C O N T E N T S

MICROSTRUCTURES, DEFORMATIONS AND METHODS OF THEIR STUDY

DEFORMATION TEXTURES

DISLOCATION-DISCLINATION MODELS

MECHANICS OF PLASTIC DEFORMABLE MATERIALS

ABSTRACTS OF PUBLISHED ARTICLES

UDC 548.4:539.374

REGULARITIES OF MESOSTRUCTURES DEVELOPMENT IN METALS IN THE COURSE OF PLASTIC DEFORMATION. R y b i n V. V. – Problems of Materials Science, 2003, N 1(33), p. 9–28

A review of the basic experimental evidence and theoretical concepts of mesodefects and mesostructures formation in the process of a large plastic strain is presented. A genetic interrelation between the formation of mesodefects and self-organization of an ensemble of interacting dislocations at their critical density values has been revealed. A classification of mesodefects and their interpretation in terms of partial and junction disclinations are given. A detailed consideration of fragmentation and analysis causes and acting forces giving rise to the phenomenon are presented. A large body of data on the statistics of fragment boundary distribution in the value and direction of a misorientation vector as well as the type of boundaries is given.

Key words: plastic strain, mesodefects, mesostructures, disclinations, fragmentation, theoretical and experimental investigations.

UDC 669.14–41:539.374.

MODELLING THE PLASTIC BEHAVIOUR OF STEEL SHEETS UNDER COMPLEX STRAIN PATH CHANGES. T e o d o s i u C.– Problems of Materials Science, 2003, N 1(33), p. 29–36

The numerical simulation of sheet metal forming processes requires a reliable description of the plastic behaviour of the deformed materials, in connection with the evolution of their texture and microstructure. The present paper aims at reviewing some recent progress in developing such advanced constitutive models for steel sheets.

Key words: steel sheet, forming, evolution of texture, microstructure, numerical simulation.

UDC 539.375

STRUCTURAL LEVELS OF PLASTIC DEFORMATION AND FRACTURE OF SOLIDS. P a n i n V. E. – Problems of Materials Science, 2003, N1(33), p. 37–48

Qualitatively new propositions are put forward within the concept of the structural levels of deformation and fracture of solids. Plastic flow of a solid under loading is treated as an evolution of its shear stability loss at different scale levels: micro-, meso-, and macrolevels. A solid is considered as a multilevel system where micro-, meso-, and macrolevels are self-consistent. The formation of dissipative mesostructures and the fragmentation of a solid under loading are the main features of the plastic flow at the mesoscale level. Fracture is the final stage of fragmentation of a solid in the case where it is localized at the macrolevel.

Key words: solid, plastic deformation, structural levels, fragmentation.

UDC 548.4:537.533.35

ADVANCES IN EXPERIMENTAL METHOD AND ANALYSIS FOR ESTIMATION OF GEOMETRICALLY-NECESSARY DISLOCATIONS. E l - D a s h e r B. S., A d a m s B. L., R o l l e t t A. D. – Problems of Materials Science, 2003, N1(33), p. 49–54

Advances in experimental methods for determination of the geometrically-necessary dislocation (GND) tensor, based on electron backscattering diffraction, are described. Data are presented for directionally-solidified 99.999% Aluminum possessing a strong <001> columnar texture, with the primary focus being the interactions of the plastic deformation field with grain boundaries. Alternate methods of solving for the GND content are illustrated and compared. Implications of the observations for strain-gradient plasticity theory are discussed.

Key words: geometrically-necessary dislocation, experimental methods, plastic deformation field.

UDC 669.3:539.385

CRYSTAL ORIENTATIONS IN COPPER DEFORMED BY HIGH PRESSURE TORSION. S t u w e H. P., P i p p a n R., H e b e s b e r g e r T., V o r h a u e r A. – Problems of Materials Science, 2003, N1(33), p. 55–60

Copper was deformed to = 25 by HPT and the distribution of local orientations was measured by EBSP. An original crystal is strongly fragmented into small volumes of different orientations. The reasons for fragmentation are discussed. Correlation functions for misorientation angles and rotation axes seem to be nearly random. On the other hand, the specimen shows a clear deformation texture. The apparent discrepancy is explained.

Key words: copper, deformation, high pressure torsion, cristal, deformation texture.

UDC 620.187:539.382

TEM STUDY AND NUMERICAL SIMULATION OF A TERMINATED SHEAR MICROBAND FORMED UNDER ORTHOGONAL STRAIN-PATH CHANGE. N e s t e r o v a E., R y b i n V., Z i s m a n A., T e o d o s i u C. – Problems of Materials Science, 2003, N1(33),p. 61–75

A terminated shear microband, developed in mild steel under an orthogonal strain-path change (simple shearing in the direction of a previous tensile strain), has been detected and subjected to quantitative TEM analysis. Based on the obtained misorientations at the microband interfaces and on the shear offsets at the microband intersection with preformed dislocation boundaries, the underlying slip activity has been simulated. The best fit to TEM data was obtained by assuming a single slip inside the microband, on the slip system , which was most favourably oriented with respect to the last imposed deformation mode. The tilt misorientation fraction, systematically increasing towards the termination area of the microband, suggests a particular rearrangement of outer lattice dislocations before the propagating microband front. Such a transient process is considered to gradually form dipolar low-angle boundaries parallel to the microband, eventually intersecting and penetrating previously formed dislocation boundaries on its way.

