Poster report

Structure Features and Properties of Zirconium After Severe Plastic Deformation

Vladimir M. Azhazha, Alexei N. Velikodny, Michael A. Tikhonovsky[1],
Igor D. Tolmachev, Natalia F. Andrievskaya and Tatiana Yu.Rudicheva
National Science Center “Kharkov institute of physics and technology”.
1 Akademicheskaya St., Kharkov 61108, Ukraine
[1] tikhonovsky@kipt.kharkov.ua

As been shown in many researches, severe plastic deformation may lead to substantial subdivision of grain structure and dramatic changes in mechanical properties of material [1]. At that time, structural behavior depends significantly on the crystal lattice type. In this work, influence of severe plastic deformation on structure and properties of α-Zr (with HCP lattice type) was studied.

Double electron-beam remelted iodide zirconium has been used in investigation. Initial rod was 10 mm in diameter and had a grain size of 5÷15 μm. Severe plastic deformation was done by drawing at room temperature. A quantitative value to measure deformation was $\varepsilon = \ln d_0^2/d^2$, where d_0 is initial rod diameter (10 mm) and d is diameter of specimen studied. The highest value of deformation was ε ≈ 9.2. Thermoelectric power (under room temperature relative to copper), specific electrical resistance at 77 K and 293 K (ρ_{77} and ρ_{293}) and microhardness H_μ were measured. Microstructure was investigated by transmission electron microscopy (TEM).

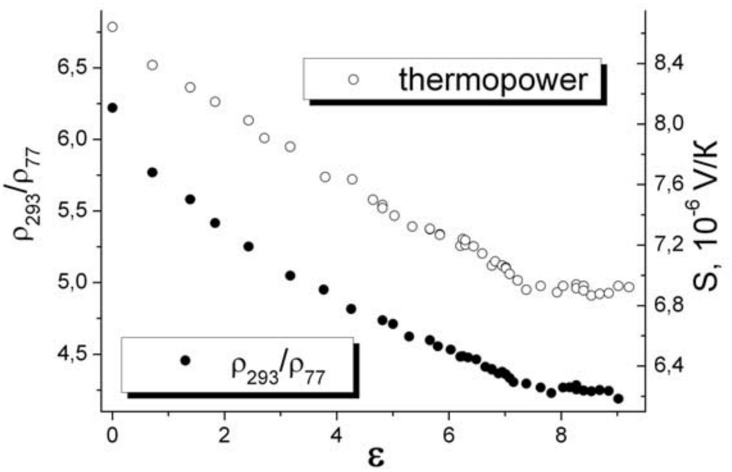

Figure 1. Relative electrical resistance and thermopower of zirconium versus deformation

As established by TEM investigation, grain subdivision process is very nonuniform at the initial stages of deformation (ε ≤1.4). When ε = 1,4, regions with initial grains size exists in material along with bands where fragment size is about 400 nm. With increasing ε, fragmented regions of material expand and average fragment size decreases. When deformation reaches the value of ε = 5.9, the uniform structure with average size of about 100 nm forms in cross section of material. Specific electrical resistance of material at

77 K steadily rising in all deformation range whereas resistance at room temperature reaches the plateau at $\varepsilon \approx 2$ but begins to rise again when $\varepsilon \approx 6$. Temperature coefficient of resistance α measured at temperature range of 5 ÷ 70°C steadily decreasing with deformation from value of $44\times10^{-4}K^{-1}$ when $\varepsilon = 0$ to $38{,}4\times10^{-4}K^{-1}$ when $\varepsilon \approx 9$. Values of thermoelectric power and relative electrical resistance ρ_{293}/ρ_{77} (see fig. 1) decrease under deformation in a similar manner.

When reaching $\varepsilon \approx 7.5$ they tend to attain saturation. Microhardness of zirconium under deformation (Fig.2) increases by 2.5 times (from 850 MPa to 2150 MPa). Drastic H_μ increasing at initial stages of deformation turns into smoothly rising at $\varepsilon \geq 3$ but don't tend to reach a plateau up to $\varepsilon = 9.2$. Possible mechanisms causing observed structure formation and properties changes of zirconium are discussed.

