NC structure as well. At the same time, annealing of non-deformed RQ TiNiCu does not allow to process homogeneous NC structure, since its crystallization immediately leads to the formation of relatively large individual grains of submicron sizes.

Annealing of HPT-processed RQ NdFeB alloys leads to the formation of more homogeneous and refined structure than that processed by annealing of non-deformed amorphous RQ NdFeB samples. As a result, the magnetic properties of $H_{c,}$ Br, of RQ NdFeB alloys processed by HPT and annealing are 20- 30 % higher than the properties of the non-deformed annealed alloys [2,3]. This effect occurs both in RQ stoichiometric $Nd_{12}Fe_{82}B_6$ and in RQ nonstoichiometric $Nd_9Fe_{85}B_6$ alloys and may be viewed as the phenomenon of generic character [2,3].

Thus, the impact of SPD and further annealing on initial amorphous RQ alloys is a new technique to fabricate bulk NC samples with enhanced magnetic and mechanical properties.

This work was supported within the framework of ISTC project 3208, RFBR project 05-02-16728 and 06-02-16695-a.

[1] A.G. Popov, D.V. Gunderov, V.V. Stolyarov JMMM, 157/158 (1996) 33

[2] D.V. Gunderov, A.G. Popov, N.N. Schegoleva, V.V. Stolyarov, A.R. Yavary. In "Nanomaterials by Severe Plastic Deformation"/ Edited by M.Zehetbauer and R.Z.Valiev, Verlag GmbH&Co. KGa, Weinheim, (2004) 165

[3] 3 A.G. Popov, D.V. Gunderov, V.V. Stolyarov, X.Y. Zhang at al Nineteenth International Workshop on Rare Earth Permanent Magnets and Their Applications Aug. 29-Sept. 5, 2006 Beijing , China

[4] V.G. Pushin, V.V. Stolyarov, D.V. Gunderov, R.Z. Valiev, T.C. Lowe, Y.T. Zhu Mater. Sci and Eng. A 410-411 (2005) 386

[5] D.V. Gunderov, V.G. Pushin, R.Z. Valiev, E.Z. Valiev Deformation and destruction of materials, 4 (2006) 22 (*in Russian*)

Oral session

Physical and Mechanical Properties

Invited report

Bulk Nanocrystalline Copper-based Alloys with Superior Mechanical Properties and Controlled Color

Alain Reza Yavari[a,1], Katsumi Ota[a,1], Frederic Charlot[a,1], Alain LeMoulec[a,1] and Gavin Vaughan[b,2]

[a] SIMAP-CNRS UA29, Institut National Polytechnique de Grenoble, BP 75 Saint Martin d'Hères Campus 38402, France

[b] European Synchrotron Radiation Facility – ESRF, Grenoble France

[1] euronano@ltpcm.inpg.fr, [2] vaughan@esrf.fr

We report on the development of copper-based nanostructured bulk specimens prepared by injection casting from the liquid state. Usually copper-based alloys are mechanically soft with strengths below 1300 MPa for the hardest. Additional strength can be achieved with further elemental additions but results in the loss of any shade of copper coloring. In our research supported by the International Copper Association-ICA, we have developed nanostructured copper-based alloys with typical copper color and strengths up to 1900 MPa.

The thermodynamic approach behind the nanostructure development will be presented. Detailed microstructural analysis will be reported using field emission gun high resolution SEM and X-ray microscopy using a focused high-energy monochromatic beam of synchrotron origin.

Oral report

Thermal Stability and Annealing Behaviour of HPT Processed Iron

Yulia Ivanisenko[a,1], Ralf Theissmann[a,2], Alexander Minkov[b,3], Kejing Yang[b,4], Ruslan Valiev[c,5] and Hans-Jörg Fecht[b,6]

[a] Institut für Nanotechnology, Forschungszentrum Karlsruhe, 76021 Karlsruhe, Germany

[b] Materials Division, University of Ulm, 89091 Ulm, Germany

[c] Institute of Physics of Advanced Materials, USATU, 12 K. Marx St., Ufa 450000, Russia

[1] ivanissenko@int.fzk.de, [2] ralf.theissmann@int.fzk.de, [3] alexander.minkow@uni-ulm.de, [4] kejing.yang@uni-ulm.de, [5] RZValiev@mail.rb.ru, [6] hans.fecht@uni-ulm.de

Recent past revealed a growing interest to the processes of severe plastic deformation because they offer a promising way for microstructure refinement in metals and alloys. As a rule, SPD-methods include very intense plastic straining at low homological temperature [1], and resulting microstructures are characterised not only by the very small grain size (typically in the range between 50 and 500 nm), but also by a non equilibrium state which is manifested in high level of micro and macro stresses. Investigations of annealing behaviour of SPD-processed metals and alloys revealed that it may differ from that of their coarse grained counterparts. In particular, the mechanism of the recrystallisation is changed from discontinuous to continuous [2], and grain growth activation energy is notably reduced. At the same time for understanding of mechanisms governing the recovery and recrystallisation of SPD-processed UFG materials, further investigations are necessary.

Present paper describes the comprehensive investigation of microstructure evolution upon annealing in HPT-processed iron (two grades have been studied: Armco iron of 99.7 % purity, and very pure iron of 99.99 % purity) using conventional and high resolution TEM and orientation imaging microscopy (OIM).

Initial as-HPT microstructure was typical for severely deformed metals and consisted of lightly elongated grains of 100 and 200 nm in diameter in Armco iron and 99.99% iron, respectively. Furthermore, a high level of microstrains of 0.3% was found in both as-HPT samples. The microstructure evolution after isochronal anneals for 1 hour in temperature range between 200 and 500 °C had revealed very different behaviour of iron samples with different purity. In Armco iron the grain growth was observed only after annealing at 450°C (Fig. 1). In the temperature range between 200 and 450°C processes of recovery of high angle grain boundaries and dislocation subboundaries had occurred: mean subgrain misorientation had increased from 5° to 6.5° (Fig. 1), the grain boundaries become narrower in TEM images, the fraction of low angle boundaries decreased from 22% in as-HPT state till 7.5 % after annealing at 450°C. Simultaneously the mean subgrain size had increased from 93 to 127 nm (Fig. 1) and the microstrains decreased to the values typical for those in well annealed coarse grained iron.

This indicates that the basic mechanism of recovery of HPT-processed Armco iron is the relaxation of non-equilibrium grain boundaries (both low- and high angle).

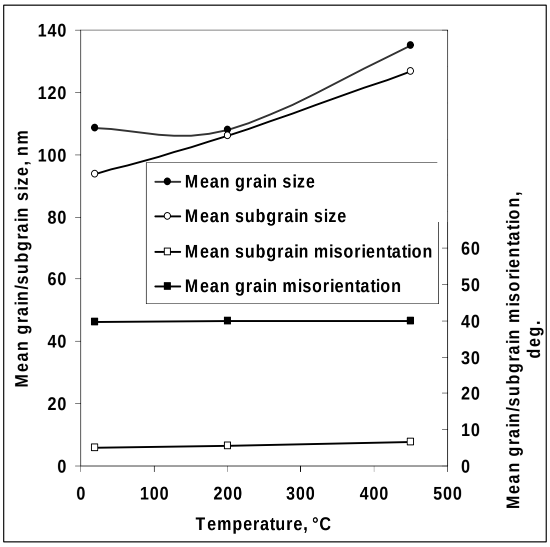

Figure 1. Mean grain/subgrain size and mean misorientation angle as a function of annealing temperature in HPT-processed Armco iron

In contrast to that we observed a significant increase of mean grain size up to 285 nm in 99.99% iron sample already after annealing at 200°C for 1 hour. Surprisingly, a very high density of defects was observed inside recrystallised grains. Using *in situ* TEM we have shown that these defects had appeared as a result of migration of nonequilibrium grain boundaries.

[1] R.Z. Valiev, Y. Estrin, Z. Horita, T.G. Langdon, M.J. Zehetbauer, Y.T. Zhu, JOM 58 (2006) 33

[2] A. Belyakov, T.Sakai, H. Miura, R. Kaibyshev, K. Tsuzaki, Acta Mater 50 (2002) 1547

[3] Yu. Ivanisenko, R.Z. Valiev, H.-J. Fecht, Mat. Sci. Eng. A390 (2005) 159

Oral report

Common Trends in Texture Evolution and Flow Anisotropy of Ultra-Fine Grained HCP Materials during Strain Path Changes

Ibrahim Karaman[a,1], Guney G. Yapici[a,2], Irene Beyerlein[b,3] and Carlos N. Tomé[c,4]

[a] Department of Mechanical Engineering, Texas A&M University, College Station, TX 77843-3123

[b] Los Alamos National Laboratory, Theoretical Division, Los Alamos, NM 87545

[c] Los Alamos National Laboratory, Materials Science and Technology Division, Los Alamos, NM 87545

[1] ikaraman@tamu.edu, [2] ggyapici@tamu.edu, [3] irene@lanl.gov, [4] tome@lanl.gov

Recent findings show that large strains and abrupt strain path changes alter the microstructure and crystallographic texture of HCP materials, leading to considerable flow stress anisotropy. We have recently conducted an extensive investigation on the effect of strain path changes of a few HCP materials during and after severe plastic deformation on the resulting texture and uniaxial (tensile and compressive) flow anisotropy. In particular, we have used Equal Channel Angular Extrusion (ECAE) to severely process: 1) Pure Zr billets with strong basal texture at room temperature; 2) Commercial Purity (CP) Ti Grade 2 and Grade 4 following various routes at minimum possible temperatures (300°C and 400°C, respectively) followed by room temperature conventional rolling (Figure 1); and 3) Ti-6Al-4V alloy at temperatures above 550 °C followed by room temperature tension and compression. In addition, compressive flow anisotropy along three orthogonal directions of the ECAE processed Zr billets was explored. In Ti, in-plane tensile anisotropy of the ECAE processed and rolled billets was investigated. In Ti6Al4V, tension-compression asymmetry in the yield strengths of the ECAE processed billets was demonstrated. A Visco-Plastic Self Consistent (VPSC) polycrystal plasticity model was used to predict the flow behavior and texture evolution after post-processing uniaxial experiments.

In this talk, we will summarize the common trends and subtle differences on the texture evolution and flow anisotropy in these materials while also elaborating on the microstructural mechanisms responsible for these phenomena. In all cases, it was found that both deformation texture and processing induced microstructure have to be considered in interpreting the flow anisotropy and tension-compression asymmetry. The VPSC model helped understanding relative importance of governing deformation mechanisms responsible for texture evolution and flow anisotropy trends. The most important observation was the necessity of the activation of "unconventional" deformation mechanisms for capturing the resulting deformation textures, even after one ECAE pass and in some cases independent of initial texture and processing temperature. For example, it was found that activation of basal slip was necessary for capturing the texture evolution after ECAE, even though basal slip activity in Zr is rarely documented in the literature at ambient temperature. Similarly, compression twinning was found to be operative in Ti-6Al-4V processed above 700 °C through extensive TEM observations (Figure 2). The necessity of this deformation mode was also supported by texture predictions. We believe that the die geometry (constrained simple shear) during ECAE and/or the refinement of the microstructure leading to high strength levels may permit the activation of 'unconventional' deformation mechanisms.

