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1 July 1983

# USSR Report

MATERIALS SCIENCE AND METALLURGY

No. 90

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UDC: 669.017

FRACTURE TOUGHNESS OF CAST ALLOYS IN THE SYSTEM Al-Mg-Zn-Cu-Fe-Si

Ordzhonikidze IZVESTIYA VYSSHIKH UCHEBNIKH ZAVEDENIY: TSVETNAYA METALLURGIYA in Russian No 6, Nov-Dec 82 (manuscript received 18 Jan 82) pp 81-86

BELOV, N. A., YEVSEYEV, Yu. V. and ZOLOTOREVSKIY, V. S., Moscow Institute of Steel and Alloys, Department of Metallography of Nonferrous, Rare and Radioactive Metals

[Abstract] A study is made to determine the variation of fracture toughness as a function of composition of cast and heat treated alloys in the system Al-Mg-Zn-Cu with total magnesium plus zinc content 6 to 14%, copper content 0 to 4%, containing up to 0.5% iron and silicon. An attempt is made to relate microstructural parameters to fracture toughness. After fracture toughness testing the specimen parts were used to determine the Brinell hardness and manufacture tensile testing specimens. It is found that an increase in the volumetric fraction of excess phases greatly decreases fracture toughness. An increase in the microhardness of dendritic aluminum solid solution cells also usually decreases fracture toughness, though in some cases it does not influence it. Mathematical models are constructed of the variation of fracture toughness as a function of magnesium and zinc content in the cast, hardened and aged states. The maximum fracture toughness is found in the hardened state, the minimum in the cast state. Figures 3; references 11: 9 Russian, 2 Western.

[120-6508]

UDC 669.71'793.5

METASTABLE CONSTITUTION DIAGRAM OF Al-Sc IN HIGH-ALUMINUM RANGE

Moscow IZVESTIYA AKADEMII NAUK SSSR: METALLY in Russian No 1, Jan 83 (manuscript received 8 Jul 81) pp 179-182

DRITS, M. Ye., TOROPOVA, L. S., BYKOV, Yu. G., GUSHCHINA, F. L., YELAGIN, V. I. and FILATOV, Yu. A., Moscow

[Abstract] The constitution diagram of the Al-Sc binary system in the 0-1.9 wt.%Sc (0-3.2 at.%Sc) range was determined in a study with cast alloys of A99 aluminum and 99.87% pure scandium. The specimens were cooled at rates up to 100°C/sec without subsequent homogenization by annealing. Differential

thermal analysis with heating at a rate of 60°C/sec was applied to specimens in both liquid and liquid-solid states, with the KSPP-4 low-frequency thermograph calibrated against salts (KNO<sub>3</sub>, K<sub>2</sub>SO<sub>4</sub>, Na<sub>2</sub>SO<sub>4</sub>, NaCl) and metals (Al, Cu).

Changes of phase equilibria in the solid state were tracked by microstructural and x-ray structural analysis as well as by electrical resistance and micro-hardness measurements. The results reveal the effect scandium and its solubility on the metastable state during crystallization, namely a lowering of the horizontal eutectic line by a few degrees depending on the cooling rate and a comminution of the dendritic grains depending on the scandium distribution. Scandium is found to be an effective modifier, in accordance with the Kibula-Maltsev theory, forming with aluminum a refractory intermetallic compound structurally and dimensionally compatible with the aluminum crystal lattice, also in accordance with the Lamikhov-Samsonov electron d-shell theory. It is most effective in an amount of 0.6 wt.%. Figures 4; references 8: 7 Russian, 1 Western.

[85-2415]

UDC 620.17:669.71:621.78

#### MECHANICAL PROPERTIES OF A8 AND A85 ALUMINUM AT ELEVATED TEMPERATURES

Moscow METALLOVEDENIYE I TERMICHESKAYA OBRABOTKA METALLOV in Russian No 2, Feb 83 pp 46-47

VOLGA, V. V. and KHOLODILO, A. A., All-Union Scientific Research and Design Institute of Chemical Machinery Building, Severodonetsk branch

[Abstract] Mechanical properties of A8 and A85 aluminum under short-duration and long-duration loads at temperatures up to 150°C were measured on specimens cut transversely from 25-mm-thick plates. Specimens 6 mm and 10 mm in diameter with gauge lengths of 30 mm and 50 mm were slowly heated (over a period of 1 hour) to temperatures of 50, 100, and 150°C and held there, within  $\pm 3^\circ\text{C}$ , for 20-30 min. Specimens 10 mm in diameter with a 100-mm gauge length were heated over a period of 8 hrs and held for at least 1 hr. Mechanical tests were performed subsequently for tensile strength, 0.2% yield strength, percent elongation and percent area reduction. The test data were processed according to the method of least squares, with the relation  $\tau = A\sigma^{-\alpha}$  ( $\tau$ -time under load till fracture,  $\sigma$ - stress, A and  $\alpha$  material constants depending on temperature) assumed for the durability. The results can serve as a basis of supplementary norms for design of vessels and other equipment with aluminum. Figures 1; references: 1 Russian.

[83-2415]

## STRUCTURE AND MECHANICAL PROPERTIES OF ALUMINUM-SILICON ALLOYS PRODUCED BY CRYSTALLIZATION UNDER PRESSURE

Moscow METALLOVEDENIYE I TERMICHESKAYA OBRABOTKA METALLOV in Russian No 2, Feb 83 pp 44-46

SHINYAYEV, A. Ya., LITVINTSEV, A. I. and PIVKINA, O. G., All-Union Institute of Light Alloys

[Abstract] Cast aluminum alloys have been produced by crystallization under pressures up to 1500 MPa. A study of three such alloys with silicon (one hypoeutectic with 5% Si, two hypereutectic with 15% Si and 19% Si respectively) was made, for the purpose of determining the effect of high pressure on their structure and mechanical properties. Ingots 50 mm in diameter and 100 mm high produced by the semicontinuous casting process, were crystallized under pressures of 1000-1500 MPa from temperatures 50-80°C above the liquidus line. The lattice parameters of the dendritic  $\alpha$ -phase solid solution and the solubility of silicon in it were determined before and after crystallization, of particular interest being the changes occurring with transition from hypoeutectic through eutectic to hypereutectic alloy. The results of metallographic local x-ray microanalysis reveal that high pressure during crystallization produces a dense homogeneous structure supersaturated with  $\alpha$ -phase solid solution and containing comminuted primary silicon in the eutectic region. The microhardness increases as the eutectic point shifts toward higher silicon content. The results of mechanical tests for Brinell hardness, tensile strength, elongation, and toughness, were compared with available data on ingots of the same alloys crystallized under a pressure of 300 MPa and of aluminum alloys with 10-13% Si cast under a piston. The ingots crystallized under high pressure were found to have better mechanical properties and to retain them up to an annealing temperature of 300°C, owing to high stability of the  $\alpha$ -phase, as compared with conventionally cast ingots retaining a stable  $\alpha$ -phase only up to 100-200°C. The electrical conductivity was also measured, and found to begin to increase with softening of the alloys at 200-300°C. Figures 3; references 6: 5 Russian, 1 Western. [83-2415]

UDC: 620.172.254

## MECHANICAL PROPERTIES OF HIGH-STRENGTH ALUMINUM ALLOY IN IMPACT LOADING

Kiev PROBLEMY PROCHNOSTI in Russian No 2, Feb 83  
(manuscript received 4 Dec 81) pp 59-63

STEPANOV, G. V., ASTANIN, V. V., ROMANCHENKO, V. I., VASHCHENKO, A. P., TOKAREV, V. M., CHUKHIM, B. D., GUK, Yu. P., Kiev, Moscow, Institute of Strength Problems, Ukrainian Academy of Sciences

[Abstract] Results are presented from studies of impact load behavior of high-strength Al-Zn-Mg alloys with total zinc and magnesium content of 9%.

High-speed tensile testing was performed on a vertical drop hammer. Dynamic compressibility was studied by measuring the propagation velocity of a shock wave as determined by the time shift between signals from two dielectric transducers located at various distances from the surface of collision of a striker with the specimen. The impact compressibility of various aluminum alloys was found to depend little on chemical composition, processing technology or material strength. The deformation resistance in the high speed area of deformation increases with increasing deformation speed. When there is no correlation between strength characteristics in uniaxial compression and uniaxial deformation states their sensitivity to load speed can be expressed by a single viscosity coefficient. Figures 5; references 14: 9 Russian, 5 Western.  
[101-6508]

## COATINGS

UDC: 621.793:621.7.044.2.001

### APPLICATION OF POWDERS TO METAL SURFACES WITH CONDENSED EXPLOSIVES

Moscow FIZIKA I KHIMIYA OBRABOTKI I MATERIALOV in Russian No 2, Mar-Apr 83  
(manuscript received 10 Nov 80) pp 25-30

KAUNOV, A. M., SHAMREY, A. V., Volgograd

[Abstract] Results are presented from studies of an explosive technology similar to explosive welding of monolithic materials for the creation of powder coatings on metals and alloys. Coatings of both metal and nonmetal (refractory compound and hard alloy) materials were applied to type St.3 steel by means of an explosively generated shock wave. The experiments showed that the method can yield coatings in various states, differing in structure, composition, thickness and bonding strength with the base metal. The processes involve melting and pressing into the surface. The existence of areas of melting and pressing of powders into the surface shows that both thin high strength melted coatings and sintered or pressed thicker coatings with bonding strengths approximating the strength of a monolithic material can be obtained. Experimental determination of the critical speed above which melting of the coating powder occurs is required to determine the specific type of bonding which will be produced in each case. Figure 4; references 15: 14 Russian, 1 Western.  
[121-6508]

UDC 620.18:669.248'781

### STRUCTURE AND PHASE CONSTITUTION OF Ni-B COMPOSITE COATINGS

Moscow METALLOVEDENIYE I TERMICHESKAYA OBRABOTKA METALLOV in Russian No 2,  
Feb 83 pp 54-56

KOSKOV, V. D., PERMYAKOV, V. G., NOGTEV, N. N., MASICH, L. G. and YAGODKINA, L.M.  
All-Union Scientific Research Institute of Drilling Technology, Perm branch,  
and Perm Polytechnic Institute

[Abstract] Boronization of a metal surface layer by diffusion increases its wear resistance, especially under conditions of friction and abrasion, as well as its hardness, heat resistance, corrosion and erosion resistance, and resistance to seizing at elevated temperatures. A study of boronized nickel coatings was made for the purpose of determining their structure and phase

constitution. Specimens were produced by electrodeposition from a nickel-salt electrolyte (400 g/l  $\text{NiSO}_4$ +50g/l  $\text{NiCl}_2$ +30 g/l  $\text{H}_3\text{BO}_3$ , pH = 3, T = 45-50°C) at current densities of 250-1000 A/m<sup>2</sup> for 0.5-2 hrs and subsequent heat treatment of the deposit at 950, 1000, 1050°C, holding for 1 hr in industrial-grade  $\text{B}_4\text{C}$  powder, followed by cooling in air. The specimens were examined metallographically by layerwise etching and x-ray diffractometry. The diffractograms reveal a c.p.h crystal lattice of nickel with boron inclusions. Structure and phase constitution depend on the heat treatment, with  $\text{Ni}_3\text{B}$  and an interstitial solid solution of boron in the nickel lattice as well as a solid solution of c.p.h. nickel in  $\alpha$ -iron forming at 950°C. The boron content in these electrolytic coatings first increases linearly with the boron content in the electrolyte and then remains constant at 4.75%B as the boron content in the electrolyte increases beyond 12%. The microhardness of these coatings ranges from 215 to 2020 H, depending on the zone within the layer and on the heat treatment temperature, the minimum surface microhardness being 1345 H. Brittleness, zero after heat treatment at 950°C, increases with increasing heat treatment temperature. A. M. Zotova and A. I. Bashlykova participated in the study. Figures 5; references: 3: all Russian.  
[83-2415]

INFLUENCE OF ISOTHERMAL ANNEALING ON STRUCTURE, PHASE COMPOSITION AND STRENGTH OF SILICON CARBIDE FIBERS

Moscow FIZIKA I KHIMIYA OBRABOTKI MATERIALOV in Russian No 2, Mar-Apr 83 (manuscript received 19 Nov 80) pp 126-131