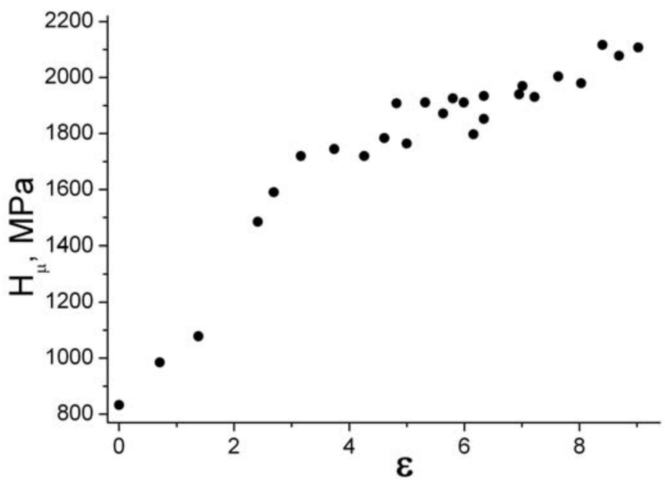

Figure 2. Microhardness of zirconium versus deformation

[1] R.Z. Valiev, I.V. Alexandrov, Nanostructured Materials Obtained by Severe Plastic Deformation, Logos, Moscow, (2000)

Poster report

Microstructure and Mechanical Properties of the Alloys of the System Cu-Al Subjected to High Pressure Torsion

Shiahao Xia[a,1], Lilia Vychigzhanina[b,2], Alfred Sharafutdinov[c],
Jing Tao Wang[a,3] and Igor Alexandrov[b,4]

[a] School of Materials Science and Engineering, Nanjing University of Science and Technology, Nanjing, Jiangsu 210094, P.R. China

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

[c] Innovation Research and Engineering Center "Iskra", 81 Pushkin St., Ufa 450000, Russia

[1] s.h.xia@tom.com, [2] llkl@rambler.ru, [3] jtwang@mail.njust.edu.cn, [4] iva@mail.rb.ru

As is known, formation of bimodal structures is considered as one of advanced possible ways of simultaneous enhancement of strength and ductility. At that, a smaller phase provides strength; a larger phase provides ductility of material. Formation of such structures is possible in the alloys with the composition similar to eutectic or eutectoid one. Various thermomechanical treatments allow regulating the size and volume fraction of phases.

The severe plastic deformation (SPD) technique allows refining the structure and forming ultrafine-grained (UFG) or nanostructured (NS) states in different metallic materials. As a result strength properties enhance, but ductility can decrease.

The report presents the investigation results of the alloys of the system Cu-Al with hypoeutectic and eutectic compositions which were subjected to martensite quenching and high pressure torsion (HPT) at room temperature and under a pressure of 5 GPa up to 5 rotations for forming UFG structures. The subsequent annealing allowed forming a bimodal structure in a hypoeutectic alloy. The grain size in the excess phase varied by means of changing temperature and time of annealing. The study of mechanical properties was conducted by tension of small samples on the specialized unique set at room temperature. The conducted investigations allowed stating interaction between the size and volume fraction of phases, on the one hand, and strength and ductility properties, on the other. The obtained results make it possible to make a conclusion about perspectives of use of bimodal structures for simultaneous revelation of high strength and ductility properties in bulk UFG and NS alloys processed by SPD.