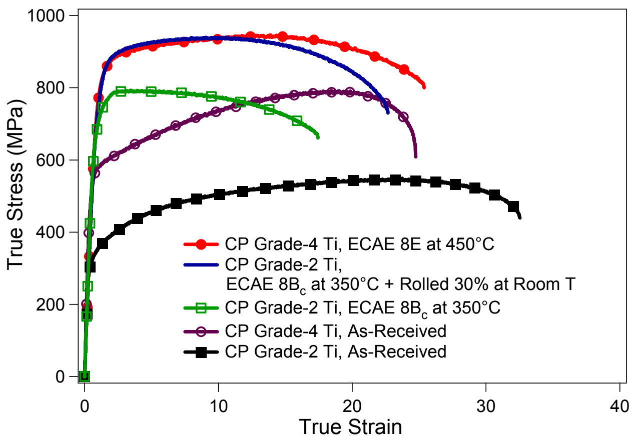

Figure 1. Room temperature tensile true stress vs. true strain response of the ECAE processed CP Grade 2 and Grade 4 Ti and ECAE plus cold-rolled CP Grade 2 Ti

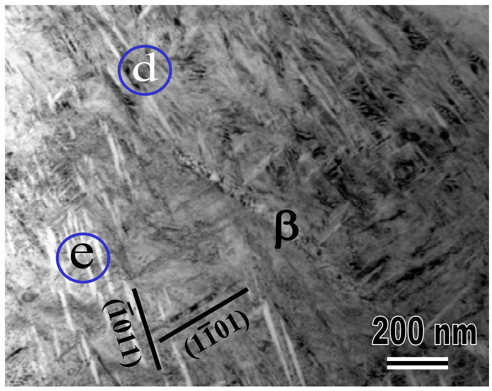

Figure 2. Deformation twins observed in Ti-6Al-4V after two ECAE passes at 800°C following route A.

Oral report

Is the Substructure a Controlling Factor of Creep Life in ECAP Materials?*

Ivan Saxl[a,1], Vaclav Sklenicka[b,2] and Milan Svoboda[b,3]

[a] Mathematical Institute, Academy of Sciences of the Czech Republic,
Zitna 25, CZ-115 67 Praha, Czech Republic

[b] Institute of Physics of Materials, Academy of Sciences of the Czech Republic,
Zizkova 22, CZ-616 62 Brno, Czech Republic

[1] saxl@math.cas.cz, [2] vsklen@ipm.cz, [3] svobm@ipm.cz

Somewhat surprising effect of ECAP of the number of ECAP passes on the creep behaviour has been observed in pure aluminium [1,2]. The creep resistance increased considerably after the first pass but the repetitive pressing led again to the gradual decrease of the creep properties. In order to explain this behaviour, a detailed study of the material substructure after 2, 4, 8 and 12 passes was carried out by means of the orientation imaging microscopy (OIM). Four intervals of the boundary misorien-tation Δ vere examined: $2^o \leq \Delta < 5^o$, $5^o \leq \Delta < 10^o$, $10^o \leq \Delta < 15^o$ and $15^o \leq \Delta$. Then standard profile count giving the mean number N_A of profiles per unit area of the section plane and intercept count resul-ting in the mean number N_L of profile chords per unit length of the test line were carried out. Two specimens, three mutually perpendicular section planes and 6 systematically selected directions of the test lines in each plane were examined. The mean boundary areas per unit volume S_V as well as the mean triple grain junction lengths per unit per unit volume L_V were then estimated by the stereological relations $[S_V] = 2N_L$ and $[L_V] = 2P_A = 4N_A$. The obtained results are presented in Table 1.

Table 1. The effect of the number of passes on area and length intensities S_V, L_V

		$[S_V]$ [μm^{-1}]				$[L_V]$[μm^{-2}]			
Number of passes N		2	4	8	12	2	4	8	12
$[S_V]$, $[L_V]$ at $\Delta > 2^o$		**1.1**	**1.6**	**2.1**	**1.6**	**1.1**	**1.9**	**3.4**	**1.8**
fractions of $[S_V]$, $[L_V]$ at $\Delta \geq 2^o$ [%]	$2^o \leq \Delta < 5^o$	54	25	12	13	68	42	23	24
	$5^o \leq \Delta < 10^o$	33	24	14	13	21	23	18	17
	$10^o \leq \Delta < 15^o$	7	15	10	10	5	14	12	12
	$\Delta \geq 15^o$	6	36	64	64	6	21	47	47
$[S_V]$, $[L_V]$ at $\Delta > 15^o$		**0.07**	**0.58**	**1.33**	**1.05**	**0.07**	**0.40**	**1.6**	**0.85**

Table 1 shows, that after 2 passes is the amount of high angle boundaries very small – approximately 6% of the total boundary area. The fraction of these boundaries gradually increases with the number of passes and exceeds 60% after eight passes. On the other hand, the amount of all boundaries with $\Delta \geq 2^{o}$ does not change considerably. Similarly behave also the triple grain junctions.

Consequently, it could be proposed that the boundary structure, namely the lack of high angle boundaries, is responsible for the high creep resistance after a low number of passes. Other feature of the boundary structure is its non-homogeneity; completely different structures are observed in two closely spaced places of one specimen and cause the great scatter in the creep properties even after the same number of passes. Thus beside the creep life $t \cong 60$ [h] of the specimen B8 shown in Fig. 1, also only $t \cong 20$ [h] was attained in another B8 specimen. This diversity can be again explained on the basis of structural differences in anisotropy and local homogeneity found in the specimens [3].

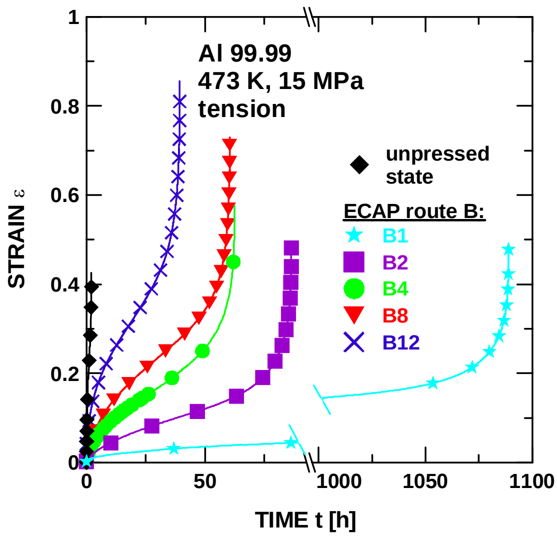

Figure 1. Effect of the number of passes on the creep life

[1] V. Sklenicka, J. Dvorak, M. Svoboda, Mater. Sci. Eng. A, 387-389 (2004) 696

[2] V. Sklenicka, J. Dvorak, P. Kral, Z. Stonawska, M. Svoboda, Mater. Sci. Eng. A, 410-412 (2005) 408

[3] I. Saxl, V. Sklenicka, L. Ilucova, M. Svoboda, P. Kral, Mat. Sci. Forum, 493-498 (2007) 493

**Support by grants GAAV ČR A2041301, GAČR 201/06/0302 and Inst. Res. Plan No. AV0Z10190503 is deeply appreciated.*

Oral report

The Flow Behaviour of a Superplastic Zn-22% Al Alloy Processed by ECAP

Megumi Kawasaki[a,1] and Terence G. Langdon[a,b,2,3]

[a] Departments of Aerospace & Mechanical Engineering and Materials Science
University of Southern California, Los Angeles, CA 90089-1453, U.S.A.

[b] Materials Research Group, School of Engineering Sciences
University of Southampton, Southampton SO17 1BJ, U.K.

[1] mkawasak@usc.edu, [2] langdon@usc.edu, [3] langdon@soton.ac.uk

Numerous data are available to date to understand the principles of ECAP and mechanical properties, especially superplastic ductility at elevated temperatures, of as-pressed polycrystalline metallic materials.

Grain boundary sliding (GBS) is an important flow mechanism to achieve superplasticity during high temperature deformation [1]. Although it is reasonable to assume that GBS occurs in materials processed by ECAP that have ultrafine grains, there are only a small number of reports on GBS tested at limited strain rates in as-pressed materials [2,3]. Therefore, the superplastic Zn-22% Al eutectoid alloy was subjected to ECAP for 8 passes. The as-pressed material showed high strain rate superplasticity having an elongation of 2230% at 473 K. Detailed observations of GBS were conducted on the as-pressed Zn-Al alloy pulled to an elongation of 30% at 473 K in order to measure the sliding contribution over a range of strain rates. This paper describes the phenomenon of GBS in the Zn-Al alloy processed by ECAP.

[1] T.G. Langdon, Mater. Sci. Eng. A, 174 (1994) 225

[2] R.K. Islamgaliev, N.F. Yunusova, R.Z. Valiev, N.K. Tsenev, V.N. Perevezentsev and T.G. Langdon, Scripta Mater., 49 (2003) 467

[3] P. Kumar, C. Xu and T.G. Langdon, Mater. Sci. Eng. A, 410-411 (2005) 447

Invited report

The Mechanical Characteristics of Nanometals with a Bimodal Grain Size Distribution

M.J.N.V. Prasad[a,1] and Atul H. Chokshi[a,2]

[a] Department of Materials Engineering, Indian Institute of Science, Bangalore 560 012, India

[1] prasad@materials.iisc.ernet.in, [2] achokshi@materials.iisc.ernet.in

A reduction in grain size to the nanocrystalline range leads to a substantial increase in strength, and a concommitant reduction in ductility. Plastic flow in crystalline materials can generally be expressed in the following form:

$$\sigma = K\varepsilon^{N}\dot{\varepsilon}^{m}$$

where σ is the flow stress, ε is the plastic strain, $\dot{\varepsilon}$ is the strain rate, N is the strain hardening coefficient, m is the strain rate sensitivity and K is a constant incorporating the dependence of flow stress on temperature and microstructural factors.

Analysis of factors influencing ductility usually focus on the parameters N and m; an increase in either or both of these terms leads to an increase in the stability of tensile deformation. While nanometals tend to have a strain rate sensitivity that is higher than their micrograin counterparts, the value of m is still relatively low (typically <0.1), so that this factor cannot support large ductility. In addition, an increase in flow stress in nanometals is also accompanied by a reduction in N, so that nanometals tend to have poor ductility. One microstructural design for enhancing ductility is to develop a bimodal grain size in nanometals, such that the fine grain population provides for enhanced strength whereas the coarse grain population enhances ductility by enabling strain hardening. While there has been some success reported in obtaining a combination of high strength and ductility using this approach, there are also several studies that do show this combination of desirable properties in materials with a bimodal grain size distribution.

The data available in the literature will be examined critically, and new experimental and analytical results on microstructural evolution (including texture) and ductility will be reported for nanocrystalline Ni with a bimodal grain size distribution. Nanoindentation and microindentation experiments will be utilized to evaluate critically the conjecture that coarse grains and fine grains can support different stresses.

Invited report

What Controls the Fatigue of SPD Metals?

Alexei Vinogradov[1], Satoshi Hashimoto[2]

Department of Intelligent Materials, Osaka City University, 558-8585 Japan

[1] alexei@imat.eng.osaka-cu.ac.jp, [2] hashimoto@imat.eng.osaka-cu.ac.jp

The problem of fatigue of bulk nanostructured materials is in focus of the present communcation. Common aspects and features of the cyclic response of various materials produced by severe plastic deformation (SPD) via equal-channel angular pressing are discussed. Special attention is paid to the influence of strain path, amount of strain and post-processing annealing on the structure, strength and ductility, fatigue life and cyclic hardening/softening of metals and alloys. Aiming at understanding of the reasons for materails degradation under cyclic straining, the available to date experimental results on the effect of the grain size on the high-cyclic and low-cyclic properties are reviewed. Mechanisms of plastic flow and degradation during fatigue are discussed from the standpoint of initial nano- or sub-microcrystalline structure and its evolution upon cyclic straining. The role of two strengthening mechanisms - dislocation accumulation and grain reduction - is highlighted. The importance of both factors for the mechanical behavior, strain localization and fracture of ultra-fine grain metals is argued. It is demonstrated that high fatigue limit can be achieved after rather small number of ECA-pressings if a uniform fine grain structure is formed during ECAP and post-processing annealing. Although, the question: ”What controls the fatigue of SPD metals?” remains open, we suppose the present review will shed some light on it.

Finally, the results of phenomenological modeling of the monotonic and cyclic response of ultra-fine grain metals are presented in terms of dislocation kinetics and a satisfactory agreement with experimental data is demonstrated.

