THE DEFORMATION CHARACTERISTICS OF
NANOCRystALLINE METALS

Atul H. Chokshi and Ravi S. Kottada
Department of Metallurgy, Indian Institute of Science, Bangalore 560 012
E-mail: achokshi@met.iisc.ernet.in

(Received 16 September 2004 ; in revised form 3 May 2005)

ABSTRACT
A reduction in the grain size of a metal offers a means for enhancing the strength by retarding dislocation activity, and at the same time enhancing ductility by processes involving grain boundaries. This overview critically examines various issues relating to strengthening and ductility in nanometals by considering both limitations to strengthening and processes contributing to weakening. It highlights the continuing interesting areas for further research.

SIZE EFFECT ON FERROELECTRIC BEHAVIOR

S. BERGER
Faculty of Materials Engineering, Technion, Haifa 32000, ISRAEL
E-mail: berger@tx.technion.ac.il

(Received 6 October 2004 ; in revised form 13 October 2005)

ABSTRACT
This paper reviews the subject of size effect on ferroelectric behavior from various points of view. It starts by describing three size regimes separated by two critical sizes, presenting experimental values of critical sizes as reported for various ferroelectric materials, giving details on structures of ferroelectric domains and domain walls as their size decreases to the nanometer scale, discussing theoretical models to predict the critical sizes, and showing specific cases where no size effect is present. The next section in this review presents the size effect on the stability of ferroelectric behavior as reflected in the transition temperature from ferroelectric to paraelectric phase. This section presents experimental evidence for a shift in the transition temperature with decreasing particle size and demonstrates the complexity of theoretical prediction the amplitude and direction of this shift. The last section of this review presents three different examples of nano-domain structures that exhibit ferroelectric behavior different than that of bulk-size domains. Their ferroelectric behavior is examined at different frequency and amplitude of applied electric field, different temperatures and sizes. In some cases theoretical models and expressions are given to show the parameters controlling their ferroelectric behavior. In summary, this review is aimed to expose the possibilities and limitations of reducing the size of ferroelectric particles to the nanometer size scale, which are needed for future applications.
DUCTILE Zr-BASE BULK NANOSTRUCTURED COMPOSITES: PRESENT STATE-OF-THE-ART

J. Eckert¹, J. Das¹,², W. Löser², U. Kühn², and S. K. Roy³
¹FG Physikalische Metallkunde, FB11 Material- und Geowissenschaften, Technische Universität Darmstadt, Petersenstraße 23, D-64287 Darmstadt, Germany
²Leibniz-Institut für Festkörper- und Werkstoffforschung Dresden, Postfach 270016, D-01171 Dresden, Germany
³Department of Metallurgical and Materials Engineering, Indian Institute of Technology, Kharagpur-721302, India
Email: j.eckert@phm.tu-darmstadt.de

(Received 9 September 2004 ; in revised form 11 May 2005)

ABSTRACT

Bulk metallic glasses or nanostructured Zr-base multicomponent alloys are attractive candidates as advanced high-strength materials for structural applications. The combination of high strength with high elastic strain renders such alloys quite unique in comparison to conventional microcrystalline materials. However, one major drawback for their use in engineering applications is the often limited macroscopic plastic deformability at room temperature, despite the fact that some of these alloys show perfectly elastic-plastic deformation behavior. To circumvent the limited ductility of these alloys, the concept of developing a heterogeneous microstructure combining a glassy or nanostructured matrix with second-phase particles with a different length-scale, has recently been employed. We review the present state-of-the-art in the production of Zr-base multicomponent structural bulk metallic glass/nanostructured composite materials by manipulating the microstructure to achieve high strength together with high ductility via controlling the instabilities responsible for early failure. We emphasize the possibilities to manipulate such composite microstructures in favor of either strength or ductility, or a combination of both, and also discuss the acquired ability to synthesize such in-situ high-strength composite microstructures in bulk form through inexpensive processing routes.
ON THE EVOLUTION OF A NANOCRYSTALLINE PHASE FROM THE Al-Cu-Fe QUASICRYSTALLINE ALLOY DURING HIGH ENERGY BALL MILLING


a Department of Physics, Banaras Hindu University, Varanasi-221005, India
b Department of Metallurgical Engineering, Institute of Technology, Banaras Hindu University, Varanasi-221005, India
E-mail: mukho_nk@rediffmail.com

(Received 21 September 2004; in revised form 11 July 2005)