Key words: transmission electron microscopy, tensile strain, terminated shear microband, lattice dislocations, numerical simulation.

UDC 548.4

MATERIAL ROTATION AND LATTICE RE-ORIENTATION IN INTER-ACTION OF DIFFERENTLY DEFORMED STRUCTURAL ELEMENTS. Z i s m a n A. A., R y b i n V. V. – Problems of Materials Science, 2003, N1(33), p. 75–81.

Compatibility condition, involving both the strain rate and spin, has been formulated for *whole* structural elements, each specified by a shape tensor of second order and considered to deform uniformly. On this ground the element spin is analyzed in interaction with differently deformed sur

roundings represented by i) a uniform matrix and ii) a few neighbouring elements. Use of obtained kinematical relationships in texture simulation is then considered.

Key words: differently deformed structural elements, lattice re-orientation, texture simulation.

UDC 669.15–194:539.25:620.187:539.382

QUANTITATIVE EVALUATION OF THE MICROSTRUCTURAL FEATURES OF THE MAIN TEXTURE COMPONENTS OBTAINED AFTER COMPLEX STRAIN PATHS IN LOW CARBON STEELS. B a c r o i x B. , N e s t e r o v a E., R i c h a r d V. , T e o d o s i u C.– Problems of Materials Science, 2003, N1(33), p. 81–87

The microstructures of a Ti-added interstitial free (IF) steel and of a bake-hardened (BH) steel have been examined through TEM and EBSD observations after simple-shear/simple-shear strain-path changes, in connection with the crystallographic orientation of the examined grains. It is shown that the combined use of TEM and EBSD allows to get some quantitative information about the microstructure type, the influence of initial state and orientation path.

Key words: low carbon steel, Ti-addition, TEM analysis, crystallographic orientation.

UDC 669.716:621.771:620.175.24

PLASTIC LOCALIZATION BY MACROSCOPIC SHEAR-BANDING DURING SHEAR TESTS OF COLD-ROLLED ALUMINIUM ALLOYS. G a s p e r i n i M., S w i a t n i c k i W. – Problems of Materials Science, 2003, N1(33), p. 88–95

Shear-banding during shear tests of cold-rolled aluminium alloys is described at different scales from the sample scale to the dislocation microstructure. Experimental strain distributions obtained by micro-grids permit to measure the strain gradients. FEM simulations of the shear test point out the importance of boundary conditions and of the constitutive behaviour. The effect of the microstructure and of the texture are discussed.

Key words: cold-rolled aluminium alloys, dislocation microstructure, FEM.

UDC 669.15–194:620.187

TEM EXAMINATION OF THE MICROSTRUCTURE EVOLUTION IN THE DUPLEX AUSTENITIC-FERRITIC STEEL. Ś w i ą t n i c k i W., B a u d i n T., J u r a J., M a t h o n M. H., G l o w a c k a A. – Problems of Materials Science, 2003, N1(33), p. 96–103

The dislocation microstructures in two-phase austenitic-ferritic steel have been investigated by transmission electron microscopy (TEM) after various amounts of cold rolling deformation (up to 80% of reduction). The succeeding steps of microstructure evolution are correlated with the texture of each phase measured by neutron diffraction. It was shown that the microstructure and texture evolve differently in austenite and ferrite. As a result, various types of deformation microstructures appear in ferrite as well as in austenite grains.

Key words: austenitic-ferritic steel, dislocation microstructures, transmission electron microscopy, neutron diffraction.

UDC 669.15–194.53:539.374.2

MICROSTRESSES IN COLD DRAWN PEARLITIC STEEL WIRES. Z o l o t o r e v s k y N. Yu., V a s i l i e v D. M., T i t o v e t s Yu. F.– Problems of Materials Science, 2003, N1(33), p. 104–110

The influence of cold drawing on the internal stresses (microstresses) developed in the ferrite phase of a pearlitic steel due to the plastic interaction of ferrite and cementite has been studied using X-ray technique. The microstresses were evaluated from experimental data by the method accounting for internal stresses caused by the ferrite plastic anisotropy (referred to as mesostresses). The main result is that microstresses in the ferrite phase gradually decrease down to near-zero level with increasing plastic strain.

Key words: pearlitic steel, cold drawn wires, X-ray technique, microstresses.

UDC 669.71:548.73

X-RAY STUDY OF MICROTEXTURE EVOLUTION WITHIN SINGLE GRAINS. Titovets Yu. F., Zolotorevsky N. Yu., Ermakova N. Yu. – Problems of Materials Science, 2003, N1(33), p. 110–118.

The X-ray diffraction techniques was used to study the evolution of microtexture in individual grains of polycrystalline aluminium under compression. The rotation trajectories of grains with close initial orientations of the compression axis were shown to differ appreciably. This allowed one to suppose that grain rotation considerably depends on the grain local neighbourhood. Grain-scale orientation gradients were shown not to play impotent role in the formation of microtexture inside individual grains.

Key words: grains of polycrystalline aluminium, X-ray diffraction, grain-scale orientation, formation of microtexture.