Oral report

Mechanical Behavior and Microstructural Evolution in ECAP Copper

Anuj Mishra[a,1], Morgana Martin[b,2], B.Kad[c,3], Naresh Thadhani[b,4] and Marc Meyers[a,5]

[a] Materials Science and Engineering, University of California- San Diego,
9500 Gilman Drive, La Jolla, CA 92093

[b] Department of Materials Science and Engineering, Georgia Institute of Technology,
771 Ferst Drive, Atlanta, GA 30332

[c] Department of Structural Engineering, University of California-San Diego,
9500 Gilman Drive, La Jolla, CA 92093

[1] amishra@ucsd.edu, [2] morgana@gatech.edu,[3] bkad@ucsd.edu, [4] naresh.thadhani@mse.gatech.edu, [5] mameyers@ucsd.edu

Equal Channel Angular Pressing (ECAP) is a severe plastic deformation technique that was used to produce ultra-fine grained copper. The microstructure was optimized using different deformation sequences. A steady state grain size of 200-500 nm was routinely obtained after eight passes (with an equivalent strain of ~1 per pass). This resulted in a random texture evidenced by EBSD results. The mechanical response was obtained under quasi-static and dynamic conditions.

The evolution of microstructure upon repeated ECAP passes was characterized by TEM and EBSD techniques. The features of grain refinement process were captured using analytical models. The minimum grain size obtained, 200-500 nm, was quantatively explained by means of grain boundary rotation and grain boundary mobility calculations at the temperature reached in deformation process (~360 K).

The as obtained ultra-fine grained structure was found to be thermally unstable. The microstructure recrystallized upon being dynamically deformed due to the adiabatic temperature rise imparted by plastic deformation. This was observed in three modes of high-strain rate plastic deformation experiments: cylindrical and hat-shaped specimens in Hopkinson bar experiments and cylindrical specimens in reverse Taylor impact experiments.

Oral report

Enhanced Fatigue Properties of Ultrafine-Grained Titanium Rods Produced by Means of Severe Plastic Deformation

Irina P. Semenova[a,1], Gulnaz Kh. Salimgareeva[a,2] and Vladimir V. Latysh[b,3]

[a] Institute of Physics of Advanced Materials, Ufa State Aviation Technical University, 12 K. Marx St., Ufa 450000, Russia

[b] “Iskra” Innovative Scientific and Technical Centre, 81 Pushkin St., Ufa 450000, Russia

[1] Semenova-ip@mail.ru, [2] sadikova_gh@list.ru, [3] latysh-VV@mail.ru

Our investigations are focused on the development of pilot technology of fabrication of titanium long-length ultrafine-grained (UFG) rods – semi-products suitable for further production of articles. It combines equal channel angular pressing (ECAP) for the formation of UFG structure and thermomechanical treatment with the purpose of additional hardening and producing the rods of specified length [1,2]. Among the set of properties fundamentally important for practical application a distinct position belongs to the fatigue resistance. New approaches to the formation of UFG structure in titanium materials for enhancement of fatigue strength are discussed.

Experimental results of study of fatigue properties of titanium long-length rods Grade 4 produced by means of combined processing with the use of severe plastic deformation (SPD) are presented in this work. Fatigue tests were performed on smooth and notched samples. The formation of homogeneous UFG structure in CP-Ti Grade 4 rods was revealed to result in fatigue strength enhancement by 1.5 times and achieved the fatigue level of the alloyed Ti-6Al-4V. UFG samples with the notch (K_T=2.7) also demonstrate enhancement of fatigue strength in comparison with the coarse-grained analogue, at that the titanium notch sensitivity after SPD processing increases which can be probably related to its lower ductility in comparison with coarse-grained state. The possibility of additional enhancement of fatigue properties of UFG titanium due to low-temperature annealing at the temperature of 350ºC by means of simultaneous increase of material’s strength and ductility is shown.

[1] I.P. Semenova, V.V. Latysh, G.H. Sadikova, Y.T. Zhu, T.C. Lowe, R.Z. Valiev, Nanostructured Materials by High-Pressure Severe Plastic Deformation, edited by Y. Zhu and V. Varyukhin, NATO Science Series, 212 (2005) 235

[2] G.H. Salimgareeva, I.P. Semenova ,V.V. Latysh, I.V. Kandarov, R.Z. Valiev, Solid State Phenomena, 114 (2005) 183

Oral report

Structure and Mechanical Properties of Sheets and Profiles from the UFG 1421 Alloy

Rinat K. Islamgaliev[a,1], Gulnaz V. Nurislamova[a,2], Nina F. Yunusova[a,3], Nikolay A. Krasilnikov[b,4], Vladimir A. Markovchev[c,5] and Marina A. Bardinova[a,6]

[a] Institute of Physics of Advanced Materials, Ufa State Aviation Technical University, 12 K. Marx St., Ufa 450000 Russia

[b] Ulyanovsk State University, L.Tolstoi, 42, Ulyanovsk 432700, Russia

[c]JSC "Ulyanovsky NIAT", 432010 Ulyanovsk, Russia

[1] saturn@mail.rb.ru, [2] yun@mail.rb.ru, [3] gulnaz_@mail.rb.ru, [4] nick@sv.uven.ru, [5] niat@mv.ru, [6] marina_bardinova@mail.ru

Structure and mechanical properties of sheets and profiles from the ultrafine-grained (UFG) Al 1421 alloy (Al-5.5%Mg-2.2%Li-0.12%Zr-0.2%Sc wt.%) has been investigated in the present work. Equal channel angular pressing (ECAP) with true strain e = 8 was has been applied at 370°C to refine the microstructure of the initial coarse-grained alloy. The billets processed by ECAP were subjected to warm rolling at the temperature of 350°C and the strain e = 2.7 with a view to produce a sheet with 2 mm in thickness. The samples after ECAP+rolling were characterized by equiaxed structure with the same grain size of 0,8 μm and demonstrated high strain rate 10^{-2}-$10^{-1}s^{-1}$ and low temperature (400°C) superplasticity with elongation to failure δ=780% and δ= 530%, correspondingly. Lowering of elongation to failure of the UFG sheet can be explained by occurrence of a weekly expressed rolling texture as compared to textureless state observed in the ECAP billet. However, the texture maxima in the UFG sheet were almost 2 times less than the intensity of texture maxima observed in the sheet made from coarse-grained (CG) alloy, which had the elongated grains of 8.0-10.0 μm containing subgrains (1.5 μm) with low-angle misorientations. The structure of the sheets also consisted of the particles of Al_2MgLi phase having the size of 0.4 μm and volume fraction less than 10% in the UFG sheets, and 0.7 μm and 5%, respectively, in CG sheets.

The profiles were produced at elevated pressure using bending of sheets preliminary heated up to 350°C. The profile thickness at bending area exceeded the thickness of the profile's flat elements by 5%.

Microhardness distribution at the profile's cross-section was homogeneous for UFG states and amounted to 1.6 GPa. At the same time, the CG sheet has shown microhardness 1.1 GPa, the bending area of which exhibited some insignificant decrease in microhardness (1.0 GPa). Additionally the structures of both profiles differed from the structure of the sheets by additional precipitation of δ phase AlLi, which can be connected with structure heterogenization at elevated temperature of profiling. Profile of a CG sheet had subgrained (1.2 μm) structure with the particles of δ phase (0.5 μm) and volume fraction not exceeding 10%. Whereas UFG profile was characterized by equiaxed ultra-fine grained structure (0.8 μm) and presence of δ phase (0.3 μm, 10%).

The samples of the 1421 processed by ECAP+rolling have been subjected additional shot annealing at 450^{o}C and aging to use a potential of grain refinement and dispersion hardening for enhancement of mechanical properties. As a result of tensile tests the 1421 alloy has demonstrated high ultimate tensile strength 690 MPa retaining initial ductility 9% in comparison with coarse-grained samples subjected to standard quenching and aging, which exhibited 530 MPa and 10%, respectively.

Poster session B

Invited poster report

Structural Changes during Grain Boundaries Migration of Submicrometer-Grained Alloy Al-3%Mg

Nilolay K. Tsenev, R. N. Hisaev, A.N. Tsenev
JSC “Konstructsia” office 61, 2 Neginskaya St., Ufa 450064 Russia.
nktsenev@narod.ru

The present work deals with experimental studies of structural changes and kinematics of grain growth of submicrometer-grained (d <1μm) model alloy Al-3% Mg during annealing. The submicrometer- grained structure was obtained on Bridgmen anvils under a pressure of 6 GPa and the true logarithmic strain degree e=5.

The TEM analysis of the submicrometer - grained alloy Al-3% Mg showed that in the initial state a mean grain size constituted 0.25 mm and grains were misorientated by high angles. The existence of extinction contours inside a grain body and the "blurring" of a banded contrast on grain boundaries testify to the presence of strong elastic fields. The microdiffraction pattern from an area of 0.75 mm2 has a large amount of reflexes arranged in a circle. Part of reflexes are a bit blurred, this confirms the existence of strong elastic fields. TEM methods did not reveal the presence of lattice dislocations inside a grain body.

Annealing of samples in the temperature interval 373-523 K leads to considerable changes in structure of grain boundaries. Annealing at the temperature 373 K for 1 hour results in appearing of a distinct banded contrast on grain boundaries. Grain size remains the same. These results show that at the given temperature recovery processes occur only on grain boundaries. Lattice dislocations are not revealed inside the grain body. Further increase in the temperature of annealing leads to grain growth. One should note that with increasing the grain size to 0.4-0.5 mm no dislocations are observed inside the grain body. However, as the grain size reaches 0.5-0.7 mm an aggregate of dislocations appears inside the grain body. These results show that grain boundary migration of the submicrometer - grained alloy is accompanied by concurrent precipitation of lattice dislocations. When the grain size is within the range 0.4-0.5 mm the appearance of lattice dislocations inside the grain body leads to their absorption and dissociation due to the “Mirror reflexion” law. When the grain size is more than 0.5 mm and the "Mirror reflexion" law does not act, an increase of lattice dislocation density inside the grain body occurs during annealing.

On the basis of the experimental results of investigation of grain boundary migration a model of grain growth during annealing is suggested.

Poster report

Characterization of the Microstructure of Ultrafine-Grained Materials by X-ray Line Profile Analysis

Igor Alexandrov[a,1], Tamas Ungar[b]

[a] Institute of Physics of Advanced Materials, Ufa State Aviation Technical University, 12 K. Marx St. Ufa 450000 Russia

[b] Department of General Physics, Eotvos University, Pazmany Peter setany 1A, Budapest H-1518 POB 32, Hungary

[1] iva@mail.rb.ru

X-ray diffraction analysis (XDA) is a strong tool for investigating microstructure of heavily deformed materials. Recent years are characterized by the intensive development of this technique. This is connected with advances in the used equipment as well as with development of approaches to the analysis of X-ray line profiles. All this formed the basis for wide use of XDA when studying the microstructure of bulk ultrafine-grained (UFG) materials processed by a severe plastic deformation (SPD) technique.

The present report demonstrates the results of thorough characterization of the microstructure of bulk ultrafine-grained materials processed by the SPD technique. Pure Cu and commercial pure Ti were subjects of research. SPD of Cu and Ti was realized by equal-channel angular (ECA) pressing in the die-set with the channels' intersection angle 90° at room temperature and at 450 °C respectively. The investigations were carried out for the initial state and after different number of ECA pressing passes (from 1 to 12). An approach considering the peculiarities of X-ray diffraction on dislocation of different types was used for processing the obtained X-ray line profiles.

As a result of the conducted XDA thorough characterization of the microstructure of the studied bulk Cu and Ti billets was performed. The dependencies of the microstructure parameters (sizes of coherent-scattering regions, elastic microdistortions of the crystalline lattice, preferred character of dislocations) on the crystalline lattice type and number of passes during ECA pressing were determined. The obtained results carry inference about the peculiarities of the microstructure evolution in fcc and HCP metals during SPD.

Poster report

The Increasing of Corrosion Resistance of UFG Materials in Comparison to CG Materials

Nailya A. Amirhanova[a]

[a] Ufa State Aviation Technical University, 12 K. Marks St., Ufa 450000 Russia

amirhanova@mail.ru

The UFG matrials are more corrosion active in the active electrolytes than the CG materials. It is necessary to protect these materials from corrosion damage and to increase the corrosion resistance.

The chemical polishing and chemical oxidation were used for researched materials: titanium, aluminium, nickel alloys, copper, magnesium alloys, carbon steel; as the method of corrosion protection.