ABSTRACT

Mechanical milling of an Al-Cu-Fe quasicrystalline alloy was performed in a high energy ball mill (Szegvari attritor mill) at a constant speed of 400 rpm for various milling time (from 0.5 to 40 h) under liquid hexane medium with a ball to powder ratio of 40:1. Scanning electron microscopy (SEM), transmission electron microscopy (TEM) and x-ray diffraction (XRD) techniques were employed for characterizing the milled and unmilled samples. The evolution of nanocrystalline (NC) phase (bcc, a =0.29 nm) was observed from the quasicrystalline phase after 5h of milling. This nanocrystalline phase, which was quite stable up to 40h of milling, did not transform to amorphous or any other metastable phase. The size of crystalline particles was found to vary from 60nm to minimum 10nm for different milling durations. It is interesting to note that the strain induced in the milled samples tends to increase along with milling time. The possible mechanisms for the formation of nanocrystalline phase will be put forward based on the evolution of the structural and microstructural features.
QUANTUM DOTS

B.N. Dev
Institute of Physics, Sachivalaya Marg, Bhubaneswar 751005, India
Email: bhupen@iopb.res.in

(Received 2 November 2004 ; in revised form 2 November 2005)

ABSTRACT

A quantum dot (QD) may be defined as a small patch of material confined in all three dimensions to nanometer lengths. When matter is structured and confined on the nanometer scale, some physics of little consequence for bulk systems may dominate important properties of the nanosystems. Interesting new properties of QDs are being exploited to fabricate devices like single-electron transistors, single-photon detectors, lasers, quantum computers, new catalysts and for applications in cryptography, tracing specific proteins within cells etc. QDs can be fabricated by lithography or by self-assembly. The advantages of self-assembled QDs over those lithographically fabricated are explained. Many advanced applications require epitaxially grown QDs on single crystalline substrates. Molecular beam epitaxy (MBE) is the highest precision deposition method used in semiconductor processing. Examples of growth of self-assembled epitaxial QDs by MBE in our laboratory and characterizations of QDs are presented. Single-electron tunneling is an essential aspect of single-electron transistors. Results of single-electron tunneling in QDs showing Coulomb blockade, Coulomb staircase and quantum capacitance are presented. These results were obtained by scanning tunneling spectroscopy (STS) measurements at 103 K in a variable temperature scanning tunneling microscope operating under ultrahigh vacuum and attached to the MBE system. Lastly, an ion-beam replication method for fabricating self-assembled nanostructures is described with examples of Si QDs fabricated on Si.
PROCESSING BULK STRUCTURES FROM NANO PARTICLES OF ALUMINUM

Jixiong Han1, * Martin J. Pluth,2 Jainagesh A. Sekhar1 and Vijay K. Vasudevan1
1Department of Chemical & Materials Engineering, University of Cincinnati, OH, 45221-0012 USA
2Showa Aluminum Corporation of America, 10500 O’Day-Harrison Rd, Mt Sterling, OH 43143

(Received 18 November 2004; in revised form 7 November 2005)

ABSTRACT

In the present work, the sinterability and processing of nanoparticles of aluminum to bulk nanocrystalline samples were studied. Pure Al nanoparticles, produced by the Exploding Wire Process, were uniaxially pressed at room temperature to compacts and sintered at various temperatures in the range from 500°C to 650°C. The as-synthesized powders had an average size of 130 nm with uniform 4-6 nm thick amorphous aluminum oxide coating around each particle. Studies carried out on the microstructure evolution and thermal stability of the processed materials indicated that temperature had a strong influence on the as-sintered microstructure, density and microhardness. Electron microscopy observations revealed that the sintering process at high temperature led to the breakup of the aluminum oxide scale around the particles resulting in a nanocomposite structure comprised of 100-200 nm Al oxide particles well dispersed in an Al matrix with a bimodal distribution of nanometer and micrometer size grains an Al grain matrix, with corresponding increase in sample density and hardness. Mechanisms governing the rupture of the oxide layer around the nanoparticles are discussed. Samples sintered at high temperature could be successfully rolled to high reduction in multiply passes, leading to full densification (100%) and high hardness. While cold rolling created many nanocracks in the Al matrix, hot rolling led to crack-free material.
SILICON-GERMANIUM NANOSTRUCTURES

Samit K. Ray and Kaustuv Das
Department of Physics & Meteorology, IIT Kharagpur 721 302
E.mail : physkr@phy.iitkgp.ernet.in

(Received 10 September 2004 ; in revised form 1 May 2005)

ABSTRACT

Semiconductor nanostructures are attractive because of their potentials in substantial improvements in optical and electrical properties over those of conventional two-dimensional structures. Epitaxial growth of SiGe/Si films in the Stranski-Krastanov mode can be exploited for the self-assembled growth of three-dimensional islands. Synthesis of Si and Ge nanocrystals embedded in a high bandgap insulator matrix could be utilized to achieve nanometer range structures without sophisticated nanolithography techniques. Silicon and germanium nanocrystals are promising candidates for light emission in the visible wavelength range due to quantum confinement of carriers and for flash electrically erasable and programmable read-only memory devices because of the Coulomb blockade phenomena. The growth of self-assembled Ge nanostructures, light emission in the visible range due to quantum confinement and the charge storage characteristics of Ge nanocrystals embedded in SiO$_2$ matrix are presented. SiGe/Si-based multi-quantum well semiconductor heterostructures are attractive for use in THz devices because of the compatibility with planar integration technology and the absence of the reststrahlen absorption band that is present in III-V and II-VI compound semiconductors. The characteristics of THz emitter devices fabricated using molecular beam epitaxially grown SiGe quantum well structures are reported.