PEREKATOVA, Ye. K., IVANOV, V. K., SHULEPOV, V. I., GUZEY, L. S. and DOROKHOVICH, V. P., Moscow

[Abstract] A study is made of the cause and mechanism of strength loss of fibers at high temperatures in order to develop measures to prevent fiber softening and allow the use of silicon carbide fibers with protective coatings as reinforcement for composites with metal matrices. Studies were performed on fibers 100  $\mu\text{m}$  in diameter produced by precipitation of methyltrichlorosilane and hydrogen on 18- $\mu\text{m}$ -diameter tungsten fiber at 1100-1200°C, 1-1.5 minutes, as well as model diffusion vapors obtained by pressing tungsten with pure carbide powder at 1100°C, 80 MPa, 1 hour. Mechanical testing showed that as the annealing temperature increased the strength of the fiber decreased, though metallographic and x-ray structural analysis showed no traces of interaction of tungsten with silicon carbide. Further studies were therefore performed on model specimens which were vacuum annealed and studied at 13.3 MPa, 1400, 1600 and 1800°C for 1, 25 and 100 hours. These studies indicated that the strength of silicon carbide fibers decreased during isothermal annealing as a result of interaction of the silicon carbide with the tungsten filament, beginning with carburization of the filament and the formation primarily of WC.  $\text{W}_5\text{Si}_3$  is subsequently also formed. Equilibrium composition is reached at high temperatures following long term holding. This indicates that the generally accepted system of phase equilibria in the system W-C-Si is not accurate. The formation of products with specific volumes differing significantly from those of the initial components may cause internal stresses, leading to a decrease in fiber strength after annealing. Figures 4; references 19: 13 Russian, 6 Western.  
[121-6508]

STUDY OF DEFORMATION AND RUPTURE OF EUTECTIC COMPOSITE NICKEL-BASED MATERIAL BY IN-SITU HIGH VOLTAGE ELECTRON MICROSCOPY

Moscow FIZIKA I KHIMIYA OBRABOTKI MATERIALOV in Russian No 2, Mar-Apr 83  
(manuscript received 20 Mar 82) pp 132-135

KANTOR, M. M., OL'SHANSKIY, L. M., SVETLOV, I. L. and SOROKINA, L. P., Moscow

[Abstract] In-situ high voltage electron microscopy was used to study processes of deformation and fracture of a nickel-chromium based eutectic alloy hardened by additional alloying with  $\gamma'$  particles separated upon cooling from the  $\gamma$  solid solution. The alloy was manufactured by a method of directed crystallization. Processes of deformation and fracture of this alloy were studied using specimens with the extension axis both parallel and perpendicular to the direction of NbC fiber growth. In both cases the process of plastic deformation begins with production and migration of dislocations in the matrix. Fracture, however, occurs differently. In specimens loaded along the direction of fiber growth when a certain local dislocation density is reached in the matrix, cracks develop and propagate, most of which are retained within fibers. In specimens loaded perpendicular to the crystal growth direction, microcracks develop not in the matrix but at the division boundary between matrix and fiber, the fracture process being initially local in nature. The division boundaries are apparently the most vulnerable areas in the material in this case. Figures 2; references 4: 2 Russian, 2 Western.  
[121-6508]

UDC 539.4:678.067

MODELING FAILURE OF THIN-WALLED ELEMENTS OF DESIGNS USING LAMINATED MULTIDIRECTIONAL COMPOSITE MATERIALS

Riga MEKHANIKA KOMPOZITNYKH MATERIALOV in Russian No 1, Jan-Feb 83  
(manuscript received 4 Mar 82) pp 26-32

KUZNETSOV, S. F. and PARTSEVSKIY, V. V., Moscow Energy Institute

[Abstract] Earlier studies have suggested that failure of laminated materials in itself does not lead to changes in the rigidity of the overall composite, but rather that the rigidity of the layer running parallel to the direction of reinforcement is the only key feature. The authors sought to test this with a model of deformation and failure of laminated composites, and determined certain new principles for failure in homogeneous fields of macrotension, particularly with monoaxial and biaxial loads. An incremental-iteration mathematical method was used. With heterogeneous macroscopic flat stressed states, the method was checked on the basis of the final elements method. For all angles of reinforcement, failure of the strata begins with an intralayer destruction mechanism leading to the appearance of non-linear areas in deformation diagrams. Full loss of bearing strength is accompanied by subsequent

interlayer failure or breaking of fibers in the layers. Cracks form that follow the direction of stratal reinforcement. With increased loading, a secondary zone of intrastratal failure appears. The mathematical model was judged to be satisfactory for describing the failure processes observed. Figures 5; references 12: 9 Russian, 3 Western.  
[12131-110]

UDC 669.019.9:539.67

FATIGUE AND RECOVERY PROCESSES IN MULTILAYER COMPOSITE MATERIAL BASED ON IRON AND COPPER

Kiev POROSHKOVAYA METALLURGIYA in Russian No 1, Jan 83  
(manuscript received 22 Jan 82) pp 72-77

REVO, S. L., KOPAN', V. S. and MAYBORODA, V. P., Kiev State University imeni T. G. Shevchenko, Institute of Problems of Material Science, Ukrainian SSR Academy of Sciences

[Abstract] The method of internal friction, which makes it possible to reveal the properties of defects, their distribution in a material and their interaction with one another and impurities, is employed for the purpose of estimating changes in the density of microcracks and the fastness of the pinning of dislocations in specimens of a multilayer composite with various average thicknesses of a layer,  $h$ , to determine the relationship between the orientation of internal friction and the rolling direction, and to investigate the possibility of removing internal stresses under repeated loading. A study was made of amplitude-dependent internal friction in a multilayer composite in the form of a sandwich of layers of st. 45 steel and M1 copper. The composite was produced by thermomechanical treatment of a pseudo-alloy of steel and copper with a total reduction of 70 to 95 percent. The value of  $h$  equaled 0.5, 0.35, 0.3 and 0.16 micron. The steel component had a concentration by volume of 66 percent. Repeated loading was performed at 350 MPa, approximately equaling the composite's endurance limit. Amplitude dependences of internal friction were recorded in the fatigue process. Rolling of the sheet was alternated with annealing, and annealing was performed in a protective copper jacket at 650°C for 1 h after 35 to 50 percent relative deformation. Annealing by this method corresponded to recovery. It was found that for the multilayer composite studied the degree of pinning of dislocations increases with a reduction in  $h$ . Beginning with  $h = 0.35$  micron,  $\epsilon_k$ , standing for the critical deformation corresponding to separation of dislocations from pinning points, is greater for the composite than for its components. Dislocations in the composite are blocked by impurities and the boundaries of grains and layers, and this factor plays an important role in the increase in  $\epsilon_k$  with a reduction in  $h$  for specimens deformed identically. The density of microcracks does not increase with a reduction in the mean thickness of a layer. The anisotropy of amplitude-dependent internal friction indicates disparity in the climbing directions for edge dislocations and slip directions for screw dislocations in the multilayer composite. Thermal activation and repeated loading with loads equaling the

material's endurance limit result in unpinning of dislocations and this makes it possible to choose loading conditions under which recovery of the material is possible in the process of cyclic deformation. Figures 4; references 5: all Russian.

[93-8831]

UDC 539.4.001:678.067

FAILURE CRITERION FROM ACCUMULATED DAMAGES OF THREE-COMPONENT LAMINATED COMPOSITE

Riga MEKHANIKA KOMPOZITNYKH MATERIALOV in Russian No 1, Jan-Feb 83 (manuscript received 13 Oct 81) pp 33-41

KOLOKOL'CHIKOV, V. V. and KOMAROVA, N. S., Kuybyshev State University

[Abstract] Failure of composite materials is known to be preceded by irreversible accumulation of damages accompanied by energy losses. Although this factor clearly shows the need for a record of damage accumulation, current criteria for failures of composites only consider simple processes such as stretching and compression and shift in symmetrical axis directions. The authors add anisotropic factors depending on load history to these criteria, and apply their procedure to a three-component system with hardened epoxy matrix and layers of silicon and carbon fibers. The resulting composite has an axis that is perpendicular to the isotropic layers, and the durability criterion should be invariable relative to transformation of revolutions around the axis of symmetry. The heterogeneity of the stressed state was determined using the principle of blending. Calculations revealed three stages of damage accumulation that need to be considered as components progressively reached the point of failure. Figures 3; references 5: all Russian.

[12131-110]

UDC 539.4:678.067

DURABILITY IN STRETCHING WOUND POLYESTER FIBERGLASS

Riga MEKHANIKA KOMPOZITNYKH MATERIALOV in Russian No 1, Jan-Feb 83 (manuscript received 8 Jan 81) pp 47-51

BULMANIS, V. N. and GUSEV, Yu. I., Institute of Physicotechnical Problems of the North, Yakutsk Branch, Siberian Division, USSR Academy of Sciences, All-Union Scientific Research Institute for Application of Polymer Materials in Reclamation and Water Use, USSR Ministry of Land Reclamation and Water Use, Moscow

[Abstract] Stressed state extremes for wound polyester fiberglass are described using either invariable phenomenological criteria or a "structural" method limited by difficulties in experimental determination of characteristics

of the elementary layer. The authors test a phenomenological criterion that takes into account the nature of composite failure of the given material using a high-module roving RVMN-10-1680-289 and PN-1 polyester resin based on cobalt naphthenate and cumene hydroperoxide. At slight angles of reinforcement it was found that wrapping did not improve durability. Three experimental points were found that gave a satisfactory description of durability with stretching of the given type of polyester fiberglass throughout the whole range of wrapping angles. Figures 5; references 11: 8 Russian, 3 Western.  
[12131-110]

UDC 539.3:678.067

#### FEATURES OF ELASTICITY OF UNIDIRECTIONAL REINFORCED HYBRID COMPOSITES

Riga MEKHANIKA KOMPOZITNYKH MATERIALOV in Russian No 1, Jan-Feb 83  
(manuscript received 28 Jul 82) pp 13-19

MAKSIMOV, R. D., PLUME, E. Z. and PONOMAREV, V. M., Institute of Polymer Mechanics, LaSSR Academy of Sciences, Riga

[Abstract] A study was made of plastics based on organic silicon, organic carbon, carbosilicon and organic boron. Calculations were made for single and double fiber-type materials, according to several formulas. Both calculations and experimental data are presented for anisotropic fibers and for predicting elastic features of unidirectional hybrid composites. Varying ratios of volume content for various fibers brought monotonic changes in these features, with selected values for summary reinforcement. While calculated and experimental results were within acceptable margins, enough difference was noted to be taken into account in evaluating results. Nonetheless, the procedure was judged to be applicable to engineering decisions. Figures 6; references 3: all Russian.  
[12131-110]

UDC 539.4:678.5.06

#### MORPHOLOGIC STUDY OF FRACTURE MECHANISMS OF UNIDIRECTIONAL REINFORCED THERMOPLASTIC SPECIMENS

Kiev PROBLEMY PROCHNOSTI in Russian No 3, Mar 83  
(manuscript received 22 Nov 81) pp 72-76

GOLOVKIN, G. S., CHALYKH, A. Ye., DMITRENKO, V. P. and RUBTSOV, A. Ye., Moscow Aviation Technology Institute imeni K. E. Tsiolkovskiy, Institute of Physical Chemistry, USSR Academy of Sciences

[Abstract] A morphologic study is presented of the fracture mechanism of thermoplastics reinforced with continuous fibers. Smooth specimens of poly-caproamide reinforced with glass, carbon and organic SVM and phenylon fibers

were studied. The polyamide matrix was selected because the substance is a polar amorphous-crystalline linear polymer, 41% crystallized, with good strength characteristics and good adhesion to fibers, particularly aromatic polyamide based organic fibers. The process of fracture of the plastics studied is based on various deformation mechanisms. Common for all materials is the sequence of failure of the components, in that the fibers break first. The mechanism of their fracture plus that of deformation determine the mechanism of failure of the matrix. If the fibers break by brittle fracture (carbon, glass) main cracks propagate rapidly due to viscoelastic failure of the matrix. Viscous failure of organic reinforcing fibers with delayed growth of main cracks means that there is plastic shear with the formation of characteristic slip bands in the matrix. Figures 4; references 16: 11 Russian, 5 Western.  
[118-6508]

UDC 669.14.018.8:62-426

#### STAINLESS-STEEL REINFORCING FIBERS

Moscow METALLOVEDENIYE I TERMICHESKAYA OBRABOTKA METALLOV in Russian No 2, Feb 83 pp 41-43

KLEKOVKIN, A. V., MIKHEYEV, A. A., PETRAKOV, A. F., RYABOV, Ye. S. and CHUSOV, A. G.