The chemical polishing and chemical oxidation of UFG materials was investigated in comparison with CG materials. The UFG and CG materials were immersed corrosion active solutions (3% NaCl, 0,1 m HCl) after chemical polishing and chemical oxidation. The potentials without current, corrosion rate and surface microstructure were determinated.

It is revealed, that such materials as aluminium alloys, titanium, nickel alloys, copper become covered equal thin superficial films after chemical polishing in optimum solutions and modes. UFG materials have more equal film and this film lays on a material basis. It is established, that potentials without a current have more electropositive value than potentials without a current without chemical polishing. The corrosion rate of UFG materials after chemical polishing is same as corrosion rate of CG materials. The UFG magnesium alloys, carbon steel were protected from corrosion damage in active solutions by the chemical oxidation method in $NaOH + NO_3^- + H_2O_2$ solution. The magnesium alloys, carbon steel become covered passive films which protect these materials with UFG structure from corrosion damage.

Invited poster report

The Corrosion Behaviour of UFG Materials in Comparison to CG Materials

Nailya A. Amirhanova

Ufa State Aviation Technical University, 12 K. Marks St., Ufa 450000 Russia

amirhanova@mail.ru

The corrosion behaviour of UFG materials and CG materials were investigated in the active and passive electrolytes. It is established, the materials with UFG structure are more corrosion active than materials with CG structure in corrosion active electrolytes (3% NaCl, 0,1 M HCl). The potentials without a current of UFG materials has more electronegative value than potentials without a current of CG materials, especially for 0,1 M HCl solution. The corrosion rate of UFG materials are more than corrosion rate of CG materials in 1,5 time.

Research of a surface microstructure has shown, that on a surface of UFG samples corrosion destruction as a pitting is much more than for CG materials. Observable increase of corrosion rates of UFG materials are caused by the presence of the greater number of the active centers and the greater extent of grain boundaries there is an adsorption active ions such as Cl^- and H^+.

The corrosion damage of UFG materials occurs to smaller rates than corrosion damage of CG materials in passive electrolytes, especially for Ti, Al alloys, Ni alloys. The oxygen adsorption is observed on active centers and grain boundaries in passive agues solutions, it is results to passivation of surface. The potentials without a current become identical for UFG and CG materials because UFG materials have passive films on a surface. The corrosion rates of UFG and CG materials become identical in passive electrolytes.

Poster report

Structural Alteration of As-Received Cu-1Cr-0.7Al-0.2Zr Alloy After High Pressure Torsion

Svetlana N. Faizova[a] and Natalia V. Balabanova[b,1]

[a] Institute of Mechanics, Ufa Science Center, Russian Academy of Sciences, 71 Oktyabr Pr., Ufa 450001, Russia

[b] Ufa State Aviation Technical Univercity, 12 K. Marx St., Ufa 450000, Russia

[1] Balabanova.Lis.@mail.ru

It is well known now, that the treatment by the High Pressure Torsion (HPT) increases the strength of materials as a result of the crystalline structure refinement. Simultaneously, intensive deformation may significantly influence the dissolution and precipitation processes in precipitation hardening alloys. These phenomena are very important for the development of advanced ultra-fine grained materials but remain very scarcely studied.

In the present work the influence of the pre-HPT solid solution treatment (SST) temperature and the total HPT strain on the structure and properties of the Cu-1%Cr-0.2%Zr alloy are reported. The material under investigation belongs to high-conductive high-copper precipitation strengthening alloys.

Two initial states of alloy prepared at two SST temperatures T_1 and $T_2=T_1+50°C$ with different degree of dissolution of alloying elements in the copper matrix were prepared. The HPT was carried out on ∅10mm and 0.8 mm thick samples with pressure 6 GPa and ram speed 1rpm. The structure and properties of samples were tested immediately after the initial pressing and then after 0.1, 0.2, 0.5, 1, 3 and 5 turns. Precipitation particles were identified using the extraction replicas.

The SST forms in the samples a coarse grained structure –the mean grain size was 26 and 34 μm at T_1 and T_2, correspondingly. The mean size of particles was 55 and 45 nm and average distance between them – 350 and 460 nm for T_1 and T_2, correspondingly. It should be noted, that the optical microscopy revealed also the presence of large, ~0.5 – 1 μm, particles in the both states. The microhardness was 750 MPa (T_1) and 780MPa (T_2).

At the initial stages of HPT dislocation pile-ups and cells separated by dense dislocation walls were observed. The newly formed ~20 nm precipitations might also be seen, while particles formed during the SST were still present in the material. After the first turn the large precipitation particles totally disappeared. When number of turns reached 5, the fragmentation of crystalline structure was at ~100 nm scale. The mean size of the precipitation particles and the average distance between them also decreased: the corresponding values were 26 and 110 nm for T_1, and 18 and 106 nm for T_2. It worth noting, that the size distribution of the particles was more uniform than in the initial state, particularly there were no large particles. After the HPT treatment the microhardness was 2390 MPa (T_1) and 2480 MPa (T_2) which is 1.7 times higher than after the standard industrial treatment (1400MPa).

Thus, at the initial stages of HPT deformation the strain-induced decay of solid solution produces small precipitation particles. Simultaneously the dissolution and, probably, mechanical fractioning of remaining larger precipitations take place. These processes are significantly influenced by the initial state of the solid solution.

This work was supported by RFBR grants (projects № 06-08-00971, 07-08-00567-a).

Poster report

Formation of Submicrocrystalline Structure upon Dynamic Deformation of Aluminum Alloys

Irina G. Brodova[a,1], Olga A. Antonova[a], Tatiana I. Yablonskikh[a], Vladimir V. Astafiev[a], Irina G. Shirinkina[a], Evgeny V. Shorokhov[b], Igor I. Zhgiliev[b]

[a] Institute of Metal Physics, Ural Division, Russian Academy of Sciences, 18 S. Kovalevskaya St., Yekaterinburg 620041, Russia

[b] Russian Federal Nuclear Center - Zababakhin All-Russia Research Institute of Tehnical Physics, P.O. Box 245, Snezhinsk 456770, Chelyabinsk Region, Russia

web-admin@vniitf.ru [1] brodova@imp.uran.ru

Light and electron microscopy and X ray diffraction were used to study the structure and phase composition of bulk samples from multicomponent Al-based alloys (Al3003 and Al5556) produced by the method of dynamic channel angular pressing (DCAP) [1]. The influence of the pulse loading conditions for the samples in the inlet of a matrix with crossing channels and of the geometry of the zones of the channel crossing on the process of structure formation is investigated. In experiments, the samples are speeded up using a gun to velocities of 100 to 500 m/c. The rate of deforming materials is estimated to be 10^3-10^5 c^{-1} [2].

The changes of microhardness over the sample sections are plotted versus velocity and the character of its changes depending on the number of runs through the matrix channels is established.

The examination of the sample structure after loading showed that the material responded to the high-temperature action and high-rate deformation. In particular, it was established that even after one DCAP run, the material hardening and significant changes in its structure are observed. An increase in the velocity of the sample movement unessentially affects the maximal microhardness value, which is raised by DCAP by a factor of 1.5—2 in comparison with the starting rod. The maximal values for the 5556 alloy make up 1600—1700 MPa, whereas for 3003 alloy- 800 MPa. With growing velocity, there is observed even a tendency toward the hardening lowering. Some regions of an enhanced hardness are revealed over the sample sections and a certain cycling in the changes of the given parameter is detected, which is related to the cycling character of the sample pressing through the channels.

The fine structure of the samples from the 3003 alloy was examined using electron microscopy. It was discovered that upon one run the structure becomes fragmented and consists of grains with a developed substructure and a high density of dislocations. The high density of defects gives rise to the formation of high-angular boundaries. With increasing the number of runs, the fraction of grains separated by high-angular boundaries increases and the amount of the lattice dislocations lowers. The data obtained indicate that in the course of deformation the fragmentation of the initial structure proceeds not only via the crystal lattice bending but also with a contribution of the rotation deformation modes.

Thus, the results of the studies performed show up the efficiency of the DCAP method application in the production of the Al-based bulk materials with an ultramicrocrystalline structure and a high hardness of up to 120HB.

The work was supported in part by the program of the Presidium of the Russian Academy of Sciences "Investigation of substances under extremal conditions" and by the Scientific School –5365.2006.3

[1] E.V. Shorokhov, I.N. Zhgilev, R.Z. Valiev, Patent of the Russian Federation N 2283717, Bulletin of Inventions 26 (2006)

[2] E.V. Shorokhov, I.I. Zhgilev, I.G. Brodova, A. A. Gurov, T.I. Yablonskikh, V.V. Astaf'ev, in: Yu. K. Kovneristiy et. al. (Eds.), Deformation & Fracture of Materials, Moscow: Interkontakt Nauka, 2006, p.249

Poster report

Specific Features of the Structure Formation in the Al – Mg – Sc Alloys during SPD

Sergey V. Dobatkin[a,1], Valeriy V. Zakharov[b], Vladimir N. Perevezentsev[c], Georgy I. Raab[d], Tatiana D. Rostova[b] and Elena N. Bastarache[a]

[a]A.A.Baikov Institute of Metallurgy and Materials Science of RAS, 49 Leninskii Pr., Moscow 119991, Russia

[b]All-Russia Institute of Light Alloys, 2 Gorbunov St., Moscow 121596, Russia

[c] Blagonravov Institute of Mechanical Engineering of RAS (N. Novgorod Branch), 85 Belinski St., Nizhni Novgorod 603024, Russia

[d] Institute of Physics of Advanced Materials, Ufa State Aviation Technical University, 12 K. Marx St., Ufa 450000, Russia

[1] dobatkin@ultra.imet.ac.ru

The structure and properties of aluminum alloys 01515 (Al-3.1% Mg-0.31% Sc-0.08% Zr) and 01570 (Al-5.9% Mg-0.3% Sc-0.08% Zr) have been studied after high pressure torsion (HPT) and equal-channel angular (ECA) pressing under the conditions of cold, warm, and hot deformation. HPT of samples of 10 mm in diameter and 0.6 mm in thickness was performed under a pressure of 6 GPa by 5 revolutions, which corresponds to $\varepsilon = 5.7$. The ECA pressing was performed with the samples of 20 mm in diameter and 100 mm in length at temperatures of 200 and 400°C to N=8 at an angle of 110° between the channels.

The formation of nanocrystalline structure with the grain size of 50 nm has been revealed after cold HPT. With decreasing Mg content, the grain size increases to 150 nm in the 01515 alloy. Warm deformation by torsion of the 01570 alloy at 200°C leads to formation the grains with size 90 nm. Upon HPT at T = 400°C, the grain size in this alloy remains less than 300 nm due to the structure stabilization by scandium aluminides. The maximum strengthening effect is observed after aging at 300°C of the deformed alloys.

Upon ECA pressing at 200°C, the grain size in the 01570 and 01515 alloys was 380 and 550 nm, respectively. At 400°C, the structure with an average grain size of about 6 μm is formed in the 01515 alloy.

The specific features of the mechanical behavior of the submicrocrystalline Al-Mg–Sc alloys at room temperature and at elevated temperatures under superplasticity conditions are discussed.

The work was supported by the Federal Program of Russian Ministry of Education and Science (contract no. 02.513.11.3141) and the Program of Presidium of Russian Academy of Science.

Poster report

Thermal Stubility of Nano- and Submicrocrystalline Low Carbon Steels

Sergey V. Dobatkin[a,1], Pavel D. Odessky[a,b], Evgeniy V. Naidenkin[c], Svetlana V. Shagalina[a] and Georgy I. Raab[d]

[a] A.A. Baikov Institute of Metallurgy and Materials Science of RAS, 49 Leninskii Pr., Moscow 119991, Russia

[b] Institute of Building Constructions, Moscow, Russia

[c] Institute of Strength Physics and Materials Science of RAS, Siberian Branch, 2/1 Akademicheskii Pr., Tomsk 634055, Russia

[d] Institute of Physics of Advanced Materials, Ufa State Aviation Technical University, 12 K. Marx St., Ufa 450000, Russia

[1] dobatkin@ultra.imet.ac.ru

The thermal structural stability and mechanical properties of a low-carbon ferritic-pearlitic and martensitic 0.1%CMnVTi and 0.06%CMoNbV steels have been studied after severe plastic deformation (SPD) by high pressure torsion (HPT) and equal-channel angular pressing (ECAP).