UNDERSTANDING NANO QUASICRYSTALLINE PHASE FORMATION IN Zr BASED ALLOYS

B.S. Murty$^1$ and K. Hono$^2$

$^1$Department of Metallurgical and Materials Engineering, Indian Institute of Technology Madras,
Chennai 600036, India
$^2$Metallic Nanostructure Group, National Institute for Materials Science,
1-2-1 Sengen, Tsukuba 305-0047, Japan
E-mail: murty@iitm.ac.in

(Received 25 February 2005 ; in revised form 10 October 2005)

ABSTRACT

Nano icosahedral phase formation was observed in a number of Zr-based metallic glasses. This present paper reviews the present understanding on the nanoquasicrystalline phase formation in Zr-based alloys. The results indicate that oxygen stabilizes quasicrystalline phase. A large negative enthalpy of mixing and/or existence of Frank–Kasper-type phases.
DESIGN AND SYNTHESIS OF NANOSIZED BIOCERAMIC-PARTICLES, COMPOSITES AND COATING

Arvind Sinha and Suprabha Nayar
National Metallurgical Laboratory, Jamshedpur 831 007, INDIA
Email: arvind@nmlindia.org

(Received 28 October 2004 ; in revised form 5 February 2005)

ABSTRACT

Biopolymer mediated processes for the synthesis of third generation nanosized hydroxyapatite powder; its 3-D-macroporous polymer-composites and coating on functionalized steel surfaces have been described. The manuscript briefly reviews our activities in the area of biomimetics and bioceramics.

PLASMA DEPOSITION PROCESSES FOR NANOCOMPOSITE TiN/SiNx COATINGS

F.-J. Haug1,2 and J. Patscheider1
1Empa - Materials Science & Technology, Überlandstrasse 129, CH-8600 Dübendorf, Switzerland
2Institute of Microtechnology, University of Neuchâtel, Rue A.-L. Breguet 2, CH-2000 Switzerland
Email: f.j.haugefz-juelich.de

(Received 21 August 2004 ; in revised form 4 April 2005)

ABSTRACT

Refractory transition metal nitrides like TiN show outstanding mechanical properties and high hardness which lead to their wide use as coating materials for wear protection. In most cases, such coatings are deposited by plasma processes because they allow for comparatively low deposition temperatures. Furthermore, freedom in the choice of the deposition parameters makes it possible to improve the elastic and plastic properties by influencing crystal quality, grain size, texture, stress, etc. The formation of composite materials has become another attractive path for the development of new or enhanced properties, composites consisting of crystallites with typical sizes in the 10 nm regime and amorphous phases often show effects which go far beyond simple rules of mixture. Due to their nanostructure a certain composition range of TiN/Si3N4 nanocomposites exhibits extraordinary hardness which exceeds those of TiN and Si3N4, and even approaches the values of the hardest known materials. These nanocomposites can be deposited by PACVD, UBM-PVD, and arc PVD processes. Aspects of these deposition methods are described and properties of nanocomposite films are discussed.
SYNTHESIS OF Fe-Co BASED NANOMAGNETIC MATERIALS

H.F. Li and R.V. Ramanujan
School of Materials Science and Engineering, Nanyang Technological University, Singapore, 639798
Email: ramanujam@ntu.edu.sg

(Received 5 October 2004; in revised form 5 April 2005)

ABSTRACT

Processing of FeCo based nanomagnetic materials was carried out by chemical synthesis, crystallization from amorphous precursors and mechanical alloying. It was found that the products from chemical synthesis depended on the concentration of reaction solution. Uniform fiber like and spheroidal nanopowders were produced using Fe^{+2} rich and Co^{+2} rich reaction solutions respectively. The chemically synthesized FeCo based alloys was found to be amorphous. Through crystallization of melt spun amorphous precursors, high density nanocrystalline Fe_{44.5}Co_{44.5}Zr_{7}B_{4} alloy was obtained; the nanocrystals had a compacted dendritic morphology. Spheroidal nanocrystalline structure was successfully obtained after mechanical milling of Fe_{44.5}Co_{44.5}P_{7}B_{4} for more than 20 h at 300 rpm. The fiber like and compact dendritic morphology was not suitable for soft magnetic properties. Due to the pinning of magnetic domains, the powder nanostructured FeCo based alloys had inferior soft magnetic properties to the ribbon form alloys. The fiber like chemically synthesized and mechanically alloyed FeCo based alloys powders showed large coercivities. The magnetization of chemically synthesized FeCo alloy powders was low, which was considered to be due to solid solution contaminations, amorphous phase formation and the oxidation layer.
GROWING AND FULL GROWN COINAGE METAL NANOPARTICLES FOR CATALYTIC REDUCTION OF NITROCOMPOUNDS IN AQUEOUS AND MICELLAR ENVIRONMENTS