[Abstract] A special grade of stainless steel has been developed for use as wire in the reinforcing fiber mesh of composite materials. This alloy, 18Kh15N5AM3 (VNS-9), contains 0.16-0.21% C, 14.5-16.0% Cr, 6.0-7.5% Ni, 2.7-3.2% Mo, 0.04-0.09% N,  $\leq 1.0\%$  Mn,  $\leq 0.6\%$  Si and features not only high static and fatigue strength but also high corrosion and heat resistance. Proper alloying of the steel ensures that an ingot material containing stable austenite and no martensite is obtained. Wire is produced by drawing at normal temperature, after quenching from 1150°C in water and hot rolling of the ingot, high strength (3450-4450 MPa) being acquired as a result of cold working of austenite and transformation of the latter into martensite which is also cold worked in the process. Wire drawing proceeds stepwise with intermediate annealing after each pass. Further treatment consists of tempering at 450°C and electropolishing of the finished wire. The wire does not soften after 4 hrs at 500°C or after 10 min at 550°C. Composite materials using this wire 0.15-0.6 mm in diameter have already been developed: with aluminum as the matrix in sheet form and in rope form, and also with epoxy resin as a binder. With a cold-hardening adhesive, such wire is used in a composite material for torsion bars of lifting propellers in helicopters. S. A. Ogolikhin participated in the development of this new steel. Figures 2; references 3: all Russian.  
[83-2415]

## ROLLING EXPANSION OF FIBER COMPOSITES PARALLEL TO REINFORCEMENT

Moscow FIZIKA I KHIMIYA OBRABOTKI MATERIALOV in Russian No 1, Jan-Feb 83  
(manuscript received 28 Jul 82) pp 136-137

TIKHONOV, A. S., AREF'YEV, B. A., GALAKHOV, A. V. and MALASHENKOV, S. G.,  
Moscow

[Abstract] The shape change of flat fiber aluminum-boron composite specimens upon rolling parallel to reinforcement was experimentally studied. Multilayer plasma strips with 0.1 mm diameter boron filaments at intervals of 0.13 mm alternating with aluminum foil interlayers 0.09 mm thick were rolled. In all specimens, even those with significant crushing of the fibers during deformation, spreading was observed rather than lengthening. The relative width of the rolled strips was great and stresses acting along the generatrix of the roll caused stresses in the fibers which exceeded their ultimate strength. This effect of anomalously high spreading provides additional capabilities for optimizing the process of composite formation with brittle fibers. This is particularly promising for producing hot reinforced rolled profiles. Figures 2; references 4: all Russian.

[103-6508]

## RESIDUAL STRESS AND DEFORMATION IN THERMAL CYCLING OF EUTECTIC COMPOSITES

Moscow FIZIKA I KHIMIYA OBRABOTKI MATERIALOV in Russian No 1, Jan-Feb 83  
(manuscript received 16 Feb 81) pp 116-122

SVETLOV, I. L., PIROGOV, Ye. N., ABALAKIN, N. P. and YEPISHIN, A. I.

[Abstract] The Harmong equations are used to calculate the stresses and strains arising in a matrix upon thermal cycling of directed Co (Cr, Ni)-TaC and Ni/Ni<sub>3</sub>Al-NbC eutectics. Calculation curves of the variation of stress in the matrix with temperature during cycling under four sets of conditions are presented. During the cooling half cycle tensile stresses arise in the matrix; compressive stresses arise during heating. The cooling speed has practically no influence on residual tensile stresses in the matrix at the minimum cycle temperature of 293°K. If irreversible plastic deformation occurs in the matrix, hysteresis loops appear on the curves. The irreversible deformation may result either from plastic flow or creep at stresses considerably below the yield point. Figures 6; references 12: 7 Russian, 5 Western.

[103-6508]

CONFERENCES

SEMINAR "PHYSICS AND CHEMISTRY OF PROCESSING MATERIALS WITH CONCENTRATED ENERGY FLOWS"

Moscow FIZIKA I KHIMIYA OBRABOTKI MATERIALOV in Russian No 1, Jan-Feb 83  
pp 142-143

UGLOV, A. A.

[Abstract] The seminar was held on 25 March 1982 at the Institute of Metallurgy imeni A. A. Baykov, USSR Academy of Sciences, under the chairmanship of academician N. N. Rykalin. The seminar was dedicated to problems of the thermal physics of technological processes. Eighty persons representing organizations from 11 cities attended. Problems discussed included unsteady heating and melting of metals by laser radiation and plasmas and optimal control of the width and depth of the hot working zone of plates by moving surface heat sources.

[103-6508]

CORROSION RESISTANCE OF MATERIALS OF  $\text{AlN-Si}_3\text{N}_4$  SYSTEM

Kiev POROSHKOVAYA METALLURGIYA in Russian No 1, Jan 83  
(manuscript received 19 Aug 81) pp 53-56

ALEKSEYEV, A. F., BARTNITSKAYA, T. S., GONCHARUK, A. B., LAVRENKO, V. A., LUGOVSKAYA, YE. S., PANASYUK, A. D., PIKUZA, P. P. and TIMOFEYEVA, I. I., Kiev Polytechnical Institute, Institute of Problems of Material Science, Ukrainian SSR Academy of Sciences

[Abstract] The results are given of a study of the corrosion resistance of materials based on  $\text{Si}_3\text{N}_4$  and  $\text{AlN}$ . Aluminum nitride and silicon nitride both begin to oxidize at temperatures higher than  $800^\circ\text{C}$  and represent some of the most scaling-resistant materials. The oxidation rate with a rise in temperature is considerably faster for silicon nitride than for aluminum nitride, but silicon nitride is more suitable as a construction material with respect to heat resistance, mechanical strength and the absence of shrinkage in sintering. Plasma-chemical aluminum nitride and silicon nitride produced by the Zaporozh'ye Abrasives Combine served as the subjects of study. Samples were produced by powder metallurgy with residual porosity of about 20 percent. The ratio of components varied over a broad concentration range with an  $\text{Al} : \text{Si}$  atomic ratio of from 6 : 1 to 1 : 6. The samples produced represented a mixture of silicon and aluminum nitride as well as of sialones based on them. Corrosion resistance was studied in air and in oxygen at temperatures of 800 to  $1400^\circ\text{C}$ . Oxidation to  $1200^\circ\text{C}$  was performed by the continuous weighing method using a vacuum microscale apparatus, and above  $1200^\circ\text{C}$  the specimens were oxidized only in air in a resistance furnace. The specimens were studied by x-ray, metallographic, crystal optical and chemical analysis. Gaseous oxidation processes were studied by infrared spectroscopy. It was revealed that there is considerable mutual influence on the part of silicon nitride and aluminum nitride in the oxidation of materials based on them, and that these materials have higher resistance to oxidation than do pure nitrides right up to  $1400^\circ\text{C}$ . An x-ray phase analysis of specimens oxidized at  $1200^\circ\text{C}$  showed that the oxidation products are alpha-cristobalite and sialones based on silicon nitride and aluminum nitride. Specimens of the  $\text{Si}_3\text{N}_4\text{-AlN}$  system throughout the entire range of concentrations and temperatures studied are distinguished by higher resistance to oxidation than that of silicon nitride. The corrosion resistance of the material produced depends on porosity and temperature, but resistance to oxidation is limited to a greater degree by the material's composition, for it increases monotonically with an increase in the concentration of

silicon nitride. A minimum increase in mass of oxidized specimens is observed with additions of up to 30 percent aluminum nitride to silicon nitride and of silicon nitride to aluminum nitride. The high resistance of the specimens to oxidation is apparently associated with the presence of a silone of the corresponding nitride. Figures 2; references 5: 3 Russian, 2 Western.  
[93-8831]

ENERGY EFFECTS

UDC: 535.211

LASER WORKING OF ROCK (REVIEW)

Moscow FIZIKA I KHIMIYA OBRABOTKI MATERIALOV in Russian No 2, Mar-Apr 83  
(manuscript received 18 Feb 82) pp 3-17

SOBOL', E. N. and UGLOV, A. A., Moscow

[Abstract] This review of Soviet and American literature covers publications on the effects of laser radiation on natural rock, discussing the possibility of using lasers for various rock working processes. The process of absorption of optical radiation, heating and fracture of rock under the influence of a laser beam is outlined. Results of experiments on the effects of laser radiation on rock are discussed. The phenomena which may occur when rock is heated by a laser beam include chemical reactions, phase transitions and destructive processes. Absorption of light and fracture of the rock are greatly influenced by the characteristics of the radiation, composition and properties of the rock. Various fracture mechanisms are possible, including melting, evaporation, chemical decomposition, sublimation, thermal fracture and shock wave damage. However, accompanying phenomena which may significantly influence energy consumption and quality of laser working have not been sufficiently studied. Work in which the possibility of practical utilization of laser beams for rock working is studied has been mostly preliminary. The authors call for systematic study of the interaction of laser radiation with rock to allow concrete determination of conditions of useful application of laser technology to the process. References 82: 67 Russian, 15 Western.  
[121-6508]

UDC: 621.9.048.7

TECHNOLOGICAL CONTROL OF SURFACE STATE PARAMETERS IN LASER WORKING

Moscow FIZIKA I KHIMIYA OBRABOTKI MATERIALOV in Russian No 1, Jan-Feb 83  
(manuscript received 23 Jan 80) pp 20-22

RYZHOV, E. V., TYUTYUNNIKOV, V. I., BLYUDOV, V. G. and GORLENKO, O. A., Bryansk

[Abstract] The technological factors which determine the status of a laser beam treated surface include processes related to hardening of the material and factors characterizing the laser radiation. Metallographic studies have shown

that laser processing forms a zone of thermal influence consisting of a hardened layer and a transition layer. With identical working conditions, there is a significant (up to 40%) spread in values of hardened layer depth, as well as nonuniformity of hardening depth distribution around a light spot. Repeated application of a laser beam to the same point does not change the depth of microhardness or structure of steels. Equations are derived which can be used for technological control of surface state parameters during laser working. Figures 2; references 2: both Russian.  
[103-6508]

STUDY OF CHANGES IN GRAIN BOUNDARY STRUCTURE UPON RECRYSTALLIZATION OF  
MAGNESIUM ALLOY AFTER SLIGHT DEFORMATIONS

Sverdlovsk FIZIKA METALLOV I METALLOVEDENIYE in Russian Vol 55, No 3, Mar 83  
(manuscript received 23 Feb 80) pp 554-558

VALIYEV, R. Z., GERTSMAN, V. Yu. and KAYBYSHEV, O. A., Ufa Aviation Institute  
imeni Ordzhonikidze

[Abstract] Two explanations have been suggested for the relaxation of lattice dislocations captured by grain boundaries during deformation: delocalization of captured dislocation nuclei and dissociation of these nuclei into discrete grain-boundary dislocations. Studies were performed on MA8 magnesium-manganese-cerium alloy after cold rolling and 30 minutes annealing at 670°K. The specimens were stretched in a tensile testing machine to  $\epsilon = 0.010$  to 0.060. Mean grain size was determined in each specimen after various annealing periods. Thin foils were examined in an electron microscope. A previously unknown correlation is found between the behavior of deformation grain boundary defects and the kinetics of grain growth in the alloy. An attempt is made to explain the correlation based on the structure and properties of grain boundaries, which have elevated energy when deformation defects are present. This means that the mobility of nonequilibrium grain boundaries in migration will be quite high. If a motive force acts on the boundary, therefore, the rate of migration is high due to the high boundary structure mobility. Figures 3; references 17: 7 Russian, 10 Western.