The grain size in the 0.1%CMnVTi steel after HPT is larger in the case of ferritic-pearlitic state (95 nm at 20°C and 120 nm at 500°C) in comparison with martensitic structure (65 nm at 20°C and 85 nm at 500°C). Martensitic state of this steel provides less intense grain growth upon heating to 500°C after cold HPT (450 and 860 nm).

The ECAP of these steels with both ferritic-pearlitic and martensitic initial structures leads to the formation of partially subgrained and partially submicrocrystalline structure with an average size of structure elements of 0.3 μm.

The strength characteristics of martensitic 0.1%CMnVTi steel after ECAP are higher than those of ferritic-pearlitic steel: $\sigma_{0.2}$ = 1125 and 870 MPa, respectively, at T_{test} = 20°C and $\sigma_{0.2}$ = 485 and 400 MPa, respectively, at T_{test} = 500°C. At T_{test} = 600°C, the strength decreases for both initial states. The strength of the 0.06%CMoNbV steel at 600°C is substantially higher than that of the 0.1%CMnVTi steel. Yield strength of the 0.06%CMoNbV steel at T_{test} = 500°C after ECAP is equal to the yield strength of this steel at T_{test} = 20°C after quenching and high-temeprature tempering.

Thus, the high-strength state of the 0.1%CMnVTi and 0.06%CMoNbV steels after ECA pressing is retained upon increasing test temperature to 500°C. At T_{test} = 600°C, the strength characteristics for the submicrocrystalline state are higher by 20-30% than those observed for the undeformed state.

The work was supported by the RFBR, project no. 07-03-00342.

Poster report

The Effect of Severe Plastic Deformation Method on the Properties and Microstructure of 316 L Steel

Malgorzata Suś-Ryszkowska[a,1], Anna Drużycka-Wiencek[a,2],
R.Kuziak[b,1], F.Grosman[b,2] and K.J.Kurzydłowski[a]

[a] Warsaw University of Technology, Faculty of Materials Science and Engineering, Woloska 141, 02-507 Warszawa, Poland

[b] Department of Process Modeling and Medical Engineering, Silesian University of Technology, 8 Krasinskiego, Katowice, Poland

[1] msus@inmat.pw.edu.p , [2] ania@inmat.pw.edu.pl

Recently growing interest is observed in materials processed by SPD methods which enables production of relatively large bulk nanomaterials with a significant grain size refinement due to the plastic strain at a range of e=10. In this work for the 316L steel, which is important for medical applications has been subjected to Max Strain and transverse rolling. Max Strain unit has been used also to conduct thermoplastic treatment. Plastic strain was applied cyclically along three principal axes. All samples have been deformed up to logarithmic strain approaching e = 40. Three strain intervals have been used (ej=0,2:0,4;0,6). The DUO rolling process is an original technology protected by a patent. Sample deformation system assures full control of rolling conditions the amount of plastic strain is. The SPD of samples have been shown by light microscopy and TEM. Microhardness measurement was also carried. The results show that both method produce nano-scale structure with very high mechanical properties.

[1] F. Grosman, J.Pawlicki, Acta Metallurgica Slovaca, R.8 1 (2002), 178

[2] F. Grosman, J. Pawlicki, Proceedings of the 7th International Conference on Technology of Plasticity, Advanced Technology of Plasticity, Yokohama, Japan, 1 (2002) 1219

[3] Z. Pakila, H. Garbacz, M.Lewandowska,A. Druzycka-Wincek, M. Suś-Ryszkowska, W. Zielinski, K. Kurzydłowski, Nukleonika 51 (SUPPL.1) (2006) S19

[4] K.J. Kurzydłowski, M.Richert, J. Richert, J. Zasadziński, M. Suś-Ryszkowska, Solid State Phenomena, 101-102 (2005) 31

[5] Z. Pakieła, M. Suś-Ryszkowska, A. Drużycka-Wiencek, K. Sikorski, K. J. Kurzydłowski, Proceedings of the 7th International Conference on Nanostructured Materials, June 20 - 24, 2004, Wiesbaden/Germany (2004)

Poster report

Precipitation Hardening of Copper Alloys after Severe Plastic Deformation Methods

Svetlana N. Faizova[a,1], Georgy I. Raab[b]

[a] Instititute of Mechanics, Ufa Science Center, Russian Academy of Sciences,
71 Oktyabr Pr., Ufa 450001, Russia

[b] Ufa State Aviation Technical University,
12 K. Marx St., Ufa 450000, Russia

[1] snfaiz@mail.ru

High-copper bronzes with high thermal and electrical conductivity are very important copper based alloys. For most modern industrial application they must posses not only the high conductivity but also the high mechanical strength and thermal stability of properties.

The traditional industrial treatment of the precipitation strengthening alloys, to which Cu-1Cr-0.2Al-0.7Zr and Cu-0.5Cr-0.1Ag alloys belong, includes the three stages. The fist – solid solution treatment – includes high temperature annealing with the subsequent rapid quenching. At this stage the supersaturated solution of alloying elements in the matrix is prepared. At the second stage the material is deformationally strengthened by cold working. And finally, the material is precipitation strengthened by post-deformation thermal treatment. As the strain rate at the second stage of this process is comparatively low, the influence of the deformation on the precipitation kinetics may be neglected.

It is known that the deep structural refinement of materials by the severe plastic deformation (SPD) techniques leads to higher strength values. The development of the materials with advanced properties by combining the SPD with the precipitation strengthening poses a new problem because their mutual influence is a significant factor. During the SPD the high dynamical density of defects is induced in the material, which enhance the diffusion processes and influence the chemical potential values for alloying elements. Conversely, the presence of the hard precipitation particles significantly modifies the effectiveness of the structure refinement by the SPD. Thus no reliable technology may be developed without full elucidation of the phenomena involved.

The present work repots the results of investigation of the structure refinement by SPD techniques – the equal channel angular pressing (ECAP) and the high pressure torsion (HPT). The mutual influence of the deformation mechanisms and the decay of the solid solution has been demonstrated. This phenomenon is especially manifest at early stages of the process and is reflected in the strength of the obtained material.

The post-deformation thermal treatment causes the precipitation of the remaining soluted atoms what leads to the restoration of electrical conductivity and to the further strengthening. Simultaneously it reduces the dislocation density, which may result in the coarsening of structure and in the softening of material. The relative effect of these processes also depends on the precipitation-dissolution kinetics during the SPD stage.

This work was supported by RFBR grant (projects No. 06-08-00971, 07-08-00567-a).

Poster report

RKKY Interaction of Magnetic Moments in Nanosized Systems

E. Z. Meilikhov and Rimma M. Farzetdinova

Russian research center "Kurchatov Institute", 1 Kurchatov Sq., Moscow 123182, Russia

rimfar@imp.kiae.ru

In systems with free carriers of high concentration (metals or degenerate semiconductors), indirect magnetic impurities' interaction $J(r)$ of Ruderman-Kittel-Kasuya-Yosida (RKKY) type is considered as one of the basic mechanisms of the magnetic ordering. There are a lot of papers dealing with RKKY interaction in three-, two- and one-dimensional systems of *infinite* size. However, to our knowledge, nobody considered how that interaction should be modified for systems of the *finite* size. It is actual because every potentially interesting electronic device is either characterized by nanosizes or include some nanosized formations.

For example, though two-dimensional structures represent the most natural systems for the embedding in the traditional semiconductor technology, almost all theoretical works (including those "attached" to concrete experiments) are dealt with the three-dimensional systems. In addition, it is known that magnetic impurities in diluted magnetic semiconductors (DMS) incline to the correlation and can form nanosized clusters. In this connection, the question arises concerning the influence of the impurity correlation on their interaction (for instance, by means of the RKKY-mechanism). In the present paper, we consider that problem for the case of the spherical system of the finite radius.

In the case of finite system sizes or magnetic ions' clustering, the classic expression for the energy of the RKKY-interaction should be rectified. For simplicity, we consider the case when magnetic ions form the spherical cluster. Due to the quasi-neutrality, its radius R determines not only the area where ions are arranged but also the region where carriers, produced by those ions, are localized. In other words, the carriers are contained in the potential well of the radius $\sim R$. Therefore, the carrier momentum k and its variation q are limited by the intervals $k_1 \le k \le k_F$, $k_1 \le q \le k_2$, where $k_1 \approx \pi/R$, $k_2 \approx \pi/a$ (a is the lattice constant).

In addition, due to the spatial quantization the distance between energy levels of carriers grows that leads to increasing the Fermi energy and Fermi momentum with decreasing the well size: $k_F = k_F(R)$. Together, it complicates calculations and the final expression for $J(r)$ turns out to be more bulky than the canonical expression.

It is of interest to understand how the Curie temperature T_C depends on the system size R at k_{F0}=const ($k_{F0} = k_F(\infty)$) or varies with the carrier concentration (determined by the Fermi momentum) in systems of fixed (but different) sizes.

The dependence T_C(R) turns out to be non-monotone, with pronounced oscillations of the period $2a$ at higher k_{F0} values.

The most significant distinction of the dependence T_C(R) (associated with accounting the finite k_1 value) is observed at small R where the drop of T_C is observed, as compared to the "standard" (corresponding to k_1=0).

As for the dependence $T_C(k_{F0})$, the Curie temperature increases almost monotonously with k_{F0} (i.e., with rising the carrier concentration). In that case also, there is the considerable decreasing T_C (down to zero at some finite size R) as compared to the $T_C(k_{F0})$ dependence for $R\to\infty$.

In conclusion, we studied nanosized spherical systems of magnetic moments interacting indirectly via the RKKY mechanism. The interaction energy which determines the temperature T_C of ferromagnetic ordering depends strongly on the system size. Obtained in the mean-field approximation, dimensional and concentration dependencies of the Curie temperature testify to the necessity of taking into account the finite size of such systems to calculate their features. Results may concern both artificially constructed nanosystems and naturally arising formations (such as clusters of magnetic ions in diluted magnetic semiconductors, etc.).

This work has been supported by Grant No. 06-02-116313 of the Russian Foundation of Basic Researches.

Poster report

Fatigue Behavior of Ultra-Fine Grained NiTi-Stents

Matthias Frotscher[1], K. Neuking[1], R. Böckmann[2], K.-D. Wolff[2] and G. Eggeler[1]

[1] Ruhr-Universität Bochum, Institut für Werkstoffe,
Universitätsstr. 150, 44801 Bochum, Germany

[2] Universitätsklinik für Mund-Kiefer-Gesichtschirurgie,
im Knappschaftskrankenhaus Bochum-Langendreer

matthias.frotscher@rub.de

The use of Ni-rich NiTi shape memory alloys (SMAs) for medical devices, such as stents, shows a high economic potential. During the manufacturing process a casted and subsequently rolled NiTi rod is gun drilled and then cold-drawn to a thin tubular shape with an outer diameter of about 1.6 mm [1]. The characteristic geometry of the stent is then laser cut into the tube. The structure is brought into its final dimensions by gradual expansion interrupted by short heat treatment steps in between. After the final short heat treatment to set the service temperature, the material exhibits a pseudoelastic behavior. Electropolishing is necessary to remove surface defects, primarily laser burrs and heat affected zones (HAZs) from the cutting. During its thermo mechanical treatment the material undergoes a high degree of deformation. In our study we perform in situ cooling experiments and characterize the microstructure in a transmission electron microscope (TEM). The samples are prepared using a focused ion beam (FIB) system due to the small dimensions of the struts, the elementary building units of medical stents. The microstructure is characterized by nanocrystalline grains and a high dislocation density. During cooling from the high temperature austenitic phase, the material shows a two step transformation which is associated with two sequential martensitic transformations, B2 →R followed by R→B19’. We perform fatigue tests of strut assemblies which were taken out of a coronary stent by using a miniature mechanical test rig for in situ pull pull cycling and subsequent straining to failure in a SEM. Results are reported and the influence of parameters like type of loading, surface quality and the presence of inclusions are discussed.