Sudipa Panigrahi¹, Narayan Pradhan¹, Anjali Pal² and Tarasankar Pal¹,*
¹Department of Chemistry, Indian Institute of Technology, Kharagpur 721302, India.
²Department of Civil Engineering, Indian Institute of Technology, Kharagpur 721302, India.
E-mail: tpal@chem.iitkgp.ernet.in

(Received 16 September 2004 ; in revised form 3 May 2005)

ABSTRACT

Reduction of different aromatic nitrocompounds is carried out successfully by NaBH₄ in presence of coinage metal nanoparticles in aqueous as well as micellar environments. The detailed kinetic profiles are studied in aqueous and three different micellar media (SDS, TX-100 and CTAB) using all the three coinage metal particles one at a time. The catalytic activity of the metals is found to be the maximum for Au particles (Au > Ag > Cu) in aqueous phase whereas it is reversed (Au < Ag < Cu) in TX-100 media. The reduction reactions were considered with full grown (FGME) and growing (GME) particles in presence and absence of oxygen. Different form of particles showed different kinetic paths. GME is always associated with some induction time with zero order kinetics for nitrocompound reduction but FGME shows altogether a different kinetics in different atmosphere. Induction time was found to be maximum for Au in both aqueous and micellar media. The kinetic profile of the reaction has been observed critically at different concentrations of the micelles to identify the location of metal particles in micelle and its subsequent bearing on the kinetics of the reaction.
DEVELOPMENT OF NANOCRYSTALLINE
MATERIALS FOR SOFT-MAGNETIC APPLICATIONS

Amitava Mitra and Ashis Kr. Panda
Magnetism Group, National Metallurgical Laboratory, Jamshedpur
Email: amitra@nmlindia.org

(Received 29 October 2004 ; in revised form 20 October 2005)

ABSTRACT

The structural and soft magnetic properties of Fe and FeCo-based nanocrystalline alloys have been investigated. These alloys were initially prepared in the form of amorphous ribbons with consistent properties by optimising different melt-spinning parameters. The structural behavior and soft magnetic properties depended on the alloy chemistry. The effect of metalloids in the Fe$_{73.5}$Nb$_3$Cu$_1$Si$_{22.5-X}$B$_X$ (X = 5, 9, 10, 11.25 and 19 at %) was studied. X-ray diffractograms showed that formation of α-Fe(Si) and/or Fe$_3$Si nanoparticles were responsible for the superior soft magnetic properties of the alloy with 9 at% Boron. All other alloys (X = 5, 10, 11.25 and 19 at%) exhibited early appearance of highly magnetocrystalline anisotropic boride phases leading to deterioration in soft magnetic properties. The role of extra alloying elements Al and Mn in the FeNbCuSiB system was also investigated. The alloy exhibited superior soft magnetic properties with a coercivity value of 0.32A/m (~4mOe) when heat-treated at 790K for 15min. Transmission electron microscopy study showed that this was due to the formation of ~ 6.0nm sized α-Fe(Si,Al) and/or Fe$_3$(Si,Al) nanoparticles. However, this alloy has a limitation on its use for high temperature soft magnetic application due to its low Curie temperature in nanocrystalline state. Hence, a new Fe$_{40}$Co$_{40}$Cu$_{0.5}$Al$_2$Zr$_9$Si$_4$B$_{4.5}$ alloy system was developed in which the Curie temperature of 736K in amorphous state increased above 1000K on annealing to nanocrystalline state. The saturation magnetization of the annealed alloy was also found to increase due to the formation of nanocrystalline α-(Fe,Co)(Si,Al) phase with higher magnetization suggesting the suitability of the alloy for high temperature soft magnetic applications.
Severe plastic deformation (SPD) is widely used now to produce a nanocrystalline structure in metals. Being applied to alloys it allows not only to refine the microstructure, but also lead to dissolution of second phases. An example of such effect of SPD is complete dissolution of cementite in eutectoid steel. In the present paper the mechanism of the strain induced cementite dissolution was analysed in terms of a model where a plastic phase (ferrite) flows under high pressure and high external stress around hard precipitates like a viscous fluid. The friction at the precipitate/matrix interface leads to two effects. One is a high strain energy accumulated in the carbides, which may strongly contribute to their thermodynamic instability, and the second is their wear due to the flow of the ferrite. The dissolution of carbon with the ferrite phase can be considered as a driven transformation, where two driving forces for mass transport flow are competing. One is the mechanically induced drag of carbon atoms, which depends mainly on the deformation rate. The second is diffusion of carbon induced by thermodynamic energy gradients, which are connected with high strains in the precipitates.
BULK NANOMETALS PRODUCED BY SEVERE PLASTIC DEFORMATION