[119-6508]

## EFFECT OF MAGNESIUM ON THERMAL STABILITY OF POLYGONIZED STRUCTURE OF ALUMINUM-ZINC-MAGNESIUM ALLOYS

Moscow METALLOVEDENIYE I TERMICHESKAYA OBRABOTKA METALLOV in Russian No 2, Feb 83 pp 47-49

ZAKHAROV, V. V., ROSTOVA, T. D. and MAKAROVA, Z. V., All-Union Institute of Light Alloys

[Abstract] A study was made of semicontinuously cast Al- 6% Zn - (0.2-1.2)% Mg alloys (with 0.6% Mn, 0.2% Zn, - 0.04% Fe+Si) in cold-rolled strip form, for the purpose of determining the dependence of the thermal stability of their structure on the magnesium content. Specimens 92 mm in diameter were successively homogenized at 400°C for 24 hrs, cooled in air, reheated to 360°C, and extruded into 6 x 80 mm strips at a flow rate of approximately 0.02 m/sec. The strip was rolled to thicknesses of 4, 3, 2, and 1 mm with a total reduction of 33, 50, 67, and 83% respectively. The volume fraction of recrystallized structure after 1 hr of annealing was measured by the Glagor'yev point method on longitudinal microsections and then plotted as a function of the annealing temperature. From these curves the thermal stability of the polygonal structure was estimated, taking into account the nonuniformity of the recrystallization process over the ingot volume. With the magnesium content increasing, the recrystallization temperature was found to first decrease to a minimum at 0.4-0.6% Mg and then increase again while consistently remaining higher for thicker specimens. (In the case of hot-rolled strip the recrystallization temperature does not change significantly with the magnesium content over this range). The results of metallographic analysis indicate that polygonization, the principal mechanism of structural recovery, and grain growth are very intensive when the magnesium content is lowest. Prerecrystallization heating produces large subgrains and lowers the level of stored strain energy necessary for recrystallization. As the magnesium content increases to 0.5%, the polygonization process becomes more inhibited. With further increase of the magnesium content, the level of strain energy again increases and the size of subgrains decreases so that the recrystallization temperature becomes higher again and the structure becomes more thermally stable. The practical implications are that alloys with 0.8-1.2% Mg will have the best mechanical properties and highest heat and corrosion resistance. Figures 3; references 4: all Russian.  
[83-2415]

## ELECTRON MICROSCOPE STUDIES OF STRUCTURE OF SURFACE LAYERS OF TITANIUM CARBIDE AFTER RUBBING AT 20 TO 1400°C

Kiev POROSHKOVAYA METALLURGIYA in Russian No 1, Jan 83  
(manuscript received 22 Jan 82) pp 63-67

PILYANKEVICH, A. N., BRITUN, V. F., TKACHENKO, Yu. G. and YULYUGIN, V. K.,  
Institute of Problems of Material Science, Ukrainian SSR Academy of Sciences

[Abstract] A description is given of electron microscope studies of structural changes in the area of contact when specimens of TiC are rubbed under vacuum in the temperature range of 20 to 1400°C. This is the first time experiments of this sort have been done with high-melting compounds. Specimens of TiC close to stoichiometric in composition were produced by compacting a powder of commercially pure TiC in metal molds and by sintering under vacuum. A high-temperature vacuum apparatus was used to test for friction and wear. The face surface of identical specimens was rubbed at an average rate of 0.01 m/s under a 1-MPa load and experiments were performed under  $5 \cdot 10^{-3}$  Pa vacuum at 20, 400, 800, 1200 and 1400°C. It was found that the friction coefficient and rate of wear for a TiC-TiC rubbing pair when heated under vacuum from 20 to 1200°C are reduced and these characteristics exhibit a tendency to increase with a further rise in temperature. The microhardness of the rubbing surfaces after testing, measured at points of contact, is reduced from 28,000 MPa at 400°C to 20,000 MPa at 1400°C. A 50-micron-thick wafer section measuring 3 x 3 mm was subjected to study under a scanning electron microscope. Sections 100 nm thin directly containing surface layers of the area of contact were produced by ion sputtering on the side opposite the rubbing surface. For the purpose of studying layers lying at various depths, sputtering was performed on the rubbing surface side for a fixed time interval and then the opposite side was subjected to ion bombardment. By two-sided sputtering of sections made perpendicularly or obliquely to the rubbing surface foils were produced in which it was possible to observe simultaneously the structure of layers lying at various distances from the rubbing surface. The structure of surface layers formed by rubbing at temperatures above 800°C is essentially different from that observed in low-temperature friction. After high-temperature friction practically the entire original material is covered with a layer of finely dispersed TiC. The thickness of the finely dispersed layer was nonuniform and equaled about 0.1 to 1 micron and the finely dispersed material filled all recesses, pores and microcracks reaching the surface. At temperatures of 20 to 400°C, as revealed by the external appearance of the rubbing surface and features of the microstructure observed by electron microscopy, brittle failure of grains in the

rubbing surface layers with the appearance of elements of microductility is the primary mechanism. The finely dispersed layer formed prevents further failure of the original grains and is conducive to improved wear resistance. At high temperatures hardening of grains of the original material takes place in surface layers, but softening processes are also evidenced, in particular, by formation of a cellular structure representing nonuniform distribution of dislocations without distinct subboundaries. Figures 6; references 6: 5 Russian, 1 Western.  
[93-8831]

UDC: 621.762

#### STUDY OF HIGH PRESSURE TITANIUM CARBIDE HOT PRESSING KINETICS

Kiev POROSHKOVAYA METALLURGIYA in Russian No 3, Mar 83  
(manuscript received 15 Oct 81) pp 30-32

STASYUK, L. F. and KAYDASH, O. N., Institute of Superhard Materials,  
Ukrainian Academy of Sciences

[Abstract] A study was made of the kinetics of compacting titanium carbide at 1-7 GPa, 1000-1800°C with a "toroid" high pressure chamber. Pressure was determined by phase transitions of reference materials; temperature was established with a tungsten-rhenium thermocouple. Studies were performed with titanium carbide powder produced by the Donetsk Chemical Reagent Plant. It is concluded that at high pressure plastic flow mechanisms apparently dominate, with diffusion mechanisms decreasing in significance due to the reduced diffusion rate. Low activation energy of the first stage of sintering indicates that compacting occurs by fragmentation of particles and their slippage at the contact point level. In the second stage of sintering the predominant mechanism of mass transfer is deformation by slipping on grain boundaries. Figures 1; references 9: 6 Russian, 3 Western.  
[116-6508]

UDC: 621.762

#### FORMATION OF WEAR RESISTANT COATING ON DEEP DIFFUSION ZONE BY PRECIPITATION FROM GAS PHASE

Kiev POROSHKOVAYA METALLURGIYA in Russian No 3, Mar 83  
(manuscript received 17 May 82) pp 37-40

MUKHA, I. M., PROSKURNIN, A. F. and DEREVYANKO, T. P., Kiev Production Union  
imeni S. P. Korolev

[Abstract] A study was made of the possibility of saturating porous hard alloy blanks with refractory metal carbides and of some of the physical and mechanical properties of the products. Work was performed on an installation for application of gas phase coatings. A study was made of processes of

saturation of porous hard alloys after preliminary sintering with titanium carbides in the 1000-1100°C temperature interval for 1 to 6 hours by precipitation from the gas phase at reduced pressure in a closed space. Optimization factors and intervals were selected and variation levels determined. The use of various conditions and variation of the process parameters showed that a very thick wear resistant diffusion zone (up to 1200 μm thick) can be obtained by precipitation from the gas phase in a closed space at reduced pressure. The depth of the diffusion zone increases with increasing pore channel size. Increasing holding time, process temperature and pore channel size cause increased weight gain. Figures 3; references 3: all Russian.  
[116-6508]

UDC: 539.89

#### COMPOSITE MATERIALS BASED ON HARD ALLOY WITH CUBIC BORON NITRIDE OBTAINED BY VARIOUS METHODS

Kiev POROSHKOVAYA METALLURGIYA in Russian No 3, Mar 83  
(manuscript received 15 Oct 81) pp 43-45

ANDREYEV, V. D., BONDARENKO, V. P., BARANOVSKIY, A. M., PEREYASLOV, V. P., KOLOMIYETS, V. P., MANZHELEYEV, I. V. and CHUKHNO, N. I., Institute of Superhard Materials, Ukrainian Academy of Sciences

[Abstract] Since tungsten is in short supply, the problem has arisen of replacing tungsten carbide with other compounds such as cubic boron nitride, increasing the hardness of composite materials and their wear resistance in various corrosive media. Results obtained in the present study indicated that when composite materials were sintered in hydrogen or a vacuum at the liquid phase temperature of 1320°C, time 30 minutes, cubic boron nitride and the hard alloy interact with the formation of CO<sub>2</sub> and W<sub>2</sub>B, while pores arise at the interfaces between cubic boron nitride and the hard alloy due to accumulation of gaseous nitrogen which is liberated as CBN interacts with the hard alloy. The most promising method for producing materials with good abrasive capacity is impulse sintering. It was found that at a pressure of 1-5 GPA, specific energy 25 J/mm<sup>3</sup>, compact specimens with a porosity of not over 0.5% are produced. Figures 1; references: 1 Russian.  
[116-6508]

UDC: 621.762:621.763

#### COMPARATIVE STUDY OF PERMEABLE METAL POWDER AND FIBER MATERIALS

Kiev POROSHKOVAYA METALLURGIYA in Russian No 3, Mar 83  
(manuscript received 24 Mar 82) pp 49-51

KOSTORNOV, A. G., LUNIN, L. Ye., SEMENETS, V. P. and CHERNYSHEV, L. I., Institute of Material Science Problems, Ukrainian Academy of Sciences

[Abstract] A comparison is presented of the strength, permeability and pore size of powder and fiber materials. Permeable materials of carbonyl nickel

were used which were obtained by the addition of pore formers with particle sizes of less than 0.04 to 0.6 mm. Sintering conditions were selected so as to produce identical sintering quality, evaluated by the ratio of specific conductivity to that of the compact material. With equal tensile strength the gas permeability of fiber materials was 6 to 7 times higher than that of materials sintered from nickel powder. With equal permeability, the fiber materials were significantly stronger. Figures 2; references 3: all Russian. [116-6508]

UDC: 621.762:669.29:532.64:621.357.76

#### CONTACT INTERACTION OF TITANIUM WITH LOW-MELTING-POINT METALS

Kiev POROSHKOVAYA METALLURGIYA in Russian No 3, Mar 83  
(manuscript received 4 Mar 82) pp 54-57

KARPINOS, D. M., TUCHINSKIY, L. I., SAPOZHNIKOVA, A. B., PANASYUK, A. D.,  
and YENEVICH, V. G., Institute of Material Science Problems, Ukrainian Academy  
of Sciences

[Abstract] The standing drop method is used to study the contact interaction of titanium with liquid low melting point metals (lead, tin, bismuth and cadmium) to establish the possibility of saturation of sintered titanium frameworks with these metals. The contact wetting angle was determined in dried argon at 93 Pa. The substrates were technically pure type VT1-0 titanium; the low melting point metals were pure. Both wetting of the titanium and interaction between the titanium and the low melting point metals were studied. Wetting of the titanium with the metals required that they be heated to temperatures approximately twice the melting point of the low melting point metals in order to break down the oxide film which formed on the surface of the metals. To estimate the nature of the interphase interaction for the system, the energies of physical (Van-der-Waals) interaction was calculated by an equation presented in the text. For systems with the physical type of interaction the work of adhesion is similar in order of magnitude to the energy of Van-der-Waals interaction. The work of adhesion for titanium-lead is more than double the energy of dispersion interaction, indicating that this system has a chemical interaction which increases in intensity with increasing temperature. References 4: all Russian. [116-6508]

## COMPOSITE MAGNETIC-ABRASIVE POWDERS BASED ON IRON, CHROMIUM, VANADIUM AND TITANIUM CARBIDES

Kiev POROSHKOVAYA METALLURGIYA in Russian No 3, Mar 83  
(manuscript received 18 Nov 81) pp 94-100

POLISHCHUK, V. S., NALIVKA, G. D. and KISEL', N. G., Donetsk Chemical Reagents Plant, Institute of Superhard Materials, Ukrainian Academy of Sciences, All-Union Scientific Research Institute Reaktivelektron

[Abstract] Electrolytic powders of titanium, vanadium and chromium with particle size less than 50  $\mu\text{m}$  and iron powder with particle size 500-1000  $\mu\text{m}$  of reagent purity were studied for magnetic-abrasive polishing. Chemical phase analysis of the specimens was performed, based on the use of the differing solubility of carbides and the iron matrix in mineral acids. The carbides thus liberated were analyzed for content of the carbide forming metal as well as bound and free carbon. In practically all specimens the total content of carbon was higher than the computed content, since the process was performed in graphite tube electric vacuum furnaces in carbon-containing crucibles. The results confirm the presence of areas with preferential concentration of carbide-forming metal or iron. Carbon is apparently concentrated primarily in the area of the carbide-forming metal, i.e., in the carbide grain, there being relatively little in the iron matrix. The mutual penetration between carbide and iron is not over 3 to 7% of the carbide grain diameter. Optimal compositions and synthesis conditions are determined. Figures 3; references 15: 14 Russian, 1 Western.  
[116-6508]

UDC: 621.762:621.771

## GRANULATED ALLOY PRESSED STRIP DEFORMATION RESISTANCE

Kiev POROSHKOVAYA METALLURGIYA in Russian No 2, Feb 83  
(manuscript received 22 Feb 82) pp 18-22

GORBUNOV, Yu. A., RUSOV, I. G., KRAYNOV, V. I., KIR'YANOV, V. A., Krasnoyarsk Institute of Nonferrous Metals