UDC 539.21:620.187:539.374

TEM-INVESTIGATIONS OF THE CORRELATIONS BETWEEN THE CELL BLOCK STRUCTURE AND DISCLINATION CONFIGURATIONS IN PLASTICALLY DEFORMED METALS. Klemm V., Klimanek P., Motylenko M., Pavlovitch T., Straube H. – Problems of Materials Science, 2003, N1(33), p. 118–124.

TEM diffraction contrast imaging and local disorientation measurements with help of TEM-micro- and nanodiffraction verify in fcc, bcc and hcp deformed metals large range stresses due to characteristically microstructure elements. Typical partial disclination configurations were observed. These are disclination multipoles in non-compensated nodes of dense dislocation walls, at torn-off dense dislocation walls and along dense dislocation walls.

Key words: deformed metals, disclination configurations, large range stresses, TEM-investigations.

UDC 548.4:620.187

A NEW METHOD FOR THE PRECISE DETERMINATION OF SMALL LOCAL MISORIENTATIONS IN CRYSTALS FROM TEM KIKUCHI PATTERNS. Straube H., Klemm V., Klimanek P., Motylenko M. – Problems of Materials Science, 2003, N1(33),p. 124–131

A new method is presented by which local orientations and misorientations in thin crystals with arbitrary lattice structure can be determined with high accuracy. The procedure uses TEM Kikuchi patterns and is based on the analysis of the intersections of Kikuchi-line pairs. The attainable angular accuracy of the orientation is □±0.01° for the rotation about an axis in the image plane and □±0.1° for a rotation about the normal direction of this plane. As illustrated in this paper, the method is ideally suitable for the characterisation of disclinations in heavily distorted crystals.

Key words: thin crystals, local orientations and misorientations, transmission electron microscopy, characterisation of disclinations.

UDC 539.219.2:539.374:620.187

MEZOSTRUCTURE, INTERNAL STRESSES AND PLASTIC DEFORMATION STAGES. K o n e v a N. A. – Problems of Materials Science, 2003, N1(33), p. 132–141

In work the study of internal stresses (IS) on different stages of plastic deformation of FCC metals and alloys of solid solutions is carried out by the method of transmission electron microscopy. The basic sources of IS are determined. Statistical data on distribution of IS in materials having different density of defects and a different type of a substructure (mezostructure) organization are obtained. It is recognized that substructures originating during deformation are characterized by a correlated ordered arrangement of dislocations. It leads to screening an internal elastic field. On the base of the performed measurements the principal difference of an amplitude and homogeneity of IS in low-energy and high-energy dislocation structures (LEDS and HEDS accordingly) are shown.

Key words: FCC metals, plastic deformation, low-energy dislocation structure, transmission electron microscopy.

UDC 548.4:539.374

DEFORMATION-INDUCED BOUNDARIES AND THEIR DISORIENTATIONS. P a n t l e o n W. – Problems of Materials Science, 2003, N1(33), p. 142–150

During plastic deformation dislocations are stored in different types of boundaries and a hierarchical dislocation boundary structure is established. Simultaneously, orientation differences across the boundaries arise and these disorientations are modeled by dislocation dynamics. The evolution of the disorientation angles with strain and the obtained distributions are in good agreement with experimental data. An extension of the model describes correlations between disorientations across neighbouring boundaries also.

Key words: plastic deformation, dislocation boundary, disorientations, dislocation dynamics, modelling of disorientations.

UDC 548.73:620.187

CRYSTALLOGRAPHIC TEM ANALYSIS OF HEAVILY DEFORMED STRUCTURES BY THE SINGLE REFLECTION TECHNIQUE. N e s t e r o v a E. V., R y b i n V. V. – Problems of Materials Science, 2003, N1(33), p. 151–163.

A brief description of single reflection technique (SRT) is presented. Advantages of SRT in crystallographic attestation of heavily deformed and martensitic microstructures have been demonstrated on example of a-titanium, cold-drawn lamellar pearlite and low carbon steels. Crystallographic features of matrix and twin fragmentation in plastically deformed □-titanium have been analyzed. Crystallographic analysis is shown to be a successful way to restore the formation conditions of microstructures associated with uncontrolled adiabatic heating under very strong localization of plastic deformation. The pearlite colonies of stable <110> orientation are found to differ in fragmentation rate and type as compared with unstable one. The interphase misorientations in martensitic microstructures have been shown to keep a lot of information. The material rotations, produced by the Bain deformation and further plastic accommodation, have been distinguished by the crystallographic analysis. The method of accommodative misorientation measurements has been worked out, and examples have been given for martensite microstructures in two low carbon steels.

Key words: single reflection technique, martensitic microstructures, accommodative misorientation, method measurements.

UDC 669.3:621.77.016.2:620.187

BOUNDARY MISORIENTATIONS IN SUBMICROCRYSTALLINE STRUCTURE FORMED IN COPPER BY EQUAL-CHANNEL ANGULAR PRESSING. K o p y l o v V. I., M a k a r o v I. M., N e s t e r o v a E. V., R y b i n V. V. – Problems of Materials Science, 2003, N1(33), p. 164–168

The orientations of submicrocrystalline fragments formed in copper by equal-channel angular pressing (ECAP) were measured using TEM. The boundary misorientations were found and analysed.