R.Z. Valiev*, and I.V. Alexandrov
Institute of Physics of Advanced Materials, Ufa State Aviation Technical University,
K.Marx St. 12, 450000 Ufa, Russia
E-Mail: rzvaliev@mail.rb.ru

(Received 16 September 2004; in revised form 31 October 2005)

ABSTRACT

The paper is devoted to bulk nanostructured metallic materials, produced by the severe plastic deformation (SPD) method. The authors successfully demonstrated that as a result of application of very large strains $e>10$, realized at relatively low temperatures under high imposed pressures of several GPa in different metallic materials, nanostructured states in bulk billets are being formed. Under certain conditions (predominantly high angle grain boundaries, structure homogeneity) the formed nanostructured states possess unique physical and mechanical properties, in particular, simultaneous appearance of high strength and ductility (SPD paradox), low temperature and/or high rate superplasticity, etc.
SURFACE ENGINEERING ISSUES IN
NANOMATERIALS

Sharmila M. Mukhopadhyay, Pratik Joshi and Rajasekhar V. Pulikollu
Mechanical & Materials Engineering, Wright State University, Dayton, OH 45435.
Email: smukhopa@cs.wright.edu

(Received 26 October 2004 ; in revised form 7 November 2005)

ABSTRACT

As feature sizes in modern materials get smaller, the surface/interface to volume ratio drastically increases. For nano-structured solids (those with one or more dimensions in the 1-100 nm range), it can be argued that the few atomic layers that constitute the interfacial region will dominate most properties. Modification and tailoring of the surface or interface may be the most effective approach of controlling these materials, and incorporating them in engineering applications. This requires an in-depth understanding of structural, physical and chemical properties of these interface regions. The general concept of “surface engineering” is not new, but when the bulk structure to be coated is itself <100 nanometers in dimension, new challenges emerge. The coating thickness has to be substantially smaller than the bulk dimensions, yet be durable and effective. In this paper, some aspects of effective nano-meter scale coatings have been discussed. Since these are deposited by non-line of sight (plasma) techniques, they are capable of modifying nano-fibers, near net shape cellular foams, and other high porosity materials. Two types of coatings will be focused upon: (i) those that make the surface inert and (ii) those designed to enhance surface reactivity and bonding. The former has been achieved by forming 1-2 nm layer of -CF₂- (and/or CF₃) groups on the surface, and the latter by creating a nano-layer of SiO₂-type compound. Nucleation and growth study of these coatings at the initial stages of formation are performed on model single-crystal surfaces of silicon, sapphire and graphite. It is seen that these coatings completely cover the surface of all these materials within a 3-4 nm coating thickness, and are fully functional by then. They are therefore applicable to nano-structural solids. The effectiveness of these coatings in engineering applications is investigated by applying them on carbon nanofibers and micro-cellular foam structures. Coated and uncoated carbon structures are infiltrated with epoxy matrix to form composites and their mechanical behaviors are compared. Carbon nanofibers are also dispersed in an organic medium, and the influence of coatings on their dispersion behavior is investigated by electron microscopy. In addition, the influence of these nano-films on graphite-metal interfaces is studied with the idea of understanding their applicability to metal matrix composites. The oxide coating is seen to provide significant improvement in epoxy-carbon and metal-carbon bond formation, thereby improving composite behavior. The fluorocarbon coating is seen to work as a deterrent to bond formation, and therefore may be used as a passivating layer on nanomaterials.
PREDICTING AND ENGINEERING PHASE STABILITIES IN NANOSCALE MULTILAYERS

R. Banerjee¹, and H. L. Fraser²

¹Department of Materials Science and Engineering, University of North Texas, Denton, TX, U.S.A.
²Department of Materials Science and Engineering, Ohio State University, Columbus, OH, U.S.A.
Email: banerjeeunt.edu

(Received 24 November; in revised form 1 May 2005)