[Abstract] A study was made of the deformation resistance of granulated aluminum alloys by upsetting cylindrical specimens in a hydraulic press. The specimens were cut from strips produced by pressing granules in various industrial presses. During upsetting adiabatic heating of the specimen occurs due to the work of plastic deformation. Circular specimens were upset to determine the coefficient of contact friction. The results of the experiment indicated that the high cooling rate of melt drops during centrifugation to produce the granules results in the formation of a structure consisting of super-saturated solid solutions. This structure has rather high dislocation density so that the rate of hardening of granulated alloys upon deformation is

not great. During rolling with slight compression deformation resistance remains practically constant, though deformation rate decreases in the deformation focus. Deformation resistance remains practically unchanged when rolling is performed in several stages with pauses between stages. Figures 3; references 4: all Russian.  
[99-6508]

UDC: 621.762.4:621.771:669.71:620.193

#### PRODUCTION OF SHEET CLAD ROLLED MATERIAL OF SECONDARY ALUMINUM GRANULES

Kiev POROSHKOVAYA METALLURGIYA in Russian No 2, Feb 83  
(manuscript received 25 Feb 82) pp 28-31

VOROPAYEV, V. S., VINOGRADOV, G. A., KATASHINSKIY, V. P. and KALUTSKIY, G. Ya.,  
Institute of Material Science Problems, Ukrainian Academy of Sciences

[Abstract] A study was made of the possibility of producing sheet rolled material from secondary aluminum alloys clad with A6 aluminum by two methods. In the first, the clad strip was produced directly in the process of shaping rolling, in the second a strip of secondary alloys was clad after shaping rolling. In the first case the clad strip was produced by simultaneous rolling of granules and cladding foil. Metallographic studies showed that the clad layer thus produced had discontinuities and nonuniform thickness, varying from 0.1 to 0 mm. In the second method, preparation of the preliminarily prepared product surface and the heating temperature before cladding rolling were important. The formed strip and aluminum foil were degreased and wire brushed. Cladding rolling was performed with a compression of over 50% per pass. Preheating improved layer adhesion at less than 50% per pass. Metallographic studies revealed continuous and uniform cladding layers. Figures 6; references 4: all Russian.  
[99-6508]

UDC: 621.762.4.001

#### COLD PRESSING OF WURZITE BORON NITRIDE POWDERS AT HIGH PRESSURES

Kiev POROSHKOVAYA METALLURGIYA in Russian No 2, Feb 83  
(manuscript received 10 May 82) pp 32-34

DZHAMAROV, S. S. and SHCHERBAN', N. I., Institute of Material Science Problems  
Ukrainian Academy of Sciences

[Abstract] A study is presented of the variation between applied pressing pressure and powder medium density for wurzite boron nitride powders containing up to 11% graphite-like boron nitride subjected to shock wave treatment. Cold pressing was performed in a toroidal high pressure chamber at 1.0 to 10.0 GPa. The results produced indicate that there is a stage of particle slipping relative to each other, followed by a stage of brittle fracture of particles

and denser compacting and a stage of packing of pores between particles with products of particle fracture in the process of cold pressing of wurzite BN powders. Logarithmic or exponential equations were found to apply to the compacting of these powders, and apparently to other superhard materials under high pressure conditions as well. Figures 2; references 7: all Russian.  
[99-6508]

SINGLE CRYSTALS

UDC: 621.785.532

STRENGTHENING OF SINGLE CRYSTAL Mo-Nb-Zr-C ALLOY BY INTERNAL NITRIDING

Kiev PROBLEMY PROCHNOSTI in Russian No 3, Mar 83  
(manuscript received 7 Jan 81) pp 88-90

BELOMYTTSEV, M. Yu. and BELYAKOV, B. G., Moscow Institute of Steel and Alloys

[Abstract] A study is presented of high temperature strengthening of molybdenum alloy single crystals by internal nitriding. Experiments used single crystals of an alloy of molybdenum with 1.7 mass% Nb, 0.15 Zr and 0.02C. The crystals were produced by electron beam zone melting and were 15 to 20 mm in diameter, up to 250 mm in length, growth direction  $\langle 111 \rangle$  with maximum deviation from this direction not over  $5^\circ$ , subgrain disorientation level not over 2 to  $3^\circ$ . Flat specimens cut along the  $\langle 111 \rangle$  axis with orientation of the broad face parallel to the  $\{110\}$  plane were used for mechanical testing. The structure of the single crystals was studied by transmission electron microscopy of thin foils obtained by electropolishing in  $H_2SO_4 + HF$ . The ultimate strength and yield point are increased by internal nitriding. A possible mechanism is described. Relative elongation is decreased by the presence of the second phase. Figures 3; references 4: all Russian.

[118-6508]

THIN FILMS

UDC: 546.815'814'232:539.216.2

PHASE COMPOSITION OF THIN  $Pb_{1-x}Sn_xSe$  FILMS

Moscow IZVESTIYA AKADEMII NAUK SSSR: NEORGANICHESKIYE MATERIALY in Russian  
Vol 19, No 3, Mar 83  
(manuscript received 1 Oct 81) pp 359-361

NURIYEV, I. R., SALAYEV, E. Yu. and SHARIFOVA, A. K.

[Abstract] An electronographic study of the phase composition and structure of thin films of  $Pb_{1-x}Sn_xSe$  specimens is performed. These films are widely used in the manufacture of semiconductor devices, and their parameters are quite sensitive to tin content. Films are evaporated at  $10^{-4}$  Pa onto celluloid and freshly fractured NaCl substrates. Unit cell parameters were determined for  $x=0.1$  to  $0.9$ . It was found that the area of solid solutions based on face-centered cubic PbSe extends up to  $x=0.5$ , the PbSe unit cell parameter  $a$  decreasing from 6.12 to 6.07 Å. Figures 3; references 4: 3 Russian, 1 Western. [102-6508]

## TITANIUM

UDC: 669.281:543.42

### DISTRIBUTION OF IMPURITY ELEMENTS IN TITANIUM ALLOYS

Moscow DOKLADY AKADEMII NAUK SSSR in Russian Vol 268, No 5, Feb 83  
(manuscript received 24 Aug 82) pp 1122-1124

TREFILOV, V. I., academician, Ukrainian Academy of Sciences, IVASHCHENKO, Yu. N. and MINAKOV, V. N., Institute of Material Science Problems, Ukrainian Academy of Sciences, Kiev

[Abstract] Results are presented from a study of the fracture surfaces of VT-22 alloy specimens in the cast state and after annealing at 750°C for two hours using Auger electron spectroscopy. The Auger electron spectra were recorded in the 70-2000 eV energy range. The initial state of the alloy in the cast state and after annealing is characterized by presence of large quantities of carbon and oxygen on the surface. Removal of a 50 angstrom layer from the fracture surface significantly reduces the content of these elements. The fracture surface following fracture along the initial  $\beta$  grain boundary carries carbon, oxygen plus sulfur, chlorine, sodium, vanadium and aluminum. Annealing at 750°C for two hours significantly decreases the oxygen and carbon content on the initial  $\beta$  grain boundaries, and sodium and chlorine peaks are practically not observed at all. The presence of sodium on the grain boundary significantly reduces the effective surface energy of crack development. Figures 1; references 6: 4 Russian, 2 Western.  
[104-6508]

UDC: 669.017

### INFLUENCE OF VACUUM ANNEALING CONDITIONS AND HYDROGEN ON FRACTURE TOUGHNESS AND FATIGUE OF VT6 ALLOY SLABS

Ordzhonikidze IZVESTIYA VYSSHIKH UCHEBNYKH ZAVEDENIY: TSVETNAYA METALLURGIYA in Russian No 6, Nov-Dec 82 (manuscript received 5 Jan 82) pp 76-81

KOLACHEV, B. A., GRINBERG, V. A., FISHGOYT, A. V. and SADKOV, V. V.

[Abstract] A study is made of the influence of various annealing conditions on the fracture toughness and endurance of three slabs 50, 125 and 200 mm thick of VT6 alloy, as well as the influence of hydrogen content on fracture characteristics under various loading conditions. The mechanical properties of the cylindrical specimens were determined by standard methods. The 50-mm-thick slabs were found to have the highest tensile strength, yield point and

ductility but the lowest low-cycle endurance and fracture toughness characteristics. Vacuum annealing at temperatures near the  $Ac_3$  point significantly improved fracture toughness. Fatigue properties varied as a function of material structure. Cracks developed at stress concentrators. High temperature vacuum annealing produces a variable increase in fracture toughness, depending on the initial structure of the material. The possibility is shown of repeatedly determining fracture toughness in a single specimen with intermediate vacuum annealing after each determination. Introduction of 0.02% hydrogen by mass results in some decrease in fracture toughness. Figures 3; references 6: 5 Russian, 1 Western.  
[120-6508]

UDC: 669.295:548.735.6:539.32

INFLUENCE OF V AND Zr ON ROLLED PRODUCT TEXTURE, RECRYSTALLIZATION AND YOUNG'S MODULUS ANISOTROPY IN Ti-V AND Ti-Zr ALLOYS

Sverdlovsk FIZIKA METALLOV I METALLOVEDENIYE in Russian Vol 55, No 3, Mar 83 (manuscript received 10 Nov 81) pp 533-537

ZAKHARCHENKO, I. G., NEMOSHKALENKO, V. V. and KSHNYAKIN, V. S., Odessa Pedagogics Institute imeni K. D. Ushinskiy

[Abstract] This work studies the texture of cold rolled alloys of titanium with 0, 0.5, 1, 1.5 and 2 weight % V and 5, 15, 25, 35, 45 and 55 weight % Zr, as well as the change in preferential orientation in the process of annealing of these alloys. The anisotropy of elastic properties is analyzed in various stages of processing of the alloys. The cold rolled texture of the alloys with up to 25% Zr after at least 60% compression is a single component type  $(0001) + \alpha$  NN-PN  $[10\bar{1}0]$ . Angle  $\alpha$  increases with increasing content of the alloying element. Subrecrystallization annealing of Ti-V alloys is accompanied by active polygonization processes leading to an increase in texture and E anisotropy, which is not the case for Ti-Zr alloys. The recrystallization texture of the alloys includes slight changes in angle  $\alpha$  and, in specimens with over 40%  $\epsilon$ , a change in crystallographic direction to  $[11\bar{2}0]$ . Phase conversions accompanying high temperature annealing of Ti-Zr alloys lead to radical changes in the initial texture and a significant decrease in anisotropy of elastic properties, which is doubtless of practical interest. Figures 3; references 6: 4 Russian, 2 Western.  
[119-6508]

STUDY OF ANODE BEHAVIOR OF TITANIUM ALLOYS DURING ELECTROCHEMICAL SOLVENT PROCESSING. I. NITRATE, CHLORATE AND PERCHLORATE SOLVENTS

Kishinev ELEKTRONNAYA OBRABOTKA MATERIALOV in Russian No 1, Jan 83  
(manuscript received 28 Jan 82) pp 11-14

PETROV, Yu. N., NISTRAN, A. Z. and SAUSHKIN, B. P., Kishinev

[Abstract] Attempts to improve processability of titanium alloys in electrochemical processing has led to development of two- and multi-component electrolytes such as  $\text{NO}_3^-$  and  $\text{ClO}_4^-$ . Data obtained during galvanodynamic polarization show that  $i_{\text{diss}}$  dissolution potential of titanium alloys decreases with increased amounts of alloy components with "transpassification" tendencies. Increased solubility with repeated polarization is related to impoverishing the sample surface of alloying elements, and the shift of polarization curves into the positive range of potentials due to increased ohm resistance of the coating of anode solution processes, such as hydrolysis. The possibility of chemical reaction of the oxidizer and the metal surface must also be considered. As alloys were dissolved in the electrolyte, gas formation on the anode surface could be observed visually. This apparently was related to pitting. The anode dissolved more rapidly in perchlorate than in the other two solvents tested, apparently due to the higher adsorption capacity of perchlorate ions. Results indicated that perchloric acid salts were the most promising electrolyte components. Figures 5; references 15: 8 Russian, 7 Western.  
[12131-109]

UDC 669.295:539.4.01/.019

PLASTICIZATION OF HEAT-RESISTANT TITANIUM ALLOYS BY HYDROGEN TREATMENT

Moscow IZVESTIYA AKADEMII NAUK SSSR: METALLY in Russian No 1, Jan 83  
(manuscript received 9 Sep 81) pp 134-137