Keywords: NiTi shape memory alloys, pseudoelasticity, fatigue, TEM, stents.

[1] A. Machraoui, P. Grewe, A. Fischer: Koronarstenting – Werkstofftechnik, Pathomorphologie, Therapie, Steinkopff Darmstadt, 2001

Poster report

Increase of Mechanical Properties of Steel Wire by Formation of Submicrocrystalline Structure of Surface Coating in the Process of Equal Channel Angular Drawing

G.C. Gun[a,1], M.V. Chukin[a,2], M.P. Baryshnikov[a,3], D.G. Emaleeva[a,4]

[a] Magnitogorsk State Technical University by Nosov G.I.

Severe plastic deformation (SPD) process is one of the most effective methods for increasing strength and plastic properties of metals. In this process a change of materials physical and mechanical properties takes place due to dispersion of its structural elements. The given direction was formed and developed by the group of scientists belonging to R.Z. Valiev`s leading scientific school. The given method is unique and it made it possible to use such methods of deformation as equal channel angular pressing (ECAP), high-pressure torsion, repetitive multiple forging, pack rolling, etc. for formation of materials submicrocrystalline (SMC) states. The disadvantages of the methods mentioned above can be discretion of nanostructuring process and therefore, quite low technological effectiveness. So the development of the alternative method for formation of submicrocrystalline (SMC) structure in the conditions of continuous processing will allow one to control the materials properties, and the objective of the work is an experimental validation of the possibility to use the new method of equal channel angular drawing (ECADrawing) for the formation of the required structure and properties of the low-carbon steel wire.

The proposed treatment process consists in repetitive pulling of wire (wire rod) through a specially developed instrument that has in section two hollow canals equal in shape and cross section. The canals cut each other at a certain angle. The technological effectiveness and continuity of processing is realized due to the installation of a required amount of instruments on the drawing machine. At the same time the peculiarity of ECADrawing is the possibility of its combination with the conventional method of wiredrawing.

The investigations of the change of the steel wire strength properties in the process of ECADrawing made it possible to identify a significant increase of tensile strength values in regard to the initial state of the processed material, to determine dependence of the given quality index on the amount of processing steps, routes, as well as the extent of the wire initial strain hardening.

The conducted metallographic and durometer investigations made it possible to identify main stages for forming the SMC structure on the wire surface in the process of ECADrawing, to determine intensity and mechanical properties of the modified surface.

The investigations confirm the fact that ECADrawing process is quite high-efficiency for increasing the strength properties of the low-carbon wire by keeping the grade composition of the steel.

Poster report

Fracture Toughness and Crack Propagation Measurements in Ultrafine-Grained Materials

Anton Hohenwarter[a,b,1], R. Pippan[a,b]

[a] Erich Schmid Institute of Materials Science, Austrian Academy of Science, Jahnstrasse 12, Leoben 8700, Austria

[b] CDL for Local Analysis of Deformation and Fracture, Jahnstrasse 12, Leoben 8700, Austria

[1] anton.hohenwarter@unileoben.ac.at, [2] pippan@unileoben.ac.at

Nanocrystalline and Ultrafine-grained (UFG) materials are commonly known as materials with extraordinary mechanical properties [1,2]. Due to the limited dimensions of HPT-deformed materials almost nothing is known about their fatigue properties whereas particulary this process delivers highly refined materials with little effort. In the framework of this study pure nickel and Armco-iron were subjected to High Pressure Torsion (HPT) and in combination with different heat treatments the grain-size was varied between approximately 100 nm and 10 µm. Crack-propagation measurements with reference to different grain-sizes were conducted. It could be shown that there is a distinctive difference in the fracture

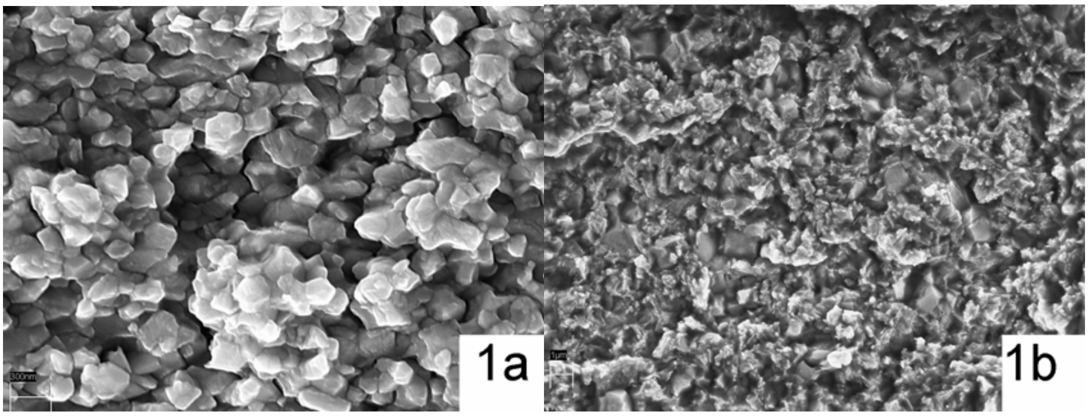

Figure 1. Comparison of the fatigue fracture surfaces of ultrafine-grained and microcrystalline Nickel

morphology with respect to the grain size. In the submicro-regime a intercrystalline fracture process is observed as shown in figure 1a. In contrast to this, specimens with grain sizes larger than 1 µm show a transcrystalline fracture behaviour with a striation like morphology (figure 1b). Despite a intercrystalline fracture behaviour under cyclic loading in the submicro-regime a ductile failure under monotonic loading is found. The fracture mechanisms and the effect of the crack path on the fatigue and fracture properties will be discussed.

[1] R.Z. Valiev, R.K. Isamgaliev, I.V. Alexandrov, Prog. Mater. Sci., 45 (2000) 103

[2] M.A. Meyers, A. Mishra, D.J. Benson, Prog. Mater. Sci., 51 (2006) 427

Poster report

Formation of Submicrocrystalline Structure in $Bi_2Sr_2CaCu_2O_{8+x}$ Superconductor during Deformation by Torsion under Pressure

Marcel Imayev[a,1], Sergey Zabolotny[a], Ruslan Khazgaliev[a,2]

[a] Institute for Metals Superplasticity Problems RAS,

39 Stepan Khalturin St., Ufa 450001, Russia

[1] marcel@imsp.da.ru, [2] leniwec-usatu@yandex.ru

The critical current density of superconductors is a structurally sensitive quantity. In order to increase its value a material must have, first of all, a strong texture (with misorientation angle between adjacent grains less than 10^0) and high density of centres for pinning of magnetic flux. Texture is necessary to reduce the amount of Josephson "weak links", the role of which is performed, as a rule, by high-angle grain boundaries. Pinning centres are necessary to reduce magnetic flux creep, since the movement of Abrikosov's vortices leads to the dissipation of energy, causing the superconductor to transform to a normal state.

It is well known that low-angle boundaries can be strong centres of pinning of magnetic flux in high-temperature superconductors [1-3]. The most abundant melt textured growth technique does not make it possible to obtain high area extent of low-angle grain boundaries, since very large grains are formed in the process. High-temperature deformation by torsion under pressure is the method allowing the formation of not only strong texture, but also the variation of grain (colony) size in superconductors [4]. In this connection it seems attractive to try to receive a microstructure combining strong texture with submicro- or nanometric size of grains in a superconducting material. Such microstructure may possess unique superconducting properties.

In this study we have undertaken an attempt to solve the first part of this task, namely, to obtain submicrocrystalline structure in $Bi_2Sr_2CaCu_2O_{8+x}$ (Bi2212). Sintered samples of Bi2212 were deformed by torsion under pressure in the temperature range 750 - 895°C. Twist angle varied from 90 to 360^0, the pressure - from 25 to 57 MPa, and the twist rate - from $1.7x10^{-3}$ to $2.2x10^{-2}$ rpm. Microstructure was studied by SEM and TEM.

It has been established that decreasing of deformation temperature and increasing of twist rate promote decreasing of grain size. The sequence of transformation of a plate-like colonial microstructure into an equiaxed fine-grained one is the following: deformation bands are formed perpendicular to the basal plane of colonies, and the increase in the twist angle leads to the increase of its thickness. Fine equiaxed grains are formed in these bands. As a result, coarse colonies are divided into parts by bands with fine-grained structure. At further increase of strain, small plates are recrystallized also, and at the end of the first revolution of the movable anvil in the most part of a sample a uniform microstructure is formed. At 750^0C a microstructure with mean grain size of 0.5 μm was obtained.

[1] N. Nakamura, G.D. Gu, K. Takamuku, M. Murakami, N. Koshizuka, Appl. Phys. Lett., 61 (1992) 3044

[2] A. Diaz, L. Mechin, P. Berghuis, J.E. Evetts, Phys. Rew. Lett., 80 (1998) 3855

[3] V.M. Pan, A.L. Kasatkin, V.L. Svetchnikov, H.W. Zandbergen, Cryogenics, 33(1993) 21

[4] R.R. Daminov, M.F. Imayev, M. Reissner, W. Steiner, M.V. Makarova, P.E. Kazin, Physica C, 408-410 (2004) 46

Poster report

The Effect of Structural-Phase State on Superplastic Properties of Ultrafine-Grained Multiphase Alloys

Evgeny N. Naidenkin [a,1], Galina P. Grabovetskaya [a,2],
I.V. Ratochka [a,3], Konstantin V. Ivanov [a,4] and Yury R. Kolobov [b,5]
[a] Institute of Strength Physics and Materials Science SB RAS,
2/1 Academichesky Pr., Tomsk 634021, Russia
[b] Belgorod State University, 85 Pobeda St., Belgorod 308015, Russia
[1] nev@ispms.tsc.ru, [2] grabg@ispms.tsc.ru, [3] ivr@ispms.tsc.ru, [4]ivanov-ru@yandex.ru, [5]kolobov@bsu.edu.ru

Investigation of the effect of structural-phase state on the characteristic features of strain behavior of submicrocrystalline (SMC) and nanocrystalline (NC) alloys exhibiting superplastic properties under several conditions has been carried out.

Using Ti-6Al-4V and Al-Mg-Li alloys by way of example, the characteristic features of superplastic deformation development in ultrafine-grained materials processed by severe plastic deformation have been considered. It has been shown that formation of ultrafine-grained structure in the dual-phase Ti-6Al-4V alloy results in the essential increase of resistance to localization of strain on microlevel at elevated temperatures and in the shift of the temperature interval of superplasticity to lower temperatures. Alloying of ultrafine-grained structure Ti-6Al-4V alloy by hydrogen up to 0.08-0.33 mas.% leads to the decrease of resistance to localization of strain on macrolevel at elevated temperatures. The above effect is assumed to be related to formation of hydrogen-rich β-phase in the most stressed areas of the sample and, as a consequent, to development of non-homogeneous plastic deformation. It is found that the main deformation mechanism of ultrafine-grained Ti-6Al-4V alloy during creep is grain boundary sliding controlled by grain-boundary diffusion. The main accommodation mechanism for grain-boundary sliding is intragrained dislocation slip controlled by volume diffusion. It has been shown that equal-channel angular pressing of aluminum alloy 1421 at 643K (~0.7 Tm where Tm is the melting point) results in the dissolution of S-phase particles containing Mg and Li. It should be noted that the above particles remains in the structure after static annealing at 793K (0.85 Tm). It has been established that the shift of the temperature interval of superplasticity to lower temperatures observed for 1421 alloy processed by severe plastic deformation relative to the as-received one is due to the analogous shift of the temperature interval of true grain boundary sliding development. The latter is assumed to be caused by the increase of Li concentration on grain boundaries and as a result by the increase of diffusivity of grain boundaries.