ABSTRACT

Nanoscale multilayers with dimensionally-constrained layers, often exhibit novel crystal structures and unusual properties. These multilayers possess an improved mechanical properties and corrosion resistance which make them attractive candidates for coatings. In addition, these multilayers also have wide applicability in the areas of information and energy storage. However, successful application of these multilayers is critically dependent on the ability to engineer both their micro- and nano-structures in a controlled manner, which has not been effected. The present paper discusses the summary of some of the recent developments in the field of nanoscale multilayers in terms of rationalizing and predicting the phase stability in nanoscale multilayers based on a simple thermodynamic model. Furthermore the present study has been able to resolve a standing controversy in the literature and, for the first time, regarding prediction of new phase transitions in given systems. Despite these successes, the model is in a fairly primitive stage of development and warrants further study to develop fully-validated computationally-based model for the prediction of phase stabilities in nanoscale multilayered materials.
CHARACTERISTICS OF MECHANICALLY ALLOYED NANOSTRUCTURED Ni-Al CATALYSTS IN H$_2$O$_2$ DECOMPOSITION

P.K. Dey$^1$, M. Dutta Gupta$^2$ and S.K. Pabi$^*$

$^1$Department of Metallurgical and Materials Engineering, Indian Institute of Technology, Kharagpur-721302, India.

$^2$Department of Chemistry, Indian Institute of Technology, Kharagpur 721302, India

E-mail: skpabi@metal.iitkgp.ernet.in

(Received 11 October 2004; in revised form 5 May 2005)

ABSTRACT

Catalytic characteristics of mechanically alloyed nanostructured phases of Ni-Al system in H$_2$O$_2$ decomposition were investigated. The catalysts were characterized by XPS, XRD, SEM, surface area measurement, and particle size analysis. The activity, activation energy, and the deactivation characteristics of each catalyst were studied for H$_2$O$_2$ decomposition at temperatures 20 – 40ºC controlled to ± 0.02ºC. The chemical states of Ni and Al of the nanostructured catalysts were analyzed by XPS and correlated with the catalytic performances of these materials. The alloyed-Ni (i.e. Ni bonded to Al) content on the surface of the nanostructured NiAl phase generally decreased with the increase in Ni-content from 30 to 65 at. % Ni, whereas the surfaces of the Ni(Al) solid solution of Ni$_{90}$Al$_{10}$ composition or the Al$_3$Ni phase were relatively depleted of alloyed-Ni content and enriched with aluminum oxide. The nanocrystalline non-equilibrium NiAl phase of Ni$_{30}$Al$_{70}$ composition showed the most pronounced catalytic activity, while the conventional microcrystalline alloy powder of the same chemical composition obtained through melting route was catalytically inactive. Deactivation of the catalysts was accompanied with the depletion of alloyed-Ni, formation of Al$_2$O$_3$ and metallic-Ni on the catalyst surface, which indicated that Ni bonded to Al were the effective specie for the catalytic activity.
NANOFLUID- A NEW CONCEPT IN HEAT TRANSFER AND THERMAL MANAGEMENT

I. Manna¹*, M. Chopkar¹ and P.K. Das²
¹Department of Metallurgical and Materials Engineering
²Department of Mechanical Engineering
Indian Institute of Technology, Kharagpur 721302, India
* Email: imanna@metal.iitkgp.ernet.in

(Received 21 August 2005 ; in revised form 4 December 2005)

ABSTRACT

Nanofluids are quasi-single phase heat transfer fluids with negligible (< 1 vol. %) amount of nanometric solid dispersion in a base fluid making a stable colloidal suspension. These fluids are of interest due to the extraordinary (40-200%) enhancement of thermal conductivity possible that eludes a precise scientific explanation as yet. In the present paper, some interesting results pertaining to the synthesis and characterization of nanometric Al-alloy particle dispersed water and ethylene glycol based nanofluids have been presented after a brief overview of the evolution of the concept of nanofluid. While the nanofluid is prepared by a two-stage process including mechano-chemical synthesis of nanocrystalline Al₆₀Cu₄₀ alloys powders, thermal conductivity is measured using an improvised thermal comparator method. The results indicate that the thermal conductivity ratio could be enhanced up to 100% with a dispersion of only 2 vol.% nanometric Al alloy particles in water or ethylene glycol.