Key words: equal-channel angular pressing, submicrocrystalline copper, TEM, boundary misorientation.

UDC 669.3:621.77.016.2:620.187

EFFECT OF EQUAL CHANNEL ANGULAR PRESSING ON MICROSTRUCTURE AND TENSILE PROPERTIES OF PURE COPPER. H e l l m i g R. J., B a i k S. C., S e o M. H., K i m H. S., E s t r i n Y. – Problems of Materials Science, 2003, N1(33), p. 168–174

Mechanical and microstructural changes during equal channel angular pressing of 99.95% purity copper were investigated. Copper specimens were deformed following route C to a maximum strain of about 8. Tensile tests of the deformed and undeformed Cu were performed, along with TEM investigations to determine the dislocation cell structure and cell size distribution. In addition, Vickers microhardness maps were obtained for all specimens, in order to confirm the overall homogeneity of the deformed material.

Key words: 99.95% purity copper, equal channel angular pressing, transmission electron microscopy, dislocation cell structure, homogeneity of the deformed material.

UDC 669.295:531.383

FORMATION OF A MESOSCOPIC SCALE STRUCTURE AND MECHANICAL BEHAVIOR OF TITANIUM AT THE LARGE PLASTIC DEFORMATION. S a l i s h c h e v G. A., Z h e r e b t s o v S. V., M i r o n o v S. Yu. – Problems of Materials Science, 2003, N1(33), p. 175–184.

Microstructure evolution and mechanical behavior of commercial pure titanium during the severe plastic deformation at T = 400°C has been investigated. Compressive deformation of prismatic samples by $\dot{e} \approx 0.5$ was sequentially applied in three orthogonal directions with the steps number of 12. The change in the deformation axis led to decrease in the yield stress as compared to that flow stress at the end of previous step. Intensive formation of deformation induced boundaries and fragmentation of microstructure were observed even at the initial stage of strain. The increase in the strain resulted in the growth in the volume fraction of deformation induced high angle boundaries, length of which was more than the initial grain size in several times. The formation of mesoscopic scale structure led both to the significant change in the microstructure morphology (from equiaxed to banded one and backwards) and to the considerable decrease in a mean grain size (from 35 to 0.3 μm). The microstructure development from one strain step to another resulted in change of flow stress. The mechanism of structure evolution and the effect of changing the deformation axis on the microstructure development are discussed.

Key words: commercial pure titanium, severe plastic deformation, mechanism of structure evolution, effect of changing the deformation.

UDC 539.21:539.374

REGULARITIES OF STRUCTURE EVOLUTION OF METALS AND ALLOYS DURING SEVERE PLASTIC DEFORMATION AND SUPERPLASTIC FLOW. K o l o b o v Yu. R., G r a b o v e t s k a y a G. P., I v a n o v M. B., I v a n o v K. V., G i r s o v a N. V. – Problems of Materials Science, 2003, N1(33), p. 184–191

Analysis of regularities of formation and evolution of grain-subgrain structure and structural-phase state materials in f.c.c., b.c.c. and h.c.p. metal materials during SPD processing and superplastic flow has been carried out using nickel, molybdenum, titanium and Al–Mg–Li alloys as an example.

Key words: grain-subgrain structure, structural-phase state, SPD processing, superplastic.

UDC 669.018:539.37

STRONG COLD DEFORMATION AS A METHOD FOR IMPROVING PLASTICITY OF ORDERED ALLOYS. G r e e n b e r g B. A.,G r o k h o v s k a y a L. G., G u s h c h i n G. M., K r u g l i k o v N. A., R o d i o n o v a L. A., S a k h a n s k a y a I. N., V o l k o v A. Yu. – Problems of Materials Science, 2003, N1(33), p. 192–200

An optimal structure providing a combination of a high strength and good plasticity, which could not be obtained by other methods, was produced in a group of ordered alloys NiPt, FePd, CoPt and CuAu. Conditions necessary for appearance of this structure were determined. The sequence of events, which take place during ordering after a strong cold deformation, was established. The $L1_0$-type alloy with an optimal structure represents a microscale composite reinforced with a rigid dislocation framework. The role of lamellar structure was found to be significant. It acts as a buffer preventing the concentration of stresses near interfaces.

Key words: ordered alloys, strong cold deformation, high strength, good plasticity.

UDC 669.268:539.25

STRUCTURE AND MICROHARDNESS OF POLYCRYSTALLINE CHROMIUM PRODUCED BY MAGNETRON SPUTTERING. F i r s t o v S. A., R o g u l T. G., M a r u s h k o V. T., S a g a y d a k V. A. – Problems of Materials Science, 2003, N1(33), p. 201–205

The structure and hardness of polycrystalline chromium produced by magnetron sputtering were studied using methods of electron microscopy. The relationship between grain size at annealing and microhardness was obtained. It was shown that for grain size $d < 1$ □m the Hall–Petch equation has deviation. The mechanisms of drastic hardness increasing of chromium coatings are discussed.

Key words: polycrystalline chromium, magnetron sputtering, electron microscopy, hardness coatings.