NOSOV, V. K., KOLACHEV, B. A. and PAVLOV, Ye. I., Moscow

[Abstract] Plasticization of VT18U and VT3-1 titanium alloys by hydrogen treatment was studied in high-temperature tests under conditions of isothermal stamping with initial strain rates ranging from  $4.4 \cdot 10^{-4}$  to  $1.3 \cdot 10^{-1} \text{ s}^{-1}$ . Plasticization of the pseudo- $\alpha$  alloy (VT18U) lowered its yield strength by an amount increasing with the hydrogen concentration, as indicated by tension tests at  $800^\circ\text{C}$  with an initial strain rate of  $1.4 \cdot 10^{-3} \text{ s}^{-1}$ , the effect becoming weaker at temperatures both above and below  $800^\circ\text{C}$ . Plasticization of the ( $\alpha + \beta$ ) alloy (VT3-1) occurred within the  $600\text{--}950^\circ\text{C}$  temperature range, as indicated by a decrease of its yield strength by an amount increasing with the hydrogen concentration. Microstructural analysis of quenched test specimens has established that implantation of 0.3%  $\text{H}_2$  lowers the ( $\alpha + \beta$ )  $\rightleftharpoons$   $\beta$  phase transition temperature, from  $990$  to  $880^\circ\text{C}$  for the VT18U alloy and from  $960$  to  $870^\circ\text{C}$  for the VT3-1 alloy. The results suggest that hydrogenation of these

alloys will make it feasible to lower the temperature of their hot stamping process correspondingly and thus improve the stability of punches made of ZhS6K alloy steel. Figures 4; references 6: all Russian.  
[85-2415]

UDC: (546.26'25:546:27'25):546.3-19

#### HIGH TEMPERATURE FRICTION OF $TiN_x-TiB_2$ SYSTEM ALLOYS

Kiev POROSHKOVAYA METALLURGIYA in Russian No 2, Feb 83  
(manuscript received 28 Dec 81) pp 70-76

TKACHENKO, Yu. G., ORDAN'YAN, S. S., YURCHENKO, D. Z., YULYUGIN, V. K. and CHUPOV, D. V., Institute of Material Science Problems, Ukrainian Academy of Sciences

[Abstract] A study is made of conditions of production, mechanical properties and regularities of friction in a vacuum at 20-1200°C for  $TiN_x-TiB_2$  alloys, the antifriction properties of which have not been discussed previously in the literature. Following grinding of  $TiN_x-TiB_2$  and subsequent high-temperature sintering in argon the powders were dried in a vacuum oven, plasticized with 5% paraffin in gasoline and pressed to study friction and strength properties. The pressed specimens were sintered in argon for 1-1.5 hr at 1700 to 2000°C. It was found that the maximum bending strength and wear resistance were observed in the eutectic alloy. In  $TiN_{0.9}-TiB_2$  the boride phase has great plasticity in friction. Maximum deformation during friction occurs in  $TiN_{0.73}-TiB_2$ . Processes of hardening and softening at 20 to 400°C are determined by softening processes occurring in the boride phase, above 400°C by hardening and softening processes occurring in the nitride phase. Figures 4; references 4: all Russian.  
[99-6508]

UDC: 539.434

#### INFLUENCE OF CYCLE ASYMMETRY ON TITANIUM ALLOY FATIGUE IN HIGH FREQUENCY LOADING

Kiev PROBLEMY PROCHNOSTI in Russian No 2, Feb 83  
(manuscript received 9 Nov 81) pp 19-20

VOZNYI, T. S., GURVICH, Yu. V. KIRILLOV, V. I., TROYAN, I. A., Kiev, Leningrad, Institute of Strength Problems, Ukrainian Academy of Sciences

[Abstract] A study is made of the fatigue of two titanium alloys, the  $\alpha$  alloy OT4 and the  $\alpha+\beta$  martensitic alloy VT6, in symmetrical and asymmetrical extension-compression at 10 KHz. The two alloys were tested as delivered using smooth 6-mm-diameter specimens on a magnetostriction resonant installation.

Cycle asymmetry was achieved by adding a constant tensile stress to the variable stress. Curves of 50% probability of fracture were used to construct maximum amplitude diagrams for various load lengths. The ratio of ultimate strength to fatigue endurance limit for  $10^7$  and  $10^8$  cycles is determined. Figures 3; references 2: both Russian.  
[101-6508]

WELDING

UDC: 621.791.011:669.788

COMPARATIVE ESTIMATE OF PORE FORMATION TENDENCY UPON FUSION WELDING OF VARIOUS ACTIVE METALS

Kiev AVTOMATICHESKAYA SVARKA in Russian No 2, Feb 83  
(manuscript received 21 May 82) pp 30-33

REDCHITS, V. V., candidate of technical sciences, NIKIFOROV, G. D., doctor of technical sciences, Moscow Institute of Aviation Technology imeni K. E. Tsiolkovskiy

[Abstract] Pore formation should be looked upon as a heterophase physical-chemical process, the possibility of which must be estimated considering the summary effect from all stages occurring under specific conditions. Criteria for comparative estimation of the probability of pore formation in active metals can be expressed through thermophysical constants included in the equations for quantitative estimation of the characteristic parameter of the process under specific welding conditions. Assuming identical adsorption capacity of the welded edge surface, the less the absorption capacity of the hydride forming metal the higher the probability of bubble formation. Equations are presented which could be used to estimate the probability of pore formation in active metals. References 6: all Russian.  
[100-6508]

UDC 621.791.72:536.21.523.72

USING CONCENTRATED SOLAR RADIATION TO WELD METALS

Moscow SVAROCHNOYE PROIZVODSTVO in Russian No 3, Mar 83 pp 2-4

RYKALIN, N. N., Academician, UGLOV, A. A., doctor of technical sciences, and SMOL'SKIY, G. V., engineer

[Abstract] Use of solar rays offers great energy efficiency since only control and tracking systems require man-made energy. The authors present results of welding with solar radiation in a vacuum and calculations of temperature ranges near the heat spots generated by concentrated solar radiation. Metals welded were 12Ch18N10T steel 1 mm thick and OT4 alloy 1.0 and 1.5 mm thick. The apparatus used is diagrammed and described. Results showed that this

method assured sufficiently high mechanical properties of the seams and can be used for devices used under static loads. The calculated and experimental data were judged to correlate well, and a reliable formula was developed for calculating the temperature generated in welding immobile plates of 12Ch18N10T steel on a massive brass table at any distance including the center of the focussed heat. It can also be used for analogous metals. Figures 2; references 7: all Russian.  
[12131-108]

UDC 621.791.4.03:621.771:548.5

PATTERNS OF COMPOUND FORMATION DURING DETONATION WELDING OF LAMINATED COMPOSITE MATERIALS

Moscow SVAROCHNOYE PROIZVODSTVO in Russian No 3, Mar 83 pp 4-6

LYSAK, V. I., candidate of technical sciences, SEDYKH, V. S., doctor of technical sciences, and TRYKOV, Yu. P., candidate of technical sciences, Volgograd Polytechnical Institute

[Abstract] To produce laminated composite materials (LCM), a common method is the so-called "simultaneous" detonation welding with an initial parallel position of welding stock with some clearances. The authors studied patterns of such compounds in multi-layered LCM packets, with consideration of the nature of the distribution of plastic deformation energy between boundaries of the composite. All tests involved 12Ch18N10T steel of varying thicknesses. Four variations of clearances between welding stock were employed. Resulting data indicated that regardless of welding stock thickness and position, it was impossible to obtain a weld equal in strength to the initial metal. The worst results were obtained when the thin welding stock was in actual contact with the basic metal, while the best results came where there were regular clearances between layers of the composite prior to welding. The best option was to have layers of similar thickness, despite the difficulties this presents for welding LCM of numerous layers in terms of energy emissions. Figures 2; references 8: all Russian.  
[12131-108]

INFLUENCE OF COOLING RATE IN WELDING ON MECHANICAL PROPERTIES AND STRUCTURE OF VT23 TITANIUM ALLOY NEAR WELDED SEAM

Moscow SVAROCHNOYE PROIZVODSTVO in Russian No 4, Apr 83, pp 26-27

MESHCHERYAKOV, V. N., candidate of technical sciences, KIRILLOV, Yu. G., engineer, LYASOTSKIY, I. V., candidate of technical sciences and LYASOTSKAYA, V. S., candidate of technical sciences

[Abstract] The influence of cooling rate on mechanical properties and structure of VT23 titanium alloy in the near-seam zone was studied following heating to 1250-1350°C for cooling rates of between 0.66 and 600°C/s. Cooling the alloy at high rates results in a great decrease in strength and hardness and a significant increase in ductility. The most favorable combination of strength and ductility is obtained at low and high rates of cooling, with great decreases in ductility and increases in strength at moderate rates (about 3 to 85°C/s). Microstructure was studied by metallographic and electron-microscope analysis. The studies showed that the low ductility properties of the alloy achieved at moderate cooling rates are related to a decrease in the quantity of  $\beta$  phase and the large content of  $\alpha$  phase with unfavorable "rack" morphology. The  $\beta$  to  $\alpha$  phase conversion occurs at slow cooling rates by a diffusion mechanism.

[122-6508]

UDC: 621.791.052:539.4:621.643:624.142

LOW TEMPERATURE STRENGTH OF MEDIUM DIAMETER WELDED PIPE FOR GAS DISTRIBUTION NETWORKS

Kiev AVTOMATICHESKAYA SVARKA in Russian No 2, Feb 83  
(manuscript received 10 Nov 81; in final form 29 Oct 82) pp 55-57

MINDLIN, V. G., KAPLAN, A. B., GORBOVITSKIY, A. I., engineers, Urals Scientific and Technical Institute, VOLKOV, V. S., engineer, State Scientific Research and Production Institute of the Gas Industry.

[Abstract] This work studies the low temperature working capacity of heat-treated and nonheat-treated pipe 133 to 325 mm in diameter welded by high-frequency induction, and also the possibility of decreasing wall thickness in such pipes. Experiments were performed on pipe of type 10 steel without heat treatment and steel type 10 and type 10VSt3sp. A laboratory test method was used, consisting of testing of segments with notches intended to create a ratio of primary stresses characteristic for pipe under pressure. Specimens were tested on a universal vertical testing machine in a reversor preventing straightening of curved specimens. Base metal and welded joints were studied at temperatures from +20 to -60°C, strengths estimated based on maximum fracture stress. Fracture stresses were found to increase by up to 10-15% as the temperature dropped to -60°C. Regression equations were then derived for

calculation of the failure stresses. It was found that distribution gas networks operating with pressures up to 1.6 MPa and at temperatures down to  $-60^{\circ}\text{C}$  can utilize welded medium diameter pipe instead of seamless pipe, while still assuring a significant strength reserve. The replacement of seamless pipe with welded pipe and a decrease in wall thickness will allow a significant savings of money and metal. Figures 4; references 4: all Russian.

[100-6508]

UDC: 621.791.052.08:620.179.16-52.002.5

#### AUTOMATED ULTRASONIC PIPE WELDED JOINT TEST INSTALLATION

Kiev AVTOMATICHESKAYA SVARKA in Russian No 2, Feb 83  
(manuscript received 19 Apr 82; in final form 13 Oct 82) pp 68-71

TROITSKIY, V. A., doctor of technical sciences, BONDARENKO, Yu. K. and VALDAKOV, V. F., engineers, Institute of Electric Welding imeni Ye. O. Paton, Ukrainian Academy of Sciences, and NEGLYAD, Ye. V., engineer, Khartsyz Pipe Plant.

[Abstract] A method is suggested for testing of welded joints in pipes by transmitting ultrasonic waves through the joint, allowing the entire cross section of the welded joint to be tested in a single pass of the ultrasonic test unit. The automatic NK-100 unit includes two defectoscopes, an acoustical system with ultrasonic probe, a recording system, a mechanism to move and adjust the position of the ultrasonic transducers and a guide. The acoustical system carries a device for visual monitoring of the position of the probe relative to the seam. The test method suggested can locate short and long body and planar defects with a sensitivity sufficient to find a vertical cylindrical reflecting body 1.2 mm in diameter and 1.6 mm in length. The amplitude of signals reflected by artificial cylindrical apertures is not influenced by distance from the beam aperture to the seam within limits of  $\pm 5$  mm relative to the nominal distance. Figures 4; references 6: all Russian.

[100-6508]

UDC: 621.791.4:539.378.3:[669.715+669.295]

#### DIFFUSION WELDING OF AK4-1 ALLOY WITH VT1-0 TITANIUM ALLOY

Kiev AVTOMATICHESKAYA SVARKA in Russian No 2, Feb 83 pp 74-75

SERGEYEV, A. V., candidate of technical sciences, KAZAKOV, N. F., doctor of technical sciences and SYSOYEV, A. P., engineer

[Abstract] A version of cladding AK4-1 pistons with VT1-0 titanium alloy by diffusion welding is suggested. This method of welding aluminum alloys to titanium can be performed only after preliminary calorizing of the titanium with a titanium-aluminum bimetal. The bimetal used in this work was produced

by diffusion welding. Diffusion welding of AK4-1 aluminum alloy to the titanium-aluminum bimetal at  $T=783^{\circ}\text{K}$ ,  $\tau=25$  min does not result in the formation of intermetallic phases at the titanium-aluminum interface. Test stand operation for 500 hours showed that the surface of the clad titanium plate remained practically unchanged, and there were no defects at the joint.