BEHAVIOUR OF EMBEDDED METALS AND ALLOYS AT SMALL SIZES

K. Chattopadhyay
Department of Metallurgy, Indian Institute of Science, Bangalore – 560 012, India
Email: kamanio@met.iisc.ernet.in

(Received 31 January 2005 ; in revised form 13 October 2005)

ABSTRACT

Nanomaterials represent a field of vigorous activity in recent time. Although not new to metallurgists, the current widespread interests do provide opportunities to look at the issues in a new light. Drawing from the recent research and experience of the present author and his group, the article provides some thoughts on the challenges and opportunities that exist for one class of nanomaterials, namely, nano embedded materials. The article highlights the basic issues, resolution of which is necessary for the future application of these materials.
SYNTHESIS, MICROSTRUCTURE AND GMR PROPERTIES OF HALF-METALLIC CrO$_2$-PVA NANOCOMPOSITE FILMS

S. Biswas and S. Ram
Materials Science Centre, Indian Institute of Technology, Kharagpur–721302, India
Email: sram@matsc.iitkgp.ernet.in

(Received 1 November 2004; in revised form 20 October 2005)

ABSTRACT

A new giant magnetoresistance (GMR) material of CrO$_2$ – PVA nanocomposite has been developed in form of thin films by a hydrothermal casting of dispersed CrO$_2$ nanoparticles in a polymer matrix of poly-vinyl alcohol (PVA). The virgin CrO$_2$ particles have an average crystallite size of 30 nm in a D$_{4h}$:P4$_2$/nmn tetragonal crystal structure of lattice parameters $a = 0.4173$ nm and $c = 0.3156$ nm. The polymer (insulator) encapsulates ferromagnetic CrO$_2$ nanoparticles with a thin insulating surface barrier layer such that the sample offers an enhanced MR value. A value of MR of 6.8 % (at magnetic field of 1.1 kOe) lies at room temperature in a sample of 2.0 wt% CrO$_2$–PVA. Microstructure reveals a uniform distribution of CrO$_2$ particles through PVA molecules. A diamagnetic coating of polymer molecules of CrO$_2$ renders a spin-dependent tunneling between CrO$_2$ nanoparticles.

LASER PROCESSING OF NANO-FOILS IN CONFINED ENVIRONMENT FOR SECURITY CODING

Lin Li and Robert Stewart
Laser Processing Research Centre, School of Mechanical, Aerospace and Civil Engineering, The University of Manchester, Manchester M60 1QD, UK
Email: lin.li@manchester.ac.uk

(Received 4 January 2005; in revised form 8 November 2005)

ABSTRACT

Strips of thin (20 nm thick) aluminium foils laminated on both sides with transparent polymers are processed with a Q-switched Nd:YAG laser to generate specific microscopic features for security coding. The effect of laser processing parameters on material behaviour in the confined environment is analysed. Because of the confinement by the polymers, the particles generated (either by laser melting or vaporisation) of 100 nm to 2 mm in size are trapped and distributed within the polymer films not normally seen in open surface laser beam processing. This produces various microscopic features that have distinct “signatures” for identification. The interaction of the laser beam with the Al foil with a thickness close to the optical absorption length of the beam is another aspect that is different from laser processing of thicker materials. The thermal heating and cooling effects for laser processing of ultra-thin metallic foils together with the mechanisms of various microscopic feature formations are discussed.
THREE-DIMENSIONAL WULFF DIAGRAMS FOR THE DESCRIPTION OF GRAIN BOUNDARY FACETING AND ROUGHENING

B. Straumal1, Ya. Kucherinenko2, and S. Protasova1

1Institute of Solid State Physics, Russian Academy of Sciences, Chernogolovka, Moscow District, 142432 Russia
2Geological faculty, Moscow Lomonosov State University, Vorobjovy gory, 119992 Moscow, Russia
Email: straumal@issp.ac.ru

(Received 31 July 2004 ; in revised form 3 October 2005)

ABSTRACT

The properties of nanostructured materials depend crucially on the behavior of grain boundaries (GBs). It has been shown recently that the transition between faceted and rough GBs can drastically change the properties of a whole polycrystal. Particularly, high portion of faceted GBs can trigger the abnormal grain growth or lead to the enhanced non-homogeneity of mechanical properties. The construction of three-dimensional Wulff diagrams permits one to describe adequately the GB faceting and roughening behavior. In this work this novel method is applied for the description of GB faceting in Cu. The influence of orientation and misorientation deviation $\Delta \theta = |\theta - \theta_c|$ from coincidence misorientation $\theta_c$ has been studied for twin GBs.

INTRODUCING MISORIENTATION EVOLUTION INTO ECAP MODELLING: A POSSIBLE APPROACH

R.J. Hellmig1, H.S. Kim2, and Y. Estrin1

1IWW, TU Clausthal, Agricolastr. 6, 38678 Clausthal-Zellerfeld, Germany
2Dept. of Metallurgical Eng., Chungnam National University, Daejeon, 305-764, Korea
Email: juri.estrin@tu-clausthal.de

(Received 18 September 2004 ; in revised form 10 May 2005)