UDC 669.15–194.56:539.2:621.785

THE EFFECT OF THERMOMECHANICAL PROCESSING TEMPERATURE–STRAIN–TIME PARAMETERS ON THE AUSTENITIC STAINLESS STEEL MESOSTRUCTURE FORMATION. K o d j a s p i r o v G., R y b i n V. – Problems of Materials Science, 2003, N 1(33), p. 205–213

The effects of temperature–strain–time parameters at the High-Temperature Thermomechanical Processing (HTMP) on the mesostructure formation and strengthening of austenitic stainless steels has been studied. The fragmented dislocation structure observed in the different austenitic stainless steels with different carbon, nitrogen, titanium, niobium content gave evidence that HTMP effected the work-hardening and softening behaviour.

Key words: austenitic stainless steels, high-temperature thermomechanical processing, dislocation structure, work-hardening and softening.

UDC 669.017.3:621.9

STRUCTURAL AND PHASE TRANSFORMATION IN METALS AT HIGH-SPEED CUTTING. Skotnikova M., Kastorski D.,Strokina T., Krylov N. – Problems of Materials Science, 2003, N1(33), p. 214–224.

Conducted by means of optical metallography, electron microscopy was systematic research structural and phase transformation in blanks metal at high-speed cutting.

Key words: structural and phase transformation, high-speed cutting.

UDC 539.22:539.374

MODELLING DEFORMATION TEXTURES AND PLASTIC ANISOTROPY. Van Houtte P., Li S., Delannay L., Van Bael A. – Problems of Materials Science, 2003, N 1(33), p. 225–233

The validation of several models for the plastic deformation of single-phase polycrystalline materials (steel, aluminium) is discussed. The validation is done on the basis of predicted/measured cold rolling textures. Some of these models use the finite element method to solve for the local stress equilibrium/strain compatibility. Other models use simplifying assumptions. Some of these take interactions between adjacent grains explicitly into account. Finally, the use of such models to generate anisotropic yield loci is explained.

Key words: single-phase polycrystalline materials, cold rolling, models for the plastic deformation.

UDC 669.018:539.24:539.374

TEXTURE FORMATION AND DEVELOPMENT OF SUBSTRUCTURE INHOMOGENEITY BY PLASTIC DEFORMATION OF METAL MATERIALS: GENERAL NEW-DISCOVERED REGULARITIES. Perlovich Yu., Isaenkova M., Fesenko V.– Problems of Materials Science, 2003, N1(33), p. 233–243

The substructure inhomogeneity of rolled textured metal materials was studied using the new X-ray method of Generalized Pole Figures. The grain orientation relative to texture maxima and minima was shown to be the most effective criterion for systematization of observed substructure conditions. Obtained distributions of diffraction and substructure parameters give the fullest description of metal materials, experienced the plastic deformation.

Key words: rolled textured metal materials, substructure inhomogeneity, plastic deformation, X-ray method of Generalized Pole Figures.

UDC 539.374.2

THE CONCEPT OF RELAXED CONSTRAINTS RECONSIDERED. Leffers T. – Problems of Materials Science, 2003, N1(33), p. 243–250

The concept of relaxed constraints is reconsidered on the basis of simple qualitative arguments. It is concluded that there are only relaxed constraints for flat grains as produced by rolling and compression — and not, as implied earlier, for elongated grains as produced by tension and wiredrawing. Furthermore, it is concluded that the most correct relaxed-constraint model for flat grains is the "lamel model" which formally accounts for the cooperation between two neighbouring grains.

Key words: relaxed constraints, "lamel model", neighbouring grains.

UDC 669.15–194.53:548.735.6:539.374.2

PECULIARITIES OF TEXTURE DEVELOPMENT IN PEARLITIC STEEL UNDER COLD DRAWING. N e s t e r o v a E. V., Z o l o t o r e v s k y N. Yu., R y b i n V. V., T i t o v e t s YU. F. – Problems of Materials Science, 2003, N1(33), p. 250–257

Interrelation of macro- and microtexture development during cold drawing of pearlitic steel was studied. The <110> fiber texture gradually sharpens under cold drawing. At the same time, random texture component retains up to large strains. The microtexture analysis allow to suggest that such a character of the wire texture evolution is associated with the appearance of two kinds of grains (pearlitic colonies) differed in the degree and character of the fragmentation.

Key words: pearlitic steel, cold drawing, interrelation of macro- and microtexture.

UDC 539.374.2:539.24

SEQUENTIAL SELECTION OF ACTIVE SLIP SYSTEMS BY THE LEAST IN COMPATIBILITY CRITERION AND CORRESPONDING ROLLING TEXTURE OF FCC POLYCRYSTAL. Z i s m a n A., Z o l o t o r e v s k y N., E r m a k o v a N. – Problems of Materials Science, 2003, N1(33), p. 258–264.

A criterion has been formulated to select one by one active slip systems carrying out altogether a given crystal strain rate. The strain rate residual, until it vanishes, is assumed to be minimum with each next selection involving one more system (i = 1,…, 5). The rolling texture of fcc polycrystal, thereby predicted, is very similar to that of minimum shear criterion by Taylor. At the same time, the present approach proves to be computationally much more efficient and particularly flexible when taking into account the strain rate variation among grains or/and grain deformation by less than five slip systems.

Key words: corresponding rolling texture, active slip systems, crystal strain rate, texture of FCC polycrystal.

