents of nitrogen which is mostly dissolved in the austenitic phase, the corrosive mechanism of DSS can be different from the low nitrogen containing DSS, which is based on the calculations of pitting resistance equivalents number (PRE) for each phase. This work studied the effect of microstructure and local chemical compositions of newly developed nickel-free DSS on pitting resistance. By applying different heat treatment from 950ΥC to 1200ΥC, the phase ratio and partitioning of alloying elements Cr, Mo and N could be changed. The research results showed that austenite has become the stronger phase in regard to pitting potential measurements in artificial seawater in such high nitrogen alloyed DSS and was in agreement with the PRE calculations. The corrosion resistance with nitrides and intermetallic phase precipitation is seriously degraded by local sensitization caused by the depletion Cr and/or Mo. The role of Mo is emphasized on the development of such high nitrogen DSS due to its enrichment in ferrite which increases the PRE of the weaker ferritic phase. The balance of PRE between two phases can be reached through the additions of the proper Mo content.

9:50 AM
EVALUATION OF THE INFLUENCE OF ALLOYING ELEMENTS ON THE PITTING RESISTANCE OF NITROGEN ALLOYED STAINLESS STEELS: *R. E. Ricker*[1]; J. L. Fink[1]; R. D. Schmidt[1]; F. Biancaniello[1]; S. D. Ridder[1]; [1]National Institute of Standards and Technology, Metallurgy Division, Materials Science and Engineering Laboratory, Gaithersburg, MD 30899 USA

The development of improved techniques for the addition of nitrogen to stainless steels is leading to the development of new alloys with superior corrosion resistance. In many cases, these new alloys are so resistant to pitting corrosion that existing standard test methods cannot be used to guide alloy development. To overcome this problem, a new test method was developed and used to identify the influence of different alloying elements on the relative pitting resistance of a series of nitrogen containing alloys. This experimental technique will be presented along with an analysis of the influence of different alloying elements and a discussion of the impact of these results on our understanding of the mechanism of pitting corrosion in these alloys.

10:10 AM
ENVIRONMENTAL EFFECTS ON CREEP AND CRACKING OF ULTRA-HIGH PURITY Ni-16Cr-9Fe ALLOYS AT 360ΥC: *Denise J. Paraventi*[1]; Tom M. Angeliu[2]; William R. Caitlin[2]; Gary S. Was[3]; [1]University of Michigan, Department of Materials Science and Engineering, 2940 Cooley Lab, 2355 Bonisteel Blvd., Ann Arbor, MI 48109-2104 USA; [2]General Electric Corporate Research and Development Center, Building K-1, Room 3A51, 1 River Road, Schenectady, NY 12309 USA; [3]University of Michigan, Department of Nuclear Engineering and Radiological Sciences, Cooley Lab, 2355 Bonisteel Blvd., Ann Arbor, MI 48109-2104 USA

Alloy 600 has been used extensively for steam generator tubing and other components in pressurized water reactors. However, these tubes are susceptible to intergranular stress corrosion cracking (IGSCC) in the roll transition areas and the first row U-bends on the primary water side. Evidence in recent years has indicated that model alloys with lower creep resistance tend to have higher amounts of cracking. Work at the University of Michigan on high purity Ni-16Cr-9Fe has shown that the creep rates can be between a factor of 2 to 10 higher in primary water than in an inert environment. This presentation focuses the effects of the environment on the creep behavior of ultra high purity Ni-16Cr-9Fe.ne possible mechanism by which the environment can enhance creep is by hydrogen enhanced plasticity. It is proposed that hydrogen from the corrosion process enters the metal and effectively "shields" dislocation stress fields. The result is easier dislocation motion and thus enhanced plasticity. For Ni, at room temperature, it has been shown that the activation area, a measure of the size of dislocation stress fields, is reduced when hydrogen is present. Load drop tests were conducted at 360ΥC to evaluate this effect in primary water and argon environments. The effect of the environment on the creep rate as a function of stress and on the activation area were studied. The results showed that the internal stress of the alloy is lower when samples are tested in primary water compared to argon, indicating a reduction in the strength of barriers to dislocation motion. Also, the activation area was smaller by about 21% in primary water than in argon. Both of these results support a hydrogen enhanced plasticity mechanism of enhanced creep for Ni-base alloys at 360ΥC. To confirm that faster creep rates result from hydrogen enhanced plasticity, constant load tests were conducted in atomic hydrogen generated by dissociating hydrogen gas over a hot tungsten filament. This facilitated constant hydrogen charging at 360ΥC without using extreme gas pressures or an aqueous environment. Primary and steady state creep rates were obtained in both hydrogen and vacuum environments. Also, stress drops experiments were conducted to determine the activation area in the presence of hydrogen. These results will be discussed in terms of the hydrogen enhanced plasticity model and its relevance in the enhanced creep and intergranular cracking of high purity Ni-16Cr-9Fe alloys.