Figures 2; references 2: both Russian.

[100-6508]

MISCELLANEOUS

HIGH QUALITY AT KHARTSYZSK PIPE PLANT

Moscow EKONOMICHESKAYA GAZETA in Russian No 13, Mar 83 p 8

[Unsigned article]

[Text] Khartsyzsk Pipe Plant is the nation's leading enterprise in the production of pipe for underground pipelines. The products of this plant were used to construct the "friendship" gas pipeline and many others. About half of all large diameter pipe used in the construction of the Urengoy-Pomary-Uzhgorod line is produced at Khartsyzsk. The metallurgists there are particularly conscious of quality--the pipe must operate under high pressure.

The director of the enterprise, Boris Basil'evich Kondrat'yev, shares his thoughts on this theme with us. After graduating from the Moscow Institute of Steel and Alloys in 1949 he rose from assistant foreman to director of the plant. He is now in his 20th year at this post. He has been awarded the Order of Lenin, the Order of Labor Red Banner and the "Badge of Honor."

The stand at the entrance to the plant discusses the Khartsyzsk metallurgists' competition. As of early March the results were as follows: 3100 tons of 1.42-meter-diameter welded steel pipe above the assignment had been produced in the first two months of this year, including pipe for the Urengoy-Pomary-Uzhgorod main pipeline. Add this quantity to the 12,000 tons of pipe produced above the plan last year.

In attempting to fill the orders sent us by the builders of these great arteries, our workers give particular significance to the following factors: strength, ductility and dimensional accuracy of the pipe. This triple task was set before us 6 years ago.

I remember the day when I first learned of the greater technical requirements for our products and sat down to talk it over with the leading specialists at our plant. We did not have to ask the reason for these requirements. They were related to the more rapid utilization of the rich natural gas reserves in western Siberia and the far north. Large long distance gas pipelines were being planned and laid. Let me say at once that we had many difficulties. The pipe production technology, as well as steel types then in use, did not meet the new requirements.

Let me discuss briefly what we encountered. We had to design and quickly start manufacturing large quantities of high quality thick sheet pipe steel, welding wire and fluxes, radically improve the operations of shaping and welding of skelp, reorganize quality control of the finished pipe. In other words, we had to make a leap in technical progress at our plant.

This work required modernizing a great deal of our equipment, replacing welding power supplies and improving equipment.

If our team of metallurgists coped with these tasks well it is largely thanks to science. The leading institutes of the USSR Ferrous Metallurgy Industry, as well as the Kiev Welding Institute imeni Ye. O. Paton helped us directly.

A great deal of research work was done in cooperation with the institutes before our specialists could say, "This grade of metal will do the job." We had to make the transition from steel containing up to 0.2% carbon to vanadium-niobium steels manufactured by controlled rolling containing half the carbon. Let me explain: these are the steels which have the great toughness and other valuable properties required. Pipe made of these steels is comparatively low in cost, reliable and easily welded.

The plant was able to quickly start producing up to 1 million tons of pipe per year suitable for use in the north. A group of workers at the plant was awarded a prize by the USSR Council of Ministers in 1981 for successfully solving this problem.

#### In the Mainstream of Technical Progress

High product quality and the honor of the plant depend on many components. I think of them as accurately laid bricks, which must fit together precisely. I am speaking not just of excellent pipe quality assurance, but also a constant stream of scientific and technical steps which must be taken. Every metallurgist must participate in this work.

For example, last year about 1000 rationalizers' suggestions were made and, more importantly, introduced to practice. Senior foreman Yu. Andreyev and senior rolling mill operator A. Mogil'nyy changed the calibration of the shaper mill rolls. The annual savings will be over 45,000 rubles. Equally good results were achieved by rationalizers V. Zaporozhchenko and A. Pakhno, who improved the hydraulic system of pipe testing presses.

In all for the year 1.4 million rubles and a thousand tons of metal were saved. Labor consumption was reduced by 123,000 standard man hours, power consumption by 950,000 kilowatt hours. Naturally, pipe quality was increased in every case as well.

We have taken a whole range of steps to increase the quality of our large diameter pipe. Previously if defects were found, pipe was reassigned from gas pipeline use to lower quality products. The plant lost 200 rubles and

up to 12% of pipe mass for every running meter. Our experimental section has now begun cutting out defective sections and rejoining the shorter pipes to make the standard length. The savings amounted to 2 million rubles.

When they learn to use the automatic installation to match cratered sections of inside and outside seams, our metallurgists increased pipe quality and reduced fuel consumption of the thick sheet steel by 35 kg for each ton of product. Plasma cutting of pipe ends was also quite effective.

I would like to mention two more innovations. A technology of welding seams with improved transformers was developed, and an automatic system for regulating electrode gaps was designed. This improved the quality of seam shaping.

The struggle for the honor of our plant allowed the workers in the electric pipe welding shop to begin producing all products with class 1 or 2 accuracy. A combined quality assurance system is in operation throughout the plant.

And, as would be expected, since 1981 our northern rated 1.42-meter-diameter gas pipes, designed to operate at 75 atmospheres, have received the state mark of quality. Thanks to 100% ultrasonic and x-ray television testing of seams throughout the entire length of every pipe, they have improved usage qualities. They are being used in the most important sections of the gas pipeline.

As yet the share represented by pipe with the state mark of quality represents a small fraction of our production. Massive competition has developed at the plant to increase production effectiveness. The best teams have accumulated great experience which is being copied by other metallurgists. Among the leaders are the teams of electric welders A. Garus, A. Bykov, V. Masliyev, A. Kravtsov, P. Gladkov, N. Bunin, A. Surkov and S. Lyakh. They produce 96% gas-pipeline-rated pipe, whereas the plan calls for 95.2%.

This year we plan to introduce a number of technical innovations. In particular, we will install butt welding machines to produce 20-meter pipe in our first pipe electric welding shop.

To the Ukrainian Ferrous Metals Ministry

In spite of our general positive results this year, the plant team still failed to meet the planned cost figures. Our income was 3.8 million rubles low. Why did this happen? In our view it was due to unrealistic plans established by the Ukrainian Ferrous Metals Ministry. We were told that the consumption of sheet metal per ton of pipe should be 969 kg, which is not only contrary to the production technology, but flies in the face of good sense. We still have no clear idea of the plan for cost and profit for this year.

We are also bothered by the future development plans for our plant. In the future the enterprise is to be shifted to the manufacture of northern-rated gas pipes only. To do this, according to the assignment of the USSR Ferrous

Metals Ministry, "Ukrqiprometz", "Giprostal'" and other institutes, together with the plan, have developed a technical-economic foundation and plan for reconstruction of one of our main shops. However the planned reconstruction time - 1983-1984 - will probably not be met. This year, according to the capital construction plan, 7.5 million rubles have been allocated, whereas the total planned cost of the first stage of shop renovation is 45.7 million rubles. The very first projects in the system, such as the carbon dioxide production plant, sectioned for recycling metal wastes, for some reason have been scheduled for the second stage of construction.

In the past year at Khartsyzsk an anticorrosion coatings shop was constructed. This progressive process is being brought on stream first. The shop will produce pipe which is impatiently awaited by the main gas pipeline workers.

We need to bring this new facility on line immediately. We are confident that the workers with the enterprise will meet all their obligations successfully, with the practical assistance of other branches of industry.

Our workers have not used available internal resources completely in the struggle for the honor of our plant. For example, in 1982 the first electric pipe welding shop increased the output of second-quality products by 0.05% in comparison to 1981. It would seem that this is not much - a few hundredths of a percent. However, these hundredths go together to make up a more significant contribution to the economy. Due to poor care of pipe equipment, some 30,000 rubles of unnecessary compressed air losses occurred.

In other words, the workers at the plant have a good deal to do to improve labor and technological discipline and economy and to increase production effectiveness still further.

6508

CSO: 1842/102

UDC: 539.4

COMPARATIVE ANALYSIS OF LONG TERM SOFTENING OF HEAT RESISTANT AND REFRACTORY METALS

Kiev PROBLEMY PROCHNOSTI in Russian No 2, Feb 83  
(manuscript received 6 Apr 82) pp 21-23

OLISOV, A. N., ZERLENYUK, Ye. Ye. KRIVENYUK, V. V., Kiev, Institute of  
Strength Problems, Ukrainian Academy of Sciences

[Abstract] A comparative analysis is presented of the features of long-term strength loss in heat-resistant and refractory metals, using parametric temperature-time extrapolation of long-term strength characteristics. The analysis does not reveal any specific features of long-term high-temperature softening of the material studied. Constant C in the Larson-Miller parameter can be considered a characteristic of the material if comparable temperature conditions are observed. Figures 1; references 13: 10 Russian, 3 Western.  
[101-6508]

UDC 669.3:536.421.4

CRYSTALLIZATION OF COPPER UNDER CONDITIONS OF WEIGHTLESSNESS

Moscow IZVESTIYA AKADEMII NAUK SSSR: METALLY in Russian No 1, Jan 83  
(manuscript received 22 Jan 82) pp 49-51

ZEMSKOV, V. S., BELOKUROVA, I. N., BABAREKO, A. A., AGAFONOV, M. S. and  
BOGDANOVA, N. F., Moscow

[Abstract] Melting and solidification of copper under conditions of weightlessness was studied in an experiment with a graphite container in the crucible of an exothermic heat source accelerated at not more than  $10^{-4}$  g. Specimens of pure copper (-0.001 wt.%Fe+Ni+Pb) were placed in spherical cavities of this container so that they could float freely without touching the walls. The temperature of the hottest spots in this container, where the copper specimens were located, was allowed to rise to 1500°C for a few seconds of heating and melting time, and then let drop to 800°C. Weightlessness was maintained for 10 min. The structure of copper specimens after crystallization was examined under an optical microscope and an electron

microscope as well as by Laue and Debye x-ray diffraction methods. The examination has revealed all manifestations of sharply directional dendritic crystal growth in regular intervals almost equal for branches of different orders. The results indicate that "containerless" crystallization occurs at high rates in a very much subcooled melt, 200-300°C below the melting point (according to calculations). The growth of single crystals during slow acceleration indicates an absence of convection or of any effect of it on formation of the final structure. Figures 4; references 6: 4 Russian, 2 Western.  
[85-2415]

UDC 669.14.018.85:548.7

#### EFFECTS OF MICROALLOYING WITH CERIUM ON STRUCTURE AND PROPERTIES OF 4Kh4VMFS HEAT-RESISTANT STEEL

Moscow IZVESTIYA AKADEMII NAUK SSSR: METALLY in Russian No 1, Jan 83  
(manuscript received 1 Feb 82) pp 71-74

SAVITSKIY, Ye. M., KOTEL'NIKOV, G. A., TETYUYEVA, T. V. and SHUMAKOVA, I. A.,  
Kuybyshev

[Abstract] Heat-resistant steel 4KhVMS (0.42% C, 0.80% Si, 0.37% Mn, 4.0% Cr, 0.98% W, 1.55% Mo, 1.22% V, 0.01% Ca) without and with 0.08% Ce was studied for the effects of Ce in such microquantities. Specimens were successively quenched from 1060°C, chill treated at -70°C for 1 hr, and tempered at temperatures of 400-850°C in 10±10°C steps for 2 hrs. They were then examined by metallographic and x-ray microstructural methods, carbide phase-analysis, microhardness measurements and fractometry. Changes in the degree of tetragonality of the Fe<sub>3</sub>C-phase solid solution were measured by a special x-radiographic technique. The results reveal a strong effect of cerium in steel tempered at 400-500°C, manifested in selective precipitation of Me<sub>6</sub>C carbides at grain boundaries with attendant carbon depletion and resulting softening. Tempering above 500°C equalizes the distribution of cerium and carbon over the grain volume, cerium inhibiting the decomposition of the Fe<sub>3</sub>C-phase as well as tungsten and molybdenum enrichment of the Me<sub>6</sub>C carbides even as the tempering temperature approaches the A<sub>1</sub>-point. Cerium in this case reduces the diffusional mobility of carbon and other alloying elements. Metastable reactions become very significant in steel tempered at 500-675°C, secondary Me<sub>6</sub>C carbides beginning to form at 625°C in steel without cerium. Inhibition of recrystallization processes by cerium ensures a higher toughness, which is required of punches for hot stamping. Figures 4; references 7: all Russian.  
[85-2415]