UDC 669.716:621.771:548.735

AN APPROACH TO CALCULATION OF GIVEN TEXTURE COMPONENT AND STUDY OF THEIR FORMATION MECHANISMS IN ROLLED ALUMINUM ALLOYS. G r e c h n i k o v F. V., A r y s h e n s k y V. YU. – Problems of Materials Science, 2003, N1(33), p. 265–277

On the basis of designed mathematical models of intercoupling of parameters of an anisotropy with parameters of texture and constants of chips the technique of calculation of a structure of texture alignments ensuring obtaining in metal of virtual values of an anisotropy is set up. The formation and modification of texture alignments is studied during hot rolling, that has allowed to elaborate technological rolling schedules of thin belts (ribbons) with a given structure of texture.

Key words: rolled aluminium alloys, anisotropy, parameters of texture, mathematical models.

UDC 548.4:539.374

DISLOCATION KINETIC MECHANISM OF WORK-HARDENING AND FORMATION OF DISLOCATION MESOSTRUCTURES IN CRYSTALS AT LARGE PLASTIC STRAINS. M a l y g i n G. A. – Problems of Materials Science, 2003, N1(33), p. 278–286

A work-hardening (W-H) mechanism of metals at large plastic strains (shear strains >1–5) is quantitatively analysed with the aid of a dislocation kinetic equation for the average density of geometrically necessary dislocations. The analysis of the W-H curves and fragmentated dislocation mesostructures formed in pure FCC metals at large plastic strains shows that stresses at the forth and fifth W-H stages are determined, as in the case of the second and third W-H stages, by contact interaction of dislocations.

Key words: pure FCC metals, work-hardening, dislocation kinetic mechanism, large plastic strains.

UDC 548.4:620.178.154:620.178.3

DISCRETE DISLOCATIONS SIMULATIONS COMPARED TO EXPERIMENTS: APPLICATION TO NANOINDENTATION AND FATIGUE TESTS. F i v e l M. C., R o b e r t s o n C. F., D é p r é s C., V e r d i e r M. – Problems of Materials Science, 2003, N1(33), p. 286–294

A discrete dislocation dynamics code has been developed for FCC crystals based on a simple edge-screw discretisation of the dislocation lines. Although this model can not compute large plastic strain in volume big enough to be representative of an infinite single crystal, it is a powerful tool when used to analyse problems where the plasticity is strongly localised. Such a situation is observed in the case of nanoindentation where the indent induced plastic zone reduces to half a sphere located beneath the indenter and also in fatigue tests where intense slip bands quickly develop. The aim of this paper is to show simulations of these two situations for which a special effort is done on comparing experimental and numerical results.

Key words: FCC crystals, large plastic strain, dislocations simulations compared, nanoindentation.

UDC 669.15–194.56:539.388.1:548.4

THE EVOLUTION OF DISLOCATION SUBSTRUCTURES DURING FATIGUE OF AUSTENITIC STEEL. K o v a l e n k o V. V., S o s n i n O. V., K o n o v a l o v S. V., T s e l l e r m a e r V. V., G r o m o v V. E., K o z l o v E. V., I v a n o v Yu. F. – Problems of Materials Science, 2003, N1(33), p. 295–302.

In work the problem of fatigue fracture of steel and alloys was being solved for industrial austenite steel 45G17Yu3 undergone the fatigue tests for fracture. The fracture of specimens occurred at number of cycles $N = 10{,}2 \cdot 10^4$. The intermediate stage of loading with $N = 7 \cdot 10^4$ cycles corresponding to appearance of sub- and microcracks was chosen, when together with initial and fractured specimens were analysed by dislocation substructure.

Key words: austenite steel, fatigue fracture, dislocation substructure.

UDC 539.22:539.374

DISCLINATION-BASED MODELLING OF GRAIN FRAGMENTATION AND ITS IMPACT ON THE MECHANICAL ANISOTROPY. S e e f e l d t M., V a n H o u t t e P. – Problems of Materials Science, 2003, N1(33), p. 302–310

Fragmentation of f.c.c. metals under cold deformation is modelled through coupled evolution equations for dislocation and disclination densities. For plane strain compression of Al, fragment sizes and misorientations can be predicted in good agreement with TEM. Orientations where disclination dynamics and lattice rotation assist each other to give strong fragmentation are discussed. A substructure contribution to mechanical anisotropy is reproduced.

Key words: f.c.c. metals, modelling of grain fragmentation, mechanical anisotropy, TEM.

UDC 548.4:539.214

MODELLING KINEMATIC HARDENING FOR DISLOCATION BASED PLASTICITY MODELS. T a b o u r o t L., F i v e l M., B a l l a n d P., L o u c h e H., T o u s s a i n t F. – Problems of Materials Science, 2003, N1(33), p. 310–316

Preliminary work to obtain kinematics hardening modelling in the frame of dislocation-based modelling is proposed. Dislocation segment equilibrium is detailed with special attention paid to the diverse origins of stresses. Then, analysis of numerical dynamic simulation of dislocations is done in order to determine the origin of kinematics hardening. Finally, a proposition is done to modify current modelling of crystalline plasticity.

Key words: kinematics hardening, dislocation segment equilibrium, modelling of crystalline plasticity.