10:30 AM

DEUTERIUM IRRADIATION EFFECTS IN COPPER COATINGS ON 6061-Al SUBSTRATES: *M. Alam*[1]; M. Y. Inal[1]; [1]New Mexico Tech, Department of Materials Engineering, Socorro, NM 87801 USA

The US DOE is considering production of tritium via the reaction between spallation neutrons and 3He contained inside thin walled 6061-Al tubes [n(3He,p)3H]. The tritium ions will be produced with a high kinetic energy, causing a significant fraction to be embedded into the tube wall. The embedded tritium would not only be effectively lost, but may diffuse through the wall and be released into the surrounding water. This contribution deals with evaluating copper coatings on 6061-Al substrates as potential tritium permeation barriers. The coatings are prepared by the RF magnetron sputtering method. The deposited coatings are characterized for morphology (SEM), surface topography (STM), phase structure (XRD), residual stress (XRD) and bond strength (pull testing) prior to irradiation. Irradiation by deuterium ions is accomplished in a 200 kV accelerator. The variables include ion energy, fluence and irradiation time. The irradiated specimens are re-characterized by the above mentioned techniques. Deuterium depth profiles are obtained by SIMS. The changes induced by irradiation are being studied and the results will be discussed.

MECHANISMS AND MECHANICS OF COMPOSITE FRACTURE: Particle Reinforced Composites

Sponsored by: ASM International: Materials Science Critical Technology Sector, Structural Materials Division, Composite Materials Committee

Program Organizers: Bhaskar S. Majumdar, UES, Inc., Dayton, OH 45432-1894 USA; S. Krishnamurthy, UES, Inc., Dayton, OH 45432-1894 USA; Daniel B. Miracle, Wright Laboratory, Materials Directorate, Bldg 655, WPAFB, OH 45433 USA

Thursday AM — Room: Paris A
October 15, 1998 — Location: O'Hare Hilton Hotel

Session Chair: Sunil G. Warrier, UES, Dayton, OH 45432

8:30 AM

QUANTITATIVE MEASUREMENTS OF CLEAVAGE AND DIMPLE FORMATION IN THE FRACTURE OF Al-SiC COMPOSITES: *Edward Y. Chen*[1]; Lawrence R. Lawson[2]; M. Meshii[3]; [1]GE Corporate Research & Development, Physical Metallurgy Laboratory, P. O. Box 8, Schenectady, NY 12301 USA; [2]Metallurgist, 226 Interstate Parkway, Bradford, PA 16701-0286 USA; [3]Northwestern University, Department of Materials Science and Engineering, Evanston, IL 60208 USA