Poster report

Strain-Rate Sensitivity of Ultrafine- Grained CP Titanium

Vil Kazykhanov[a,1], Nariman Enikeev [a,2]

Institute of Physics of Advanced Materials, Ufa State Aviation Technical University,

12 K. Marx St., Ufa 450000 Russia

[1] vk@mail.rb.ru , [2] carabus@mail.rb.ru

Low ductility of ultrafine-grained (UFG) materials in comparison with coarse-grained materials is caused by plastic yield instability [1]. Reduction in the strain hardening capacity of UFG materials is responsible for the development of strain localization in the early stages of plastic yielding. One of the parameters characterizing the tendency of a material for necking is the strain-rate sensitivity coefficient *m* for the flow stress.

At present there's much debate in literature on various approaches allowing to enhance ductility of UFG materials [1-5]. One of these approaches concerns the formation of a structure with bimodal distribution of grain sizes [2, 3]. Another approach ensuring a high complex of mechanical properties in UFG materials is the introduction of a specific structural state in grain boundaries [5].

The aim of the present work is to investigate the impact of the structure of CP Ti forming at ECAP on the coefficient ***m*.** The coefficient *m* was measured at tensile testing flat microsamples having the gage section 2x0,3 mm and 6 mm in length, the given samples were cut out from ECAP billets subjected to 2 and 12 cycles and additional short-term annealing. ECAP was performed en route Bc in the temperature range of 400-450 ^{o}C. Annealing of the ECAP samples was performed with a view of enhancing the value of elongation to failure. Preliminary investigations have shown that after 2 ECAP cycles Ti forms heterogeneous structure with small and initial strained grains. Such structure can be presented as a variant of a bimodal structure. After 12 ECAP cycles Ti starts forming homogeneous UFG structure with mean grain size about 300 nm. Thus there are two states differing by their type of structure. Tensile tests have shown that the formation of homogeneous UFG structure in Ti after 12 cycles of ECAP leads to growth of strength and ductility as compared to the state formed after 2 cycles. Calculation of *m* value has proved that after increasing the number of ECAP cycles from 2 to 12 the value of *m* grows from 0,025 to 0,03. Therefore, the formation of homogeneous UFG structure after 12 ECAP cycles results in increase of the coefficient *m*, as well as of elongation to failure. However, ductility of Ti is lower after 12 ECAP cycles when compared to the initial coarse-grained state.

According to the literature data [2] it is possible to enhance the ductility of a material with UFG structure by way of applying additional annealing. The effect of short-term annealing at 500 ^{o}C for 15 min on mechanical properties of ECAP Ti billets after 2 and 12 cycles was studied in the present report.

In both covered states one can observe growth of ductility with some insignificant reduction in strength. Meanwhile the value of yield stress decreases noticeably. Estimation of the strain-rate sensitivity of the yield stress has shown that annealing leads to lowering of the coefficient *m* down to 0.015 and 0.02 after 2 and 12 ECAP cycles, correspondingly. Evidently, lowering of the relation of yield stress and ultimate tensile strength σy/σu, which characterizes the material's tendency for strain hardening, increases the stability of plastic yielding.

Therefore, the complex of high mechanical properties of UFG materials can be achieved by the formation of homogeneous UFG structure with enhanced strain-rate sensitivity of yield stress, or by additional annealing aimed at lowering the yield stress, which in its turn contributes to the tendency of the material for strain hardening.

The relation between the structure and mechanical properties was discussed.

[1] E. Ma, Scripta Mater., 663 (2003) 49
[2] Y. M. Wang, E. Ma. Acta Mater., 52 (2004) 1699
[3] Y.M. Wang, E. Ma, Mater. Sci. and Eng. A, 375–377 (2004) 46
[4] C.C. Koch, Scripta Mate., 49 (2003) 657
[5] R.Z. Valiev, Nature Mater., 3 (2004) 511

Poster report

The Corrosion Behavior of UFG and CG Aluminum Alloys 1420, 1421, 5083 Received by ECAP

N.A. Amirhanova[a,1], R.R. Khaidarov[a]
M.Y. Murashkin[a,4] and N.F. Yunusova[a,5]
[a] Ufa State Aviation Technical University, 12 K. Marks St., Ufa 450000 Russia
[1] amirhanova@mail.ru

The corrosion measurement of UFG and CG aluminum alloys 1420, 1421, 5083 carried out in 3%NaCl (1), 3%NaCl+10ml/l HCl (ρ=1,18 g/sm^3) (2), 3%NaCl+0,1%H_2O_2 (3) solutions. The curve $\varphi(\tau)$ to the alloy 5083 in active solutions (1) and (2) shows that UFG alloy has more negative potentials than CG alloy. The other dependence is observed at introduction of 0.1% hydrogen peroxide (oxidizer) additives: the potentials of UFG alloy have more positive value. It is connected to oxidizing properties of the additive H_2O_2. The similar picture is observed for alloys1420, 1421. The oxidizing action of hydrogen peroxide for UFG aluminum alloy 1421 is more than it is for CG alloy as the potential is shifted in positive values area on 0,25 V, that is caused by formation of double connections Al_2O_3 Sc_2O_3, which shield a surface of an alloy. The potentials without a current of aluminum alloys 1420, 1421, 5083 with UFG structure has more negative value than for CG structure all alloys after immersing in active electrolyte (1, 2) during 12 hours. The potentials without a current of aluminum alloys 1420, 1421, 5083 with UFG structure has more positive value than for CG structure all alloys after immersing in active electrolyte with 0.1% H_2O_2 during 12 hours. It is connected to passivation UFG aluminum alloys in this electrolyte. Thus, UFG alloys are more corrosion active in active electrolytes that is connected to the big extent of grain boundaries and the increased amount of structure defects of UFG alloys in comparison with CG alloys. The UFG alloys are covered a passive film in electrolyte with 0.1% H_2O_2. This passive film is formed on structure defects and in protects a material from corrosion. Influence of structure on corrosion rate was determined from change of weight (g/m^2*h) and from polarizing curve (A/sm^2). The corrosion rate of UFG alloys is more than corrosion rate of CG alloys in electrolytes (1) and (2), the corrosion rate of UFG alloys is less than corrosion rate of CG alloys in electrolyte (3) as well as it was supposed earlier.Thus, the comparative analysis of potentials without a current, corrosion rate and corrosion currents of UFG and CG aluminium alloys has shown, that CG alloys are more corrosion resistance in active electrolytes than UFG alloys, which has the big extent of grain boundaries and the increased amount of structure defects (5-10 $^{14\text{-}17}$ m^{-2}).

Poster report

Effect of Equal-Channel Angular Pressing and High Pressure Torsion on Structure and Properties of Ti-Ni-based Alloys

Irina Khmelevskaya[a,1], Sergey Prokoshkin[a,2], Irina Trubitsyna[a], Michail Belousov[a], Sergey Dobatkin[b], Evgeniy Tatyanin[c], Andrey Korotitskiy[a], Vladimir Brailovski[d], Vladimir Stolyarov[f] and Egor Prokofiev[f]

[a] Moscow State Institute of Steel and Alloys, 4 Leninsky Pr., Moscow 119049 Russia

[b] Baikov Institute of Metallurgy and Material Science, Russian Academy of Sciences, 49 Leninsky Pr., Moscow 119049 Russia

[c] Institute for High Pressure Physics, Russian Academy of Sciences, Troitsk 142190, Russia

[d] Ecole de Technologie Superieure, 1100 rue Notre-Dame Quest, Montreal, Quebec H3C 1K3 Canada

[f] Institute of Physics of Advanced Materials, Ufa State Aviation Technical University, 12 K. Marx St., Ufa 450000 Russia

[1] khmel@tmo.misis.ru, [2] sprokoshkin@mail.ru

Structure formation and functional properties of Ti-48.5, 50.0, 50.6, 50.7 at.% Ni and Ti-47 at.% Ni-3 at.% Fe shape memory alloys under conditions of high-pressure torsion (HPT) and equal-channel angular pressing (ECAP) in dependence on deformation temperature, pressure and post-deformation annealing (200-500^{o}C) were studied using transmission electron microscopy and thermomechanical testing methods (Table 1).

The highest deformation temperature for amorphous structure formation was observed in Ti-48.5%Ni alloy and located about 300^{o}C. The upper limiting continuous deformation temperature for actual nanocrystalline structure formation were determined for aging (somewhat higher than 400^{o}C) and non-aging (about 300-350^{o}C) alloys. As a result of ECAP of Ti-Ni and Ti-Ni-Fe alloys at 350-500^{o}C in N=6-8 passes, a submicrocrystalline structure with the grain size of 0.1-0.2 μm (at 350^{o}C), 0.2-0.4 μm (at 450^{o}C) and 0.3-0.5 μm (at 500^{o}C) was obtained. The highest functional properties of Ti-50.6 % Ni alloy which exceed the best results provided by traditional thermomechanical treatment creating a polygonized substructure correspond to the finest submicrocrystalline structure formation after ECAP at 350^{o}C and post-deformation annealing below 350^{o}C. For obtaining actual nanocrystalline structure under ECAP conditions, the ECAP temperature should be below 350^{o}C.

Table 1 – Structure and functional properties of Ti-Ni-base alloy after various treatments

Alloy	M_s [1)], °C	Treatment	Structure of austenite	Grain size D, μm	Functional properties $\varepsilon_{r,1}^{max}$ [2)], %	Functional properties σ_r^{max} [3)], MPa
Ti-48.5%N	70	Quenching	Recrystallized	50	3 – 4	300-400
Ti-50.0%Ni	68	HTMT[4)] ($T_{def.}$=700°C)	Polygonized	50	6.0	500
		LTMT[5)] +PDA[6)] (350 - 400°C), e=0.3	Recovered and polygonized	50	7.0	900 - 1100
		LTMT+PDA (400°C), e=1.9	Nanocrystalline	0.065	8.0	1420
Ti-50.2%Ni	20	LTMT+PDA (400°C), e=0.3	Polygonized	50	7.0	1100[7)]
		ECAP (450°C, N=4÷12)	Submicrocrystalline	0.2-0.4	8-9	800-1100[7)]
Ti-50.6%Ni	- 20	LTMT+PDA (400°C)	Polygonized	50	7	720[7)]
		ECAP (450 °C N=8)	Submicrocrystalline	0.2-0.4	9.2	700[7)]
		ECAP (350 °C, N=6)	Submicrocrystalline	0.1-0.2	8.5	780[7)]
Ti-50.7%Ni	- 20	Quenching	Recrystallized	50	6.0	400
		LTMT+PDA (400 - 500°C)	Recovered and polygonized	50	8 - 9	1200
Ti-47%Ni-3%Fe	- 160	Quenching	Recrystallized	50	7.8	250
		HTMT ($T_{def.}$=500°C	Hot-worked +polygonized	50	–	650
		($T_{def.}$=700°C)	Polygonized	50	8.2	420
		ECAP 450°C, N=8	Submicrocrystalline	0.2-0.4	9.0	615
		ECAP 500°C, N=4 + ECAP 400 °C N=4	Submicrocrystalline	0.1-0.3	9.0	695

1) The M_s temperatures correspond to quenching state, 2) maximum completely recoverable strain, 3) maximum recovery stress, 4) high-temperature thermomechanical treatment in rolling, 5) low-temperature thermomechanical treatment in rolling, 6) post deformation annealing, 7) σ_r^{max} measurement without unloading

This work was partially supported by ISTC projects Nos. 2398 and 2114, INTAS project No. 02-0320, grants from Ministry of Education and Science of Russian Federation and Natural Science and Engineering Research Council of Canada.

Poster report

Effects of the Number of Equal-Channel Angular Pressing Passes on the Anisotropy of Ultra-Fine Copper

Alexander Korshunov[a,1], Tamara Kravchenko[a,2], Alexander Morozov[a,2], Andrey Smolyakov[a,3], Irina Vedernikova[a,2] and Lev Polyakov[a,2]

[a] Russian Federal Nuclear Center – VNIIEF,
37 Mir Av., Sarov 607190, Nizhny Novgorod Region, Russia

[1] korshun1@sar.ru, [2] ivi@astra.vniief.ru, [3] smolakov@rol.ru

Tough-pitch copper M1 was used as a test material. Compression test were conducted with cylindrical specimens having a diameter of 5 mm and height of 7.5 mm. ECAP of samples was performed using route B_C. Three sets of specimens (each set consisting of six specimens) were made from as-received and post-ECAP samples. The cutting direction of the specimens was the same as the direction of coordinate axes, as shown in Fig. 1. The specimens were tested at room temperature and strain rate $\dot{\varepsilon} \approx 1.4 \cdot 10^{-3} s^{-1}$.