UDC 669.715:620.187:548.4

DISLOCATION/PRECIPITATE INTERACTION MECHANISMS IN 6xxx ALUMINIUM ALLOYS. D i r r a s G. F., D o n n a d i e u P., D o u i n J. – Problems of Materials Science, 2003, N1(33), p. 317–324

Post-mortem transmission electron microscopy (TEM) investigations have been carried out to characterize the dislocation-precipitate interaction mechanisms of a compression-tested 6061-T6 aluminium alloy. The study was complemented by an approach combining image analysis by high resolution TEM which gives a direct measurement of the strain field around precipitates that is further introduced in the simulation of the dislocation propagation.

Key words: aluminium alloys, dislocation-precipitate interaction, dislocation propagation, transmission electron microscopy.

UDC 539.374

MATHEMATICAL SIMULATION OF LARGE PLASTIC DEFORMATIONS OF METALS. K o l m o g o r o v V. L. – Problems of Materials Science, 2003, N 1(33), p. 325–340.

The paper presents a method for solving boundary value problems of the developed plastic flow and fracture of metals. The boundary value problem is solved in two stages. In the first stage the isochronous variational principles of virtual velocities and stresses are applied, as well as a principle for temperature and direct methods of the calculus of variations. Fields of flow velocities, stresses and temperatures are found with an accuracy of variable parameters. Then, in the second stage, the set of ordinary differential equations is solved with respect to the variable parameters. The paper presents some results in solving this problem obtained in cooperation with my disciples. It gives an account of how we managed to overcome the continuum constraints of mechanics and to create a theory of fracture — the emergence of discontinuities in the form of cracks and similar macrodefects in developed plastic deformation of metals.

Key words: developed plastic deformation, flow velocities, stresses and temperatures, mathematical simulation.

UDC 539.22:621.77:539.386

MECHANICALLY INDUCED STRUCTURE INSTABILITY — THE NEW OPPORTUNITY IN METAL FORMING. K o r b e l A.,B o c h n i a k W. – Problems of Materials Science, 2003, N1(33), p. 340–348

Basing upon collected after many years of experimental works data and observations on various metallic materials the conditions which favour formation of shear bands were identified. This made possible to control this mechanism and provided backgrounds for already invented and verified the new technological solution in metal forming which proved expected features in metals behaviour. Despite of that a very fundamental question appears after the research. It concerns the atomic arrangements and properties of a crystal lattice in areas of very high stresses concentration like that at the front of a shear band.

Key words: structure instability, metal forming, shear band.

UDC 539.379.4

ANALYSIS OF FINITE PLASTIC DEFORMATION DUE TO THE SEQUENCE OF SLIPS. K o r b e l K., P e c h e r s k i R. B., K o r b e l A. – Problems of Materials Science, 2003, N1(33), p. 349–356

The study of available experimental results for FCC single crystals led to the hypothesis that sequential activation of single slips is responsible for many phenomena related with plastic deformation and hardening. The aim of the paper is to propose a new mathematical description of this mechanism. The procedure of limit transition enables obtaining the analytical solution for multiple slip, which is free from constitutive assumptions. Numerical simulation of the tensile tests of a single crystal is studied.

Key words: single crystals, plastic deformation, sequential activation of slips, mathematical description.

UDC 669.3:548.4:539.374

FE SIMULATION OF MULTICRYSTALS AT LARGE STRAINS. M u s i e n k o A., S c h m i d e g g K., K o l e d n i k O., P i p p a n R.,C a i l l e t a u d G. – Problems of Materials Science, 2003, N1(33), p. 357–364

This paper presents the finite element computations on a real OFHC copper multicrystal under monotonic tension whose three-dimensional crystal structure was analyzed by orientation image microscopy. A single crystal plasticity model was used to represent crystalline behaviour. Different finite element meshes, boundary conditions and material parameter sets were investigated. Results for the strain field are compared with experimental data of the local in-plane strains.

Key words: OFHC copper multicrystal, large plastic straihs, finite element computations.

UDC 539.374

SOME OPEN QUESTIONS IN MULTISCALE MODELLING OF LARGE PLASTIC STRAINS. P e c h e r s k i R. B. – Problems of Materials Science, 2003, N1(33), p. 364–373

The multiscale hierarchy of plastic slip processes from plastic slip lamellae through coarse slip bands transforming into micro-shear bands to clusters of micro-shear bands is considered. The

question of the so-called non-Schmid effect and the formulation of reliable yield condition for a single crystal or a separate grain in polycrystalline aggregate is studied.

Key words: large plastic straihs, multiscale modelling, plastic slip lamellae, micro-shear.

UDC 539.37

MICROMECHANICAL MODEL FOR ELASTOVISCOPLASTIC HARDE-NING-SOFTENING MATERIALS AND ITS APPLICATION FOR NUMERI-CAL SIMULATION. K u k u d z h a n o v V. N. – Problems of Materials Science, 2003, N 1(33), p. 373–381

The micromechanical model of the elastoplastic deformation and continuous fracture in polycristalline materials based on the mechanism of dislocation motion and generation of microdefects is suggested. The complete system of obtained constitutive equations doesn't violate thermodynamic inequalities and give the well posedness of boundary value problems including the softening stage. This allows using this model for the description of plastic strain localization and fracture processes. The fracture problems are considered for a cylindrical specimen with a small cut subjected to quasistatic and dynamic extension.