This study examines cleavage and dimple formation in the fracture toughness testing of two composites having similar aluminum alloy matrices but different forms of silicon carbide reinforcement, particulate and whisker. Cleavage, not often observed in FCC metals without the presence of some form of chemical embrittlement (e.g. liquid metal or hydrogen), is seen in the whisker reinforced but not in the particulate reinforced composite. Whisker reinforcement is seen to induce a greater degree of constraint and to provide fractured whisker sites which could provide high-modulus crack nuclei. Fractured particulate in the particle-reinforced composite, although less common than whisker fracture, also provides high modulus nuclei. However, these nuclei are not associated with cleavage facets in the matrix. Analysis of the shapes and spacing of reinforcement suggests that, in addition to a nucleus, there must be a sufficient shadow of constraint provided by the second phase to allow a cleavage crack to grow. T he cleavage crack would appear to grow from a sharp nucleus within the high-modulus phase into the shadow. The analysis obtaining these results was performed by application of stereological methods to fractography using models of fracture toughness for correlation. It is suggested that for the same volume fraction of reinforcement, whisker reinforcement is likely to result in lower fracture toughness than particle reinforcement through its capacity to induce cleavage.

8:55 AM

FATIGUE CRACK GROWTH IN A BIMATERIAL Al 2124-(SiCp+Al2124): *N. Yang*[1]; P. Bowen[1]; [1]The University of Birmingham, School of Metallurgy and Materials, Edgbaston, Birmingham B15 2TT UK

The fatigue crack growth resistance of a bimaterial Al 2124-(SiCp+Al 2124) has been investigated for crack growth perpendicular to the bimaterial interface. The bimaterial is an Al 2124 alloy and Al 2124 matrix composite reinforced with 22.5vol.% silicon carbide particles and was processed using powder metallurgy. These two components have different elastic moduli and thermal expansion coefficients. The study shows that the fatigue crack growth of the bimaterial is influenced markedly by residual stresses due to mismatch of thermal coefficient of the two components in the as-received bimaterial. The crack can penetrate the bimaterial interface without much difficulty when approaching the interface from the Al 2124 alloy side, but it can arrest before the interface when approaching the interface from the composite side, and depending on the value of the effective stress intensify factor range. Weight functions are used to quantify these observations and finite element methods are also used to quantify behaviour close to the bimaterial interface.

9:20 AM INVITED PAPER

CREEP OF MOLYDISILICIDE COMPOSITES: *K. Sadananda*[1]; C. R. Feng[1]; M. G. Hebsur[2]; [1]Naval Research Laboratory, Washington, DC 20375 USA; [2]NASA Lewis Research Center, Cleveland, OH 44135 USA

Creep behavior Molydisilicide with Si3N4 reinforcements has been investigated as a function of stress at 1200 C under tension and compression. Creep rates are lower in compression and are relatable to the possible suppression of void formation. Effect of reinforcement, whiskers versus particulates, were also investigated. Theoretical analysis indicated that alloying element, such as Al is likely to go into Si position and increase the metallic bond between Mo and Al at the expense of covalent bond. This is expected to increase the metallic nature and reduce their brittle nature. Experiments are done therefore to evaluate the creep rates with the addition of Al. Since there is always some glassy phase (SiO2) at grain boundaries, Al can reduce silica by forming Al2O3 at the boundaries. To evaluate the relative effects of Al versus Al2O3 on creep, effect of Al2O3 additions were also investigated. The trends in the behavior and the mechanisms underlying the creep will be elucidated.

9:45 AM INVITED PAPER

SUBCRITICAL CRACK GROWTH PROCESSES IN SiC/SiC COMPOSITES: *R. H. Jones*[1]; C. A. Lewinsohn[1]; C. H. Henager[1]; [1]Pacific Northwest National Laboratory, Richland, WA USA

Time-dependent cracking can occur in SiC/SiC composites by a fiber relaxation mechanism (FRM), interphase removal mechanism (IRM) or oxidation embrittlement mechanism (OEM). These processes occur at different environmental conditions and exhibit different effects on the material. FRM occurs over a range of temperatures but at very low O2 concentrations while both OEM and IRM require the presence of O2. IRM occurs at T>Tg, the glass transition temperatrue for SiO2, and pO2 less than atmospheric pressure while OEM occurs at T<Tg and atmospheric pressure of O2. Other possible crack growth mechanisms include a viscous interphase mechanism (VIM), where the fiber/matrix interphase is viscous, and a fiber embrittlement mechanism (FEM). Neither of these latter two processes have been demonstrated in SiC/SiC composites, however, they are feasible in these materials. Evidence for the FRM, IRM and OEM processes will be given and the conditions at which each occurs will be described. * Research supported by the office of Basic Energy Sciences of the U.S. Department of Energy.