Poster report

Controllable Bimodal Structures in Hypo-Eutectoid Cu-Al Alloy for Both High Strength and Tensile Ductility

Shaohua Xia[a,1], Artur Ganeev[2], Jing Tao Wang[a,3] and Igor V. Alexandrov[b,4]

[a] School of Materials Science and Engineering, Nanjing University of Science and Technology, Nanjing, Jiangsu 210094, P. R. China

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

[1] s.h.xia@tom.com, [2] artur_ganeev@mail.ru, [3] jtwang@mail.njust.edu.cn, [4] iav@mail.rb.ru

Creating a bimodal grain size distribution has been demonstrated an effective strategy to achieve a good combination of high strength and tensile ductility in Ultrafine-grained (UFG) or nanostructured alloys. To investigate the detailed relationship between the microstructural parameters in this bimodal microstructure and tensile mechanical property, a two-steps processing was proposed: first, high pressure torsion (HPT) to ultra-refine the microstructure in a hypo-eutectoid alloy, and second, selected temperature annealing of HPT processed materials so that the grain growth to micrometer level in the hypo-eutectoid phase region was accelerated and the grain growth in the eutectoid region was strictly confined. A bimodal structure of micrometer-sized hypo-eutectoid phase embedded in ultrafine-grained eutectoid matrix in Cu-Al binary system was obtained. The size and fraction of the hypo-eutectoid phase can be controlled by the pre-HPT heat treatment through controlling the heat treatment parameters. Such a series of microstructures imparts a high strength and uniform elongation in tensile deformation was also observed at high flow stress. Meanwhile, the value of elongation to failure increases with the fraction of micrometer-sized hypo-eutectoid phase and decreases with its size. We present microscopy results to illustrate the slip and accumulation of dislocation in hypo-eutectoid phase and bending with breaking in eutectoid matrix during HPT, also recovering□grain growth and decomposition of microstructure in annealing included. Last, Mori-Tanaka method was used to made stress-strain response of this bimodal structure and optimize it to achieve the best combination of desirable mechanical properties.

Keywords: Bimodal structure; Cu-Al; high strength; high ductility

Poster report

Microstructure and Mechanical Behavior of Ultrafine Grained Tantalum Processed by Equal Channel Angular Extrusion up to 16 Passes

Qiuming Wei[a,1], Suveen N. Mathaudhu[b,2], Laszlo J. Kecskes[c,3], K. Ted Hartwig[d,4], Kaliat T. Ramesh[e,5], and Ruslan Z. Valiev[f,6]

[a] Department of Mechanical Engineering, University of North Carolina – Charlotte, Charlotte, NC 28223-0001

[b] ORISE Post-Doctoral Fellow, U. S. Army Research Laboratory Aberdeen Proving Ground, MD 21005 5069

[c] U. S. Army Research Laboratory, Aberdeen Proving Ground, MD 21005 5069

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

[e] Department of Mechanical Engineering, the Johns Hopkins University, Baltimore, MD 21218

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

[1] QWei@uncc.edu, [2] Suveen.Mathaudhu@arl.army.mil, [3] Kecskes@arl.army.mil, [4] THartwig@tamu.edu, [5] Ramesh@jhu.edu, and [6] RZValiev@mail.rb.ru

As one of the body-centered cubic (BCC) refractory metals, tantalum (Ta) exhibits some extraordinary properties. These include an extremely low ductile to brittle transition temperature (DBTT of Ta is below 10K), a very high melting point (3290K), and a high mass density (16.65 gm/cm3), etc. Such unique properties allow Ta to be a promising candidate material for many critical applications. The combination of high melting point and excellent ductility make it possible to refine its grain size via severe plastic deformation (SPD) in a very efficient manner. We report the microstructure and mechanical behavior of ultrafine grained Ta processed by equal channel angular extrusion (ECAE) for 4, 8, 12, and 16 passes. We observed that even though the apparent grain size saturates quickly in a few ECAE passes, the average grain size continues to further reduce with increased number of passes, accompanied by an increase in the number of high angle grain boundaries. Quasi-static compression mechanical tests suggest elastic-nearly perfectly plastic stress-strain behavior, but the strain hardening capability of Ta has not been completely exhausted even after 16 ECAE passes. Uni-axial dynamic compression experiments show only slight flow softening and uniform plastic deformation. This dynamic plastic deformation manner distinguishes UFG Ta from other UFG BCC metals such as W and Fe where localized adiabatic shearing becomes the predominant deformation mode.