Test data are shown in Fig. 2.

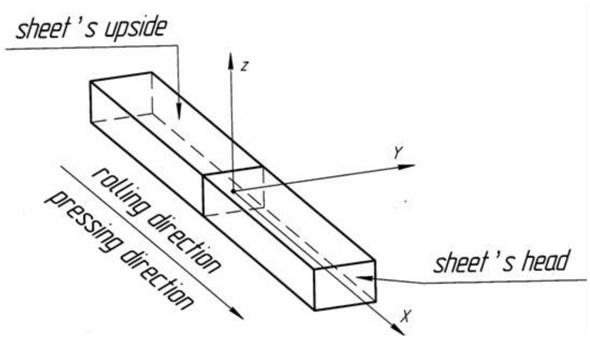

Figure 1. The coordinate system adopted

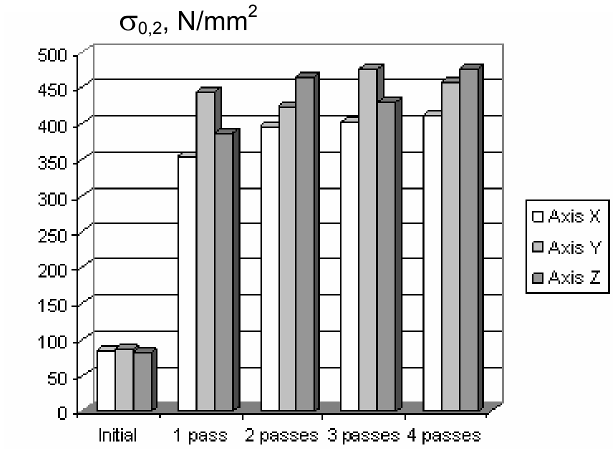

Figure 2. Conventional yield strength of copper M1 at compression versus the number of ECAP passes (route B_C) at room temperature.

The data obtained suggest that even though there is almost no anisotropy in the as-received condition, one can observe anisotropy after ECAP, which remains constant and makes about 20 percent. Anisotropy patterns after even and odd passes are different. After odd passes (1 and 3), the highest conventional yield strength is observed along the Y-axis, and after even passes, along the Z-axis.

The data of the subsequent microhardness analysis in different sections of the post-ECAP samples agree with the data given above.

Poster report

Microstructure, Phase Transformations and Mechanical Properties of Severely Deformed Fe-15%Co-25%Cr Hard Magnetic Alloy

Alexander V. Korznikov, Galia F. Korznikova
Institute for Metals Superplasticity Problems RAS,
39 Khalturin St., Ufa 450001 Russia
korznikova@anrb.ru

The FeCoCr based alloys belong to hard magnetic materials of the precipitation-hardening class. Magnets are produced from these alloys by both casting and plastic working methods. The formation of a high-coercivity ($\alpha_1 + \alpha_2$) state during spinodal decomposition leads to a sharp decrease in the strength and plasticity characteristics due to a modulated structure consisting of coherent ordered precipitates of the α_1 phase in the α_2 matrix. It is known that the plasticity characteristics of industrial alloys can be significantly increased by changing the size and morphology of ordered phases.

The purpose of this work was to study the evolution of the structure magnetic and mechanical properties of the Fe-15%Co-25%Cr alloy during shear deformation at various angles of rotation in the Bridgman anvils.

Microstructure evolution and phase transformation in Fe-15wt.%Co -25%Cr alloy was studied by means of transmission electron microscopy and scanning electron microscopy. Mechanical properties were analyzed by means of microhardness measurements and three point bending strain tests.

Severe plastic deformation of the high-coercivity ($\alpha_1 + \alpha_2$) state was shown to result in partial dissolution of the α_1 phase in the early deformation stage (φ<360°). It was shown by transmission electron microscopy techniques that dissolution occurs mainly in the shear bands. A further increase in the deformation leads to the formation of single-phase nanocrystalline structure with a grain size of about 50 nm.

The dissolution of the α_1 phase in the α_2 matrix during severe plastic deformation was found to cause an increase in the strength and plasticity characteristics of the Fe-15%Co-25%Cr alloy at all degrees of deformation studied (Fig.1a, b), and decrease of coercivity value in the early deformation stage (Fig. 1c).

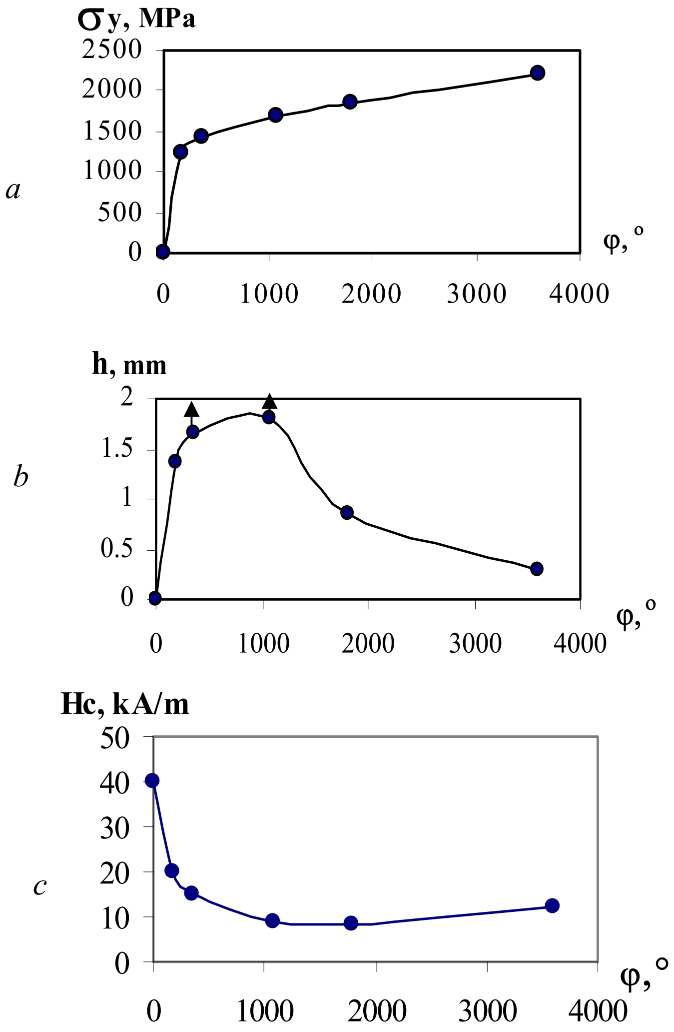

Figure 1. Mechanical and magnetic properties of the Fe-15%Co-25%Cr alloy upon bending tests. The variation of (a) the yield strength σ_y, (b) ultimate bending flexure h, (c) coercivity Hc as function of the angle φ of rotation of mobile anvil. Arrows (↑) correspond to samples that not fail upon bending.

The maximum plasticity was detected in the alloy with a mixed structure consisting of regions of submicrocrystalline and cellular types (Fig.1b). The formation of nanocrystalline grains led to a certain decrease in the plasticity and increase of coercivity. Transmission electron microscopy shows that the decrease in the plasticity is caused by a decrease in the volume fraction of regions with a cellular structure and the formation of a homogeneous nanocrystalline structure of the α solid solution in the alloy.

The enhanced plasticity of the nanocrystalline alloy is likely to be due to the disappearance of the coherently related α_1 and α_2 phases as a result of the complete dissolution of the α_1 phase during SPD and the formation of a nanocrystalline structure. In this case, the alloy can be considered as a conventional severely cold-worked single-phase structure.

This work was supported by RBRF (project N 06-02-90539).

Poster report

Excellence Mechanical Properties of Nanostructured Al-based Alloy, Prepared by Severe Plastic Deformation

Nikolay A. Krasilnikov[a,1], Alfred Sharafutdinov[b,2]

[a] Ulyanovsk State University, 42 L. Tolstoy St., Ulyanovsk 432970, Russia

[b] Institute of Physics of Advanced Materials, Ufa State Aviation Technical University, 12 K. Marx St., Ufa 450000, Russia

[1] nick@sv.uven.ru , [2] shar-alfred@list.ru

The structure and mechanical properties of Al-based alloy 2024 after high-pressure torsion (HPT) was investigated. Alloy 2024 with homogeneous structure and grain size about 70 nm was obtained using HPT at 6 GPa pressure and 5 turns of anvils at room temperature. The nanostructured alloy at room temperature demonstrated very high ultimate tensile stress above 1100 MPa, and superplastic behavior at temperature 330°C. The microhardness of nanostructured alloy after superplastic deformation (1.5 GPa) was more than after standard treatment of coarse-grained alloy (1.2 GPa). Opportunity of achievement in metals and alloys of combination high strength and good ductility opens perspectives of its application in industry, particularly, for mirco-systems and for high-strength details with complex geometry obtained due to superplastic forming. The influence parameters of severe plastic deformation and heat treatment on structure and deformation behavior of Al-based alloy were studied.

Poster report

Mechanical Properties and Structure of Materials after Hydroimpulse Treatment

Nikolai A. Krasilnikov

Ulyanovsk State University, 42 L. Tolstoy St., Ulyanovsk 432790, Russia.

nick@sv.uven.ru

Pure copper (99.9 wt. %) and nickel (99.5 wt. %), subjected to hydroimpulse treatment at room temperature were investigated. Increase of microhardness of a surface layer of samples in 2-3 times on depth up to 2 mm was revealed. Typical result was heterogeneity of distribution of microhardness along diameter of hydro-stroke with local maximum on periphery of stroke. Such distribution of microhardness is connected with turbulence of a liquid jet, and also with features of interaction of a liquid jet with a surface of metal. Structural researches have shown, that hydroimpulse treatment in copper leads to a substantial growth of dislocation density and a formation of subgrain microstructures, and in nickel occurs intensive mechanical twinning with the size of twins about 200 nm. Features of hydroimpulse treatment of metals are a small time of influence and preservation of high deformation ability of a liquid at spreading along a surface, therefore the size of the modified area of sample exceeds the diameter of liquid jet and extends on significant depth.

Poster report

Microstructure and Mechanical Properties of the Magnesium Alloy AZ91D after ECAP and HPT

Lilia R. Kurmanaeva[a,1], Rinat K. Islamgaliev[a,2]

[a] Institute of Physics of Advanced Materials, Ufa State Aviation Technical University, 12 K. Marx St., Ufa 450000, Russia

[1] lilokr@list.ru, [2]saturn@mail.rb.ru

Light magnesium alloys, due to their high specific strength and stiffness, are very attractive in many engineering applications. The disadvantages of these materials are the poor workability because of their hexagonal structure and the limited mechanical properties at elevated temperatures. It is well known that materials with small grain size have the enhanced mechanical properties. Reduction of the mean grain size in magnesium alloys is expected to increase the yield stress (and also the ultimate tensile strength) at room temperature and to promote superplastic deformation at higher strain rates and/or lower temperatures than those conventionally used for large grain size materials [1].

Ultrafine-grained (UFG) microstructure in metals can be produced by severe plastic deformation (SPD) techniques. Two different SPD techniques, equal channel angular pressing (ECAP) and high pressure torsion (HPT) were used in this work. ECAP is good for obtaining UFG structure in materials with larger dimension, and HPT makes possible to produce smaller grain size.

The aim of the present work is to study the effect of ECAP and HPT on the microstructure and the mechanical properties of magnesium alloy AZ91D. Before SPD the initial cast alloy containing dendrites was annealed at temperature 460°C for 6 hours to obtain the coarse-grained structure. ECAP (intersecting angle 120 degrees, root Bc, 6 passes) was carried out at temperature 300 °C. The temperature of HPT was 250 °C.

The microstructure before SPD was characterised with average grain size more than 100 μm and presence of quite large particles (Fig. 1a). After ECAP the average grain size has been reduced to about 5 μm (Fig. 1b), whereas the average grain size of the HPT samples was 1 μm (Fig.1c).