10:10 AM

THERMAL STRESSES IN IN SITU Cr-Cr_2Nb COMPOSITES: PART I, THEORY: *Sanboh Lee*[1]; P. K. Liaw[2]; C. T. Liu[3]; Y. T. Chou[1]; [1]National Tsing Hua University, Department of Materials Science, Hsinchu, Taiwan Republic of China; [2]The University of Tennessee, Department of Materials Science and Engineering, Knoxville, TN 37996-2200 USA; [3]Oak Ridge National Laboratory, Metal and Ceramic Division, Oak Ridge, TN 37831-6115 USA

In Part I of this paper, thermal stresses due to a spheroidal inclusion were investigated using an equivalent inclusion approach proposed by Eshelby. The temperature inside the spheroid is maintained constant and different from that of the surrounding matrix of an infinite extent. A new relationship between the Cartesian coordinates and spheroidal coordinates was established. Based on this relationship, the solution for a prolate spheroidal inclusion was readily obtained from that for an oblate spheroidal inclusion. However, it is difficult to simplify the relationship between the solutions for a prolate spheroidal inclusion and for an oblate spheroidal inclusion using the conventional coordinate transformation. The principal stresses inside the spheroid increase with decreasing m, the ratio of shear moduli of the spheroid and matrix. Among all principal stresses, the maximum tensile stress is located at the interface between the inclusion and matrix. The numerical results are in agreement with those reported in the literature. The present theory was used to predict the cracking condition in dual-phase in-situ Cr-Cr2Nb composites, as shown in Part II of this paper. This research is sponsored by the Fossil Energy AR & TD Program (R. R. Judkins program manager), U.S. DOE, and the National Science Council, Taiwan, Republic of China.

10:35 AM

THERMAL STRESSES IN IN SITU Cr-Cr2Nb COMPOSITES: PART II, APPLICATION: Sanhoh Lee[1]; *P. K. Liaw*[2]; C. T. Liu[3]; Y. T. Chou[1]; [1]National Tsing Hua University, Department of Materials Science, Hsinchu, Taiwan Republic of China; [2]The University of Tennessee, Department of Materials Science and Engineering, Knoxville, TN 37996-2200 USA; [3]Oak Ridge National Laboratory, Metal and Ceramic Division, Oak Ridge, TN 37831-6115 USA

The influence of thermal stresses on the microstructures of in situ Cr-Cr2Nb composites has been investigated. Three cases were studied: (1) Cr-rich particles surrounded by the eutectic network, (2) Cr2Nb particles embedded in the Cr-rich matrix, and (3) Cr-rich particles inside the Cr2Nb matrix. The micrographs show that cracks appear on the interface between the particle and matrix. These phenomena are explained by the thermal stresses due to spheroidal inclusions. The maximum tensile stress and the absolute maximum shear stress were found to be located at the interface for the particles with all aspect ratios. The theoretical analyses support the formation of crack embryos at the interface, as the tensile stress exceeds a critical value. In a similar situation, interface decohesion takes place as a result of dislocation pile-ups. The thermal-stress calculation predicts the crack nucleus formed by dislocation pile-ups.