## OXIDATION OF MECHANICALLY POLISHED ZINC SELENIDE UPON HEATING IN AIR

Moscow IZVESTIYA AKADEMII NAUK SSSR: NEORGANICHESKIYE MATERIALY in Russian  
Vol 19, No 3, Mar 83 (manuscript received 25 Nov 81) pp 347-351

KULAKOV, M. P. and FADEYEV, A. V., Institute of Solid State Physics,  
USSR Academy of Sciences

[Abstract] Gravimetric and optical methods were used to study oxidation of zinc selenide specimens with mechanically polished uncoated surfaces upon heating in air. Zinc selenide specimens 4 cm in diameter and 2 mm thick cut perpendicular to the growth axis were mechanically polished and the index of refraction determined by laser adiabatic calorimetry in air. The specimens were heated in a furnace in air, weight difference determined and transmission and absorption determined again through a number of cycles. It was found that polished zinc selenide specimens heated to 573, 673 and 773°K for  $5.6 \cdot 10^5$ ,  $2.2 \cdot 10^4$ , and  $4 \cdot 10^2$  seconds, respectively, show no significant increase in absorption. The main oxidation product at 573°K is  $ZnSeO_3$ , which is hydrolyzed at room temperature. As the ambient temperature increases, the oxidation products contain more ZnO, the oxidation process becoming autocatalytic as ZnO appears. Figures 6; references 13: 10 Russian, 3 Western.  
[102-6508]

UDC: 535.37

DEEP IMPURITY LEVELS IN  $ZnS_xSe_{1-x}$  CRYSTALS

Moscow IZVESTIYA AKADEMII NAUK SSSR: NEORGANICHESKIYE MATERIALY in Russian  
Vol 18, No 3, Mar 83 (manuscript received 12 Oct 81) pp 376-379

ANDREYEV, A. A., BORISENKO, N. D. and KOVALENKO, A. V., Dneprotrovsk State  
University imeni 300th Anniversary of Union of Ukraine with Russia

[Abstract] A study is made of deep levels in  $ZnS_xSe_{1-x}$  crystals and the possibility of producing these compounds with various conductivity types is analyzed. Variation in excitation conditions, temperature, degree and the type of doping, composition and heat treatment produced nine bands in the photoluminescence spectra of the crystals. The bands are described and interpreted. Optical and thermal depths of traps and parameters of non-radiative recombination centers are discussed. It is established that, depending on external conditions,  $ZnS_xSe_{1-x}$  crystals with  $x \leq 0.4$  may have either n- or p-type conductivity. Annealing in Zn melt produces n-type dark conductivity, while annealing in Se melt stabilizes p-type dark conductivity. Figures 3; references 11: all Russian.  
[102-6508]

## FRACTOGRAPHIC STUDY OF INFLUENCE OF DISTILLED WATER ON STRENGTH AND FRACTURE TYPE OF SITALLS

Moscow IZVESTIYA AKADEMII NAUK SSSR: NEOGRANICHESKIYE MATERIALY in Russian Vol 19, No 3, Mar 83 (manuscript received 30 Nov 81) pp 439-442

DUBOVIK, V. N., RAYKHEL', A. M., PAVLOVA, V. N., NEPOMIYASHCHIY, O. A., POKOLENKO, V. I. and SHVEDUN, V. G.

[Abstract] A study is made of the influence of distilled water on the flexural strength of two sitalls based on specimens 120 x 25 x 10 mm in size. In addition to differences in phase and mineralogic composition, the sitalls differed in defect type. One has combined defects including superficial macrodefects, while the other has a highly dispersed fine pore structure easily accessible to the external medium and defects are homogeneous over the surface and through the volume. Distilled water does not greatly decrease flexural strength, which is explained by the increase in specific work of plastic deformation compensating for the decrease in surface energy density. Figures 2; references 5: all Russian.

[102-6508]

UDC: 539.32+621.315.424+537.226.33

## INTERRELATIONSHIP OF ELASTICITY MODULI WITH MELTING POINT OF CERAMIC MATERIALS

Moscow IZVESTIYA AKADEMII NAUK SSSR: NEOGRANICHESKIYE MATERIALY in Russian Vol 19, No 3, Mar 83 (manuscript received 1 Sep 81) pp 472-475

NIKIFOROV, L. G., Rybinsk Institute of Aviation Technology

[Abstract] It would be very interesting to establish the relationship between elasticity modulus and melting point of crystalline substances, since melting point determination is quite simple, particularly for low-melting materials. The relationship between elasticity modulus and mp can be determined from an equation which relates melting point to the speed of sound and molecular mass and equations which relate the speed of sound to elastic constant B, unit cell volume per formula unit and molecular mass. The relationship of melting point to  $EV/N$  is nearly linear for substances with identical syngony or related crystalline structure. The influence of impurities on sintering of ceramics is explained by this relationship. Criteria which can be used to predict the speed of sound in ceramics are noted. Figures 1; references 10: all Russian.

[102-6508]

## INFLUENCE OF GRAVITATION ON PHASE LAYER FORMATION IN INTERACTION OF SOLID AND LIQUID METALS

Moscow FIZIKA I KHIMIYA OBRABOTKI MATERIALOV in Russian No 1, Jan-Feb 83  
(manuscript received 12 Nov 81) pp 63-67

PIMENOV, V. N. and MASLYAYEV, S. A., Moscow

[Abstract] Current concepts concerning phase formation in solid-liquid interactions and mass transfer processes are used to develop a plan for the interaction between solid and liquid metals under low gravity conditions, as in spacecraft. Particular attention is given to the mechanism by which phases are formed in the zone of diffusion at the solid-liquid interface. Under low gravity conditions the conditions of formation of the phase layers change. The time of initial dissolution of the solid metal and the liquid and the intensity of this process both decrease. The formation and growth of the solid diffusion zone occur with a lower liquid solution concentration in space than on earth. Figures 4; references 25: all Russian.  
[103-6508]

UDC: 620.193.01

## FIRST SENSITIVITY THRESHOLD OF AMORPHOUS ALLOYS

Moscow ZASHCHITA METALLOV in Russian Vol 19, No 2, Mar-Apr 83  
(manuscript received 30 Sep 81) pp 243-245

VASIL'YEV, V. Yu., ISAYEV, N. I., SHUMILOV, V. N., KLOCHKO, A. N.,  
ZAKHAROV, A. I. and REVYAKIN, A. V., Moscow Institute of Steel and Alloys

[Abstract] Amorphous alloys obtained by rapid cooling from a melt on a rotating metal cylinder were studied. Compositions studied were  $\text{FeCr}_x\text{P}_{13}\text{C}_7$  (where  $x=0, 2, 5, 8, 13, 18$  at.%) and  $\text{FeCr}_x\text{B}_{17}$  (where  $x=0, 5, 8, 10$  and  $15$  at.%). Measurement of corrosion potential over time showed that it stabilized rapidly, then changed little after one hour of holding in  $\ln \text{FeSO}_4$ . Electrochemical studies indicated that the first stability threshold in  $\text{FeCr}_x\text{P}_{13}\text{C}_7$  is 5 at.%, with corrosion not over  $10^{-3}$  g/m<sup>2</sup>·hr in the alloy with chromium concentration over 5 at.%. The first stability threshold was observed at 5 and 10 at.% chromium for phosphorus- and boron-containing alloys. The reasons for the changes were not only variations in chemical composition but also structural changes within the framework of x-ray amorphous states. The amorphous state was found to be more stable in alloys obtained by cooling on copper cylinders (more rapid cooling). An attempt is made to explain the difference in properties on the basis of x-ray photoelectron spectroscopy. Figures 1; references 8: 4 Russian, 4 Japanese.  
[113-6508]

## USE OF BETA-SPECTROMETER TO DETERMINE PHOSPHORUS DISSOLUTION KINETICS FROM AMORPHOUS ALLOYS

Moscow ZASHCHITA METALLOV in Russian Vol 19, No 2, Mar-Apr 83  
(manuscript received 16 Aug 82) pp 246-250

RODIN, N. N., VASIL'YEV, V. Yu., ZUDIN, M. B., FISHCHENKO, V. P., and  
KUZNETSOV, L. P.

[Abstract] The purpose of this work is to show the possibility of using beta- and gamma-spectrometry to determine the dissolution rates of P, Fe and Cr from amorphous alloys in the system Fe-Cr-P-C. A beta-spectrometer with a crystal scintillator 40 mm in diameter by 10 mm in length was used (resolution 13% for  $E_{\beta}=264$  keV) and a gamma-spectrometer with Ge(Li)-detector, volume 150 cm<sup>3</sup> (energy resolution 2.9 keV for  $E_{\gamma}=1332$  keV). Information was accumulated in a 4000-channel analyzer and processed by a YeS-1022 computer. The method was developed on model mixtures containing known quantities of chromium, iron and phosphorus. The method was then used to determine the partial rates of dissolution of phosphorus from phosphorus alloys of known composition in 10% HCl at 25°C with various anodic polarization potentials. In the interval of potentials studied the anodic dissolution rate of an alloy containing 11 at.% P was approximately 100 times higher than the dissolution rate of an alloy containing 13 at.% P. An increase in the phosphorus content of an alloy results in a rapid decrease in the phosphorus content in the soluble corrosion products. The use of the method allows determination of one of the most important parameters of amorphous alloy dissolution kinetics--the phosphorus dissolution selectivity factor. It thus allows monitoring of the behavior of phosphorus during electrochemical dissolution. Figures 3; references 11: 8 Russian, 3 Japanese.  
[113-6508]

UDC. 539.213.001

## DIFFUSIONLESS CRYSTALLIZATION AND PRODUCTION OF METAL GLASSES

Moscow DOKLADY AKADEMII NAUK SSSR in Russian Vol 268, No 5, Feb 83  
(manuscript received 20 Sep 82) pp 1120-1121

TEMKIN, D. Ye., Central Scientific Research Institute of Ferrous Metallurgy  
imeni I. L. Bardin, Moscow

[Abstract] Crystallization of a melt is generally accompanied by diffusion redistribution of components among phases and within the volume of phases. Below a certain temperature, a diffusionless process is also possible. The kinetics of diffusionless transformation have been little studied, but the first results indicate that the process is quite similar to diffusion crystallization rather than conversion in a single-component system. In the 2-phase area the speed of a boundary decreases with time, approaching zero. Crystallization of a melt in the 2-phase area (whether with or without diffusion) is

difficult and develops in a qualitatively different mode than in pure metal, and is accompanied by a decrease in growth rate with time. The formation of metallic glass is facilitated for systems and compositions for which the solidus point is below the glass point. Where the solidus point is greater than the glass point for all compositions, amorphous phases are as difficult to produce as in pure metals. References 5: 3 Russian, 2 Western.

[104-6508]

#### FORMATION OF AMORPHOUS METAL SURFACE UPON BOMBARDMENT WITH A PULSED HYDROGEN PLASMA STREAM

Leningrad PIS'MA V ZHURNAL TEKHNICHESKOY FIZIKI in Russian Vol 9, No 1, 12 Jan 83 (manuscript received 4 Sep 82) pp 42-46

ALEKSEYEV, V. A., KONKASHBAYEV, I. K., KISELEV, Ye. A., KISELEVA, T. D., LYASHENKO, V. N., MATVEYEV, V. Ye., SKVORTSOV, Yu. V., STRUNNIKOV, V. M., TSEREVITINOV, S. S. and CHISTYAKOV, V. M.

[Abstract] Calorimetric measurements were performed as specimens of steel were struck by a high power pulsed plasma flux. Under certain conditions the target absorbed up to 50% of the incident energy. Surface roughness of the specimens was reduced to 0.23 micrometers and the surface characteristically became quite shiny. Electron microscopy, x-ray and metallographic studies were used to investigate the surface layer. Microhardness decreases with increasing depth from 500 kg·mm<sup>-2</sup> to 330 kg·mm<sup>-2</sup>, then stabilizes at over 7-15 micrometers depth at the same level as that of the initial material. The appearance of diffusion maxima and a decrease in scattered x-radiation intensity resulted from the formation of an absorbing filtering layer on the surface. Heating of the specimens resulted in a return to the initial crystalline state. On 30KhGSN2A and ShKh15 steel, the amorphous layer 7 to 15 micrometers thick, with microhardness 1.5 to 2 times higher than the surrounding metal, disappeared upon heating. Figures 2; references 7: 3 Russian, 4 Western.

[95-6508]

CSO: 1842

- END -