Key words: polycristalline materials, elastoplastic deformation, plastic strain localization, micromechanical model.

UDC 669.295’71:539.22

METHODOLOGY OF MULTISCALE MODELLING OF TITANIUM ALUMINIDES. R o o s A., C h a b o c h e J.-L. – Problems of Materials Science, 2003, N1(33), p. 381–389.

In this work a three-scale model of the mechanical behaviour of Titanium Aluminides is presented. The first scale transformation between the macroscopic length scale and the scale of an individual α_2, β or lamellar α_2–γ grain is made using self-consistent transformation field analysis (TFA) with anisotropic elasticity. The constitutive equations of the α_2 and β phases are obtained through the framework of crystal plasticity. The effective behaviour of the lamellar α_2–γ phase, necessitates a second scale transformation, which is also derived in the TFA framework. Some simple simulations are presented to show the viability of the method.

Key words: titanium aluminides, lamellar α_2–γ phase, transformation field analysis, multiscale modelling.

UDC 539.56

BRITTLE AND DUCTILE FRACTURE: TRANSITION POINTS. M o r o z o v N. F., P e t r o v Yu. V. – Problems of Materials Science, 2003, N1(33), p. 390–393.

New incubation time based approach is applied to explain brittle-to-ductile fracture transition in solids. The process is governed by criterion of plasticity and criterion of brittle fracture which give the possibility to predict the rate dependencies of strength and yielding. The competition between limiting points providing the brittle fracture and yielding leads to the fracture mode transition phenomenon that occurs with the change of deformation rate.

Key words: incubation time criteria, brittle fracture, ductile fracture, transition points.

UDC 621.98:539.22

PLANE-STRAIN BENDING WITH THE EVOLUTION OF ANISOTROPY. A l e x a n d r o v S., B a r l a t F. – Problems of Materials Science, 2003, N1(33), p. 393–399

Bending of sheets is a widely used metal forming process. In the present paper we focus on the development of anisotropy during the bending process. The starting point of the study is that in the case of incompressible materials the kinematic analysis of the pure bending process is independent of the constitutive law. Then, it is shown that a compatible state of stress exists. Finally, a numerical example is given for illustrative purpose.

Key words: bending process, anisotropy, numerical example.

UDC 669.71’721’793:539.214:621.77.016.2

REGULARITIES OF MECHANICAL BEHAVIOR IN Al–Mg–Sc MICRO-CRYSTALLINE ALLOYS DURING HIGH STRAIN RATE SUPER-PLASTICITY. P e r e v e z e n t s e v V. N., C h u v i l’d e e v V. N., S y s o e v A. N., K o p y l o v V. I., L a n g d o n T. G. – Problems of Materials Science, 2003, N1(33), p. 400–410

The application of severe plastic deformation to metallic alloys through the procedure of equal-channel angular pressing (ECAP) leads to significant grain refinement and an opportunity for achieving superplastic ductilities at very high strain rates ($\square 10^{-2}$ s^{-1}). The development of high strain rate superplastic alloys is important because it provides a potential for making use of superplastic forming for the rapid fabrication of complex components. Experiments were conducted to evaluate the mechanical properties of a series of Al–Mg–Sc–Zr alloys after ECAP. The results demonstrate some of these alloys exhibit exceptionally high tensile ductilities (elongations up to >2000%) at very rapid strain rates.

Key words: micro-cristalline alloys, equal-channel angular pressing, superplasticity.

UDC 621.763–419:539.374

LARGE ELASTO-PLASTIC STRAINS OF COMPOSITES. B r i g a d n o v I. A. – Problems of Materials Science, 2003, N1(33), p. 411–417

Large elastic-plastic deformations of sandwich sheets are presented. Within the framework of the shell theory, the elastic-plastic constitutive relation for transversely anisotropic sandwich sheet taking into account of the Bauschinger effect is discussed. The results of the computer simulation of the hemispherical punch stretching operation are demonstrated.

Key words: composites**,** large elastic-plastic deformations, computer simulation.

UDC 539.2:539.411.5

MESO-MACRO ENERGY EXCHANGE AND RESPONSE OF SOLIDS ON IMPACT. M e s c h e r y a k o v Yu. I. – Problems of Materials Science, 2003, N1(33), p. 418–426.

On the basis of a series of experiments on shock loading of wide spectrum of materials, the present paper demonstrates different regimes of meso-macro energy exchange. On the basis of experimental data, a criterion for change the regime of energy exchange is obtained.

Key words: shock loading, meso-macro energy exchange, experimental data.

UDC 539.371

DYNAMIC CONTACT PROBLEMS OF ELASTOPLASTICITY. A n n i n B. D., S a d o v s k a y a O. V., S a d o v s k i i V. M. – Problems of Materials Science, 2003, N1(33), p. 426–434

New algorithm of numerical realization of contact conditions in dynamic problems is suggested. It is based on the formulation of these conditions in terms of quasivariational inequalities with one-sided constraint on velocity vectors. The model of layer deformation under finite rotations is proposed. By means of a finite difference technique, our algorithm is applied to the problem of a laminated plates deformation under dynamic loading and to the analysis of oblique impact of two plates.

Key words: laminated plates, dynamic contact, layer deformation, numerical realization.