11:00 AM

THE CYCLIC FATIGUE AND FRACTURE BEHAVIOR OF Al_2O_3 PARTICULATE-REINFORCED 2014 ALUMINUM ALLOY METAL-MATRIX COMPOSITES:: *T. S. Srivatsan*[1]; M. Manoharan[2]; [1]The University of of Akron, Department of Mechanical Engineering, Akron, OH 44325 USA; [2]Nanyang Technological University, School of Applied Sciences, Nanyang Avenue 639-798 Singapore

A study was undertaken with the objective of rationalizing the influence of the discontinuous ceramic particulate reinforcements on the mechanical response of 2014 aluminum alloy metal-matrix composites. The cyclic strain amplitude-controlled fatigue properties and fracture characteristics of the 2014 aluminum alloy metal matrix discontinuously-reinforced with varying amounts of Al2O3 particulate reinforcements will be highlighted. Specimens of the discontinuously-reinforced aluminum alloy composite were cyclically deformed over a range of cyclic strain amplitudes, using fully-reversed tension-compression loading, giving cyclic fatigue lives of less than 104 cycles. The influence of test temperature on cyclic strain resistance and stress response was critically examined. In this presentation, the intrinsic mechanisms and micromechanisms controlling the strain resistance and stress response characteristics will be highlighted and discussed in light of composite microstructural effects, deformation characteristics of the matrix, cyclic strain amplitude, response stress and test temperature

11:25 AM

CREEP CIVITATION IN DISPERSION STRENGTHENED ALUMINUM WITH HIGH VOLUME FRACTION OF Al203 PARTICLES: *B. Q. Han*[1]; D. C. Dunand[1]; [1]Northwestern University, Department of Materials Science and Engineering, Evanston, IL 60208 USA

Creep cavitation was studied by density measurements in pure aluminum containing high volume fractions of submicron alumina dispersoids. In all experiments, the cavity fraction increases linearly with strain, i.e. the ratio of cavity fraction to strain is constant. This cavitation ratio (i) decreases with increasing stress at constant temperature; (ii) is weekly dependent of temperature at constant stress; (iii) increases with increasing volume fraction of dispersoids at constant stress and temperature. The cavitation ratio was similar for materials with micron- and millimeter-size grains, indicating that cavitation occurs at dispersoid/matrix interfaces, not at matrix grain boundaries. Assuming that cavities nucleate continuously at dispersoid/matrix interfaces and that the rate of cavity growth is controlled by coupled diffusional flow and power-law creep, a model for the cavity volume as a function of strain, stress, temperature and volume fraction of dispersoids is developed for composites with high volume fraction of dispersoids. The theoretical predictions are in a reasonable agreement with the experimental results.

11:50 AM

THE TENSILE STRENGTH OF 339 ALUMINUM REINFORCED WITH KAOWOOL FIBERS: A COMPARISON OF T5 AND T6 HEAT TREATMENTS: *William J. Baxter*[1]; Anil K. Sachdev[1]; [1]GM Research & Development Center, 30500 Mound Road, Warren, MI 48090 USA

This study compares the effects of T5 and T6 heat treatment on the tensile strengths of Kaowool fiber reinforced and unreinforced 339 aluminum. The 339 Al-T6 is stronger than 339 Al-T5, but for a Kaowool/339 Al composite the T5 condition is stronger than the T6. The controlling parameter is the strength of the aluminum dendrites, which is proportional to the concentration of magnesium in the dendrites. In the T5 condition, more than half of the magnesium is in large intermetallics in both the unreinforced alloy and the composite. During a T6 heat treatment, magnesium in the intermetallics is redissolved. In the unreinforced T6 ally this additional magnesium is retained in the dendrites. But in the T6 composite, the magnesium segregates to the Kaowool/aluminum interfaces softening the dendrites. This factor alone accounts for the low strength of the T6 composites. The tensile strengths of the T5 and T6 composites correspond to the calculated values for a perfectly bonded system.

12:15 PM

OBSERVATIONS OF THE FRACTURE PROCESSES IN A Nb-Si IN-SITU COMPOSITE USING CROSS-SECTIONAL ELECTRON MICROSCOPY: *Richard Grylls*[1]; B P Bewlay[2]; H A Lipsitt[1]; H L Fraser[1]; [1]The Ohio State University, Department of Materials Science and Engineering, 2041 College Road, Columbus, OH 43210 USA; [2]G.E. Corporate Research and Development, P.O. Box 8, Schenectady, New York 12301 USA