ABSTRACT

A three-dimensional version of a dislocation density based constitutive model that allows calculating the evolution of microstructure, mechanical properties and texture was used to simulate the equal channel angular pressing (ECAP) of copper. The present paper focuses on the concomitant variation of the misorientation angle with increasing strain. Own experimental measurements and literature data were used to obtain the parameters required for simulating the evolution of the misorientation angle. A comparison of the results of simulation with experimental data shows the possible applicability of this approach for predicting microstructure evolution, including the variation of the misorientation angle, under severe plastic deformation.
CHARACTERIZATION OF NANO STRUCTURES BY TRANSMISSION ELECTRON MICROSCOPY

G. K. Dey, S. Neogy, R. T. Savalia, D. Srivastava and S. Banerjee
Materials Science Division, Bhabha Atomic Research Centre, Mumbai 400 085, India
Email: gkdey@apsara.barc.ernet.in

(Received 18 September 2004 ; in revised form 12 May 2005)

ABSTRACT

Characterization of nano-structures involves ascertaining their shape and size besides finding out the atomic arrangement inside these and their composition. Because of its ability to do imaging at an atomic scale, nanobeam diffraction and nanobeam composition analysis, the modern transmission electron microscope (TEM) has emerged as a complete characterization tool for examination of nanostructures. In this paper, examples are cited from the examination of various types of nanostructures in the TEM, with particular emphasis on the study of nanocrystalline materials. Besides nanocrystalline materials use of TEM in the study of nanotubes, mesoporous molecular materials and nanolayered materials have also been described.

A COMPARISON OF GRAIN SIZE MEASUREMENTS
BY X-RAY DIFFRACTION AND TRANSMISSION ELECTRON MICROSCOPY METHODS

R. Mitra¹, T. Ungár², and J. R. Weertman³
¹Department of Metallurgical and Materials Engineering, Indian Institute of Technology, Kharagpur – 721 302, India
²Institute for General Physics, Eötvös University, H-1455 Múzeum krt 6-8, Budapest VIII, P.O.B. 323, Hungary
³Department of Materials Science and Engineering, Northwestern University, Evanston, IL 60208, USA
Email: rahul@metal.iitkgp.ernet.in

(Received 7 October 2004 ; in revised form 13, May 2005)

ABSTRACT

Grain sizes were measured in bulk nanocrystalline copper processed by inert gas condensation and compaction, using X-ray diffraction (XRD) and transmission electron microscopy (TEM) methods. The XRD peaks were analyzed using the Warren-Averbach, integral breadth and Williamson-Hall methods, modified to include the contributions of dislocations to peak broadening. Analysis using full-width half-maximum values provided the largest average grain sizes, while analyses of integral breadth and Fourier coefficients of XRD peak profiles gave the medium and smallest average grain sizes, respectively. A significant increase in the mean grain size accompanied by broadening of the grain size distribution could be observed upon increasing the temperature of compaction of nano-powders from 69°C (342 K = 0.25T_M) to 180°C (453 K = 0.34T_M) or after a six-month exposure of samples to ambient temperatures (T_M is the absolute temperature of melting). Grain size distributions, obtained by direct measurement of the dimensions of ~500 grains per sample using bright and dark field transmission electron microscopy, were found to obey a log normal relationship. The TEM results agreed well with those of XRD measurements for narrow grain size distributions with smaller mean values, but they deviated significantly when the mean grain size increased and distributions widened, indicating that the information from XRD analyses could be misleading.
MAGNETICALLY SOFT NANOCRYSTALLINE ALLOYS FOR HIGH TEMPERATURE APPLICATIONS

Tadeusz Kulik, Jaroslaw Ferenc, Aleksandra Kolano Burian, Maciej Kowalczyk, Xiubing Liang
Faculty of Materials Science and Engineering, Warsaw University of Technology, ul. Woloska 141, 02-507 Warsaw, Poland
Email: tkulik@inmat.pw.edu.pl

(Received 29 October 2004 ; in revised form 13 September 2005)

ABSTRACTS

In the present study, it is shown that partial replacement of Fe with Co in amorphous (Fe_{1-x}Co_{x})_{73.5-Cu_{1}-Nb_{13.5-B_{9}} (x = 0.14 to 0.68) alloy increases the Curie temperature to 930°C. Another new class of nanocrystalline alloys was developed where Fe was replaced with Co in NANOPERM to obtain a composition of Fe_{45}Co_{43}Cu_{1}-B_{3.6}-Zr_{7.4}RM_{x} (where x = 3.7 and 7.4, RM = Nb and Hf). The Curie temperature in this alloy increases to over 800°C allowing retention of ferromagnetic properties at reasonably high working temperatures up to 500–600°C. However, the Co doping increases the coercivity deteriorating the soft magnetic properties slightly. The alloy with 6 at. % B and 7 at. % Hf seems to show optimum properties, thermal stability and ease of synthesis. The cobalt-to-iron ratio should not exceed 1:1 to ensure high Curie temperature and good soft magnetic properties and good thermal stability.