Composites based on Nb-Si are attractive candidates for use as structural materials at the very high temperatures required for future generation aircraft engines. Binary Nb-Si alloys typically possess very low room-temperature fracture toughness, but recently a more highly alloyed material has been developed which has fracture toughness of > 20 $MPam^{1/2}$. In this paper the fracture behavior of Nb-19Si is compared to that of the more highly alloyed material using cross-sectional transmission electron microscopy (TEM) of the fracture surface of specimens broken in four-point bending. The composites studied in this work were produced by directional solidification, which gives an in-situ composite microstructure consisting of niobium silicide dendrites surrounded by a eutectic mixture of metallic niobium solid solution and niobium silicide. Using cross-sectional TEM it is possible to view directly the micromechanisms of composite fracture, including the details of slip transmission, microcracking, crack bridging, ductile-phase pull-out and interfacial debonding. In this paper the micromechanisms of fracture of the two composites will be compared, and differences in the fracture toughness will be related to the observed deformation microstructures.

PROCESSING & FABRICATION OF ADVANCED MATERIALS VII: Nanostructured and Graded Materials

Sponsored by: Structural Materials Division, Structural Materials Committee

Program Organizers: T. Srivatsan, Univ of Akron, Dept. of Mech. Engr., Akron, OH 44325-3903; K. A. Khor, Nanyang Technological University, Sch of Mech & Prod Engrg, Singapore 639798 Singapore

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Session Chair: Dr. C. Koch, North Carolina State University, Department of Materials Science and Engineering, Raleigh, NC 27695-7907 USA

8:30 AM INVITED PAPER

NANOSTRUCTURED MATERIALS FOR STRUCTURAL APPLICATIONS: PROMISE AND PROGRESS: *Carl C. Koch*[1]; [1]North Carolina State University, Department of Materials Science and Engineering, Raleigh, NC 27695-7907 USA

There has been growing interest in nanostructured materials—materials with microstructural dimensions such as grain size ÿ 100 nm—for potential structural applications. This interest is due to both the experimental results which indicate high strength and hardness for nanostructured materials as well as predictions of ductility and toughness in normally brittle materials or even superplasticity at relatively low homologous temperatures. The many methods for synthesis of nanostructured materials can be classified into two groups. One involves particulates which must be compacted into bulk form. The other, such as devitrification, electrodeposition, or physical vapor deposition, is a "one-step" process. The artifacts/structural defects which can occur during particulate compaction can influence certain mechanical properties dramatically. This review will contrast the mechanical behavior of nanostructured materials made by "one-step" vs "two step" processes as well as review our present understanding of mechanical properties of this new class of materials.

9:00 AM INVITED PAPER

BULK MECHANICAL ALLOYING FOR FABRICATION OF NANO-STRUCTURED MATERIALS: *Tatsuhiko Aizawa*[1]; [1]University of Tokyo, Department of Metallurgy, 7-3-1 Hongo, Bunkyo-ku, Tokyo 113 Japan

The milling type and attriting type mechanical alloying methods have been widely utilized to yield various non-equilibrium phase materials in the order of grams. In addition to the small yield on the route of those mechanical alloying methods, their fatal demerits to industrial production are: 1) Long time processing, 2) Little capability for precise process control, and 3) Significant contamination from vial wall and balls. In order to overcome the above difficulties and to promote the intrinsic features to the mechanical alloying, author has been developing new mechanical alloying process: bulk mechanical alloying. Completely different from the conventional mechanical alloying methods, no vials nor balls are necessary in processing; the constituent element powder or granule mixture, or, solidified alloy bulk solids or agglomerates can be pored into a die cavity and subjected to the specified cyclic loading at Ar atmosphere in ambient temperature. With increase of the number of cycles in loading, the starting materials are uniformly mixed, homogenized, refined and alloyed. The systematic studies have been done during several years to have demonstrated that 1) 500 to 1000 cycles (4 to 8 ks) are sufficient to yield the final stage phase for each targeting material system, 2) little or no contamination is expected in principle of this processing, 3) solid or fluid parafin-wax are sometimes necessary to reduce the friction between samples and die material without oxidation or other reactions, or 4) warm pressing is also effective to consolidate the mechanically alloyed green samples. In the present study, Cu-Co and Al-Si systems are employed to produce nano-granular and nano-precipitate materials in the order of 100 grams and to control the magneto-resistance and the mechanical strength by tuning the nano-size of the secondary phase.

9:30 AM INVITED PAPER

PROCESSING OF METALLIC NANOSTRUCTURES BY ELECTRODEPOSITION TECHNIQUES: *F. Ebrahimi*[1]; D. Kong[1]; T. Mathews[1]; Q. Zhai[1]; [1]University of Florida, Materials Science & Engineering Department, Gainesville, FL USA

Electrodeposition techniques have been employed in processing nanocrystalline metals and laminated nanocomposites. Theses materials exhibit very high strength levels and have diverse applications from manufacturing tools for die casting to giant magneto resistive films for magnetic data recording. While thin films (<10 μm) can be processed relatively easily by electrodeposition, processing of bulk materials (electroforming) has remained to be a challenge. This paper discusses the effects of processing parameters, such as pulse profile, composition, pH, temperature and agitation on macroscopic defect structure, microstructure, and tensile properties of pure copper and nickel metals and laminated copper/nickel and copper/silver nanostructures.

10:10 AM

PROCESSING AND MECHANICAL PROPERTY OF FULL-DENSITY IN SITU Cu-Fe NANOCOMPOSITES CONSOLIDATED FROM MECHANICALLY ALLOYED POWDERS: *Li He*[1]; Larry F. Allard[2]; Evan Ma[1]; [1]Louisiana State University, Mechanical Engineering, RM 2420, CEBA, Baton Rouge, LA 70803 USA; [2]Oak Ridge National Laboratory, P.O. Box 2008, Oak Ridge, TN 37831 USA

A new route has been developed to produce full-density, bulk, two-phase nanocomposites. Nanocrystalline supersaturated solid solution Cu100-xFex (x=40, 85, 100)powders were produced by mechanically alloying of Cu and Fe at room temperature or liquid nitrogen temperature. These supersaturated solid solutions were decomposed on nanoscale in situ upon hot consolidation, forming Cu-Fe two-phase nanocomposites. Fully dense composite samples have been obtained using constrained sinter forging, which features near-net-shape manufacturing. Their microstructures were characterized using transmission electron microscopy. The Cu and Fe phase domains and their distributions were analyzed using energy dispersive X-ray spectrscopy with a focused electron beam. The average domain/grain sizes of Cu and Fe observed were well below 100 nm, confirming the formation of nanocomposites. The mechanical property of these nanocomposites will be studied using compression test. The strengthening mechanism will be examined in terms of interphase boundary strenthening, solid solution hardening, precipitation hardening, and dispersion hardening.

10:30 AM

MECHANICAL PROPERTIES OF GRADED MATERIALS: *Franz Josef Kahlen*[1]; [1]University of Central Florida, CREOL, 4000 Central Florida Blvd, Orlando, FL 32816-2700 USA

The authors present a one-step manufacturing tool to create graded materials suitable for industrial applications. Material powders are melted and form planar, two-dimensional geometries as the substrate is moved under the laser beam in the XY-direction. After completing the geometry in the plane, the substrate is displaced in the Z-direction, and a new layer of material is placed on to p of the just-completed deposit. By continuous repetition of this process, 3D parts were created. The material composition was altered by mixing different material powders prior to their delivery to the laser beam - substrate interaction region. A high power CO2 laser was used as the energy source, material powders under investigation were Stainless Steel SS304L, Copper, and Aluminum. Helium was used as the shield gas at a flow rate of 15 l/min. The incident CO2 laser beam power was varied between 300 W and 400 W, with the laser beam intensity distributed in a donut mode. The laser beam was focused to a focal diameter of 600 ÿm. The local material composition was investigated, to judge the effectiveness of the mixing just before deposition. Strength and hardness of the created components were measured and phases identified.