

## Russian and Japanese Aerospace Literature

Throughout 1992 the *AIAA Journal* will carry selected abstracts on leading research topics from Russian aerospace literature and, as space permits, from similar Japanese literature. The topics will be chosen and the abstracts reviewed for pertinency by *AIAA Journal* editors. This month features Alloys from Russia and Japan.

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### Russian Aerospace Literature This month: *Alloys*

**A92-33716** Fine structure of diffusion barriers on chromium-based low alloys (Tonkaia struktura diffuzionnykh bar'erov na malolegirovannykh splavakh khroma). E. R. KUTELIA, O. I. MIKADZE, B. P. BULIIA, A. N. RAKITSKII, K. E. LABARTKAVA, and K. N. DURGLISHVILI, *Akademiia Nauk Gruzii, Soobshcheniia* (ISSN 0132-1447), Vol. 142, May 1991, pp. 333-336. 4 Refs.

The structural characteristics of a barrier oxide layer formed during high-temperature oxidation on a Cr-based low alloy containing about 0.5 percent (by mass) of lanthanum and carbide-forming elements were investigated experimentally using transmission electron microscopy and microdiffraction analysis. It is found that finely dispersed LaCrO<sub>3</sub> particles are present in the growing oxide layer both at the grain and dislocation boundaries of the principal phase component and inside individual Cr<sub>2</sub>O<sub>3</sub> crystals. This suggests that lanthanum diffusion from the matrix into the scale occurs both around the lattice and through the lattice.

**A92-30226** Microstructure of materials and a model of the high-velocity penetration of plane cumulative jets (Mikrostruktura materialov i model' vysokoskorostnogo pronikaniia ploskikh kumulativnykh strui). B. K. BARAKHTIN, I. I. MESHCHERIAKOV, and G. G. SAVENKOV, *Zhurnal Tekhnicheskoi Fiziki* (ISSN 0044-4642), Vol. 61, June 1991, pp. 8-12. 16 Refs.

Results of microstructural studies of target materials (aluminum, aluminum alloys, steels, and VT6S titanium alloy) following the penetration of plane cumulative jets with initial impact velocities of 2.5-3.5 km/s are reported. It is found that jet penetration gives rise to turbulent deformation within the material which involves multiple microflows with different relative velocities. A mathematical model of cumulative jet penetration is proposed which allows for the velocity distribution of material microflows and its effect on the jet penetration depth.

**A92-27552** Changes in the dislocation structure of nickel alloys during creep (Izmenenie dislokatsionnoi struktury nikel'nykh splavov v protsesse polzuchesti). N. V. NIKULINA, L. P. SOROKINA, M. P. USIKOV, and M. B. BRONFIN, *Metallofizika* (ISSN 0204-3580), Vol. 13, Oct. 1991, pp. 22-27. Refs.

The dislocation structure formed during creep in single crystals of a high-temperature nickel superalloy with a large (greater than 60 percent) volume fraction of the gamma prime phase is investigated by electron diffraction microscopy. It is shown that spaces between the single crystal axes are the weakest areas from the standpoint of creep resistance. It is also shown that the dislocation structure formed depends on the orientation of the applied stress.

**A92-25953** Structure and texture formation in a pseudo-alpha titanium alloy during rolling in the (alpha + beta) region (Formirovanie struktury i tekstury psevd-alpha-splava titana pri prokatke v /alpha + beta/-oblasti). I. N. RAZUVAEVA, A. A. BABAREKO, V. N. KOPYLOV, G. V. MEDVEDEVA, and N. M. DOBRODEEVA, *Fizika Metallov i Metallovedenie* (ISSN 0015-3230), Nov. 1991, pp. 99-107. 8 Refs.

Studies of the microstructure and texture of pseudo-alpha titanium alloys deformed in the alpha-beta region demonstrate the existence of a relationship between the structure type and the morphological features of the texture. The effect of the dynamic recrystallization of the beta phase on the evolution of the structural state of titanium alloys is examined.

**A92-25301** Some characteristics of the initial stages of structure formation in hard alloys based on titanium carbonitrides (Nekotorye osobennosti nachal'nykh stadii strukturoobrazovaniia tverdykh splavov na osnove karbonitridov titana). V. D. LIUBIMOV and T. A. TIMOSHCHUK, *Poroshkovaia Metallurgiiia* (ISSN 0032-4795), Dec. 1991, pp. 29-35. 23 Refs.

A study is made of phase transformations taking place during the heat treatment of titanium carbonitride-nickel-molybdenum-carbon compacts in the temperature range 0.4-0.9 of the sintering temperature, corresponding to the initial stages of structure formation in tungsten-free hard alloys KNT16 and LTsk20. The discussion focuses on some of the service-related characteristics of the individual phases and their role in the formation of the overall physicomaterial properties of the sintered alloy. The effect of the principal sintering process variables (medium, temperature, time, and pressure) on the physicomaterial properties of the product is examined.

**A92-23632** Effect of the dispersity of the phase structure of an alloy on the depth of the laser-treated zone (Vliianie dispersnosti fazovogo stroeniia splava na glubinu zony lazernogo vozdeistviia). O. M. IVASISHIN, P. E. MARKOVSKII, A. F. ZHURAVLEV, and I. I. OBOZHIN, *Metallofizika* (ISSN 0204-3580), Vol. 13, Aug. 1991, pp. 34-42. 12 Refs.

The objective of the study was to investigate the effect of the phase structure dispersity of VT6 and VT23 titanium alloys on the depth of the affected zone during a pulsed laser treatment. It is found that there exists a nonmonotonic relationship between the thickness of the fused zone and the crystallite size of the initial alpha phase. It is suggested that the relationship results from the increased chemical inhomogeneity of the high-temperature beta phase formed during the polymorphic transformation under laser heating. A model is proposed for calculating the possible contributions of various thermophysical parameters to the change in the fusion depth as a function of the initial structure dispersity.

**A92-25952** M5B3 borides in high-temperature nickel alloys with about 5 and 15-20 mass percent chromium (Boridy tipa M5B3 zharoprochnykh nikel'nykh splavakh s about 5 i 15-20 mas. pct khroma). I. U. R. NEMIROVSKII, M. S. KHADYEV, V. V. POLEVA, and V. P. LESNIKOV, *Fizika Metallov i Metallovedenie* (ISSN 0015-3230), Nov. 1991, pp. 85-89. 5 Refs.

The morphology and crystallographic characteristics of M5B3 borides in high-temperature nickel alloys containing about 5 percent Cr and 10-12 percent W or 15-20 percent Cr and 3-5 percent W are investigated experimentally using transmission electron microscopy. The morphological modifications of the borides, their orientation bond with the gamma-gamma prime matrix, and the effect of the segregation, phase, and structural inhomogeneities on boride distribution over the alloy volume are discussed.

**A92-21527** A grain boundary phase transformation during the superplastic transition of a fine-grained material (O zernogranichnom fazovom prevrashchenii pri perekhode melkokristallicheskogo materiala v sverkhplasticheskoe sostoyanie). V. M. GRESHNOV, *Pis'ma v Zhurnal Tekhnicheskoi Fiziki* (ISSN 0320-0116), Vol. 17, July 26, 1991, pp. 5-9. 5 Refs.

The stress-strain behavior of two typical superplastic alloys, Zn-22 wt pct Al and VT9, was investigated experimentally with emphasis on small strain rates. An analysis of the experimental results suggests that the transition of a fine-grained material from the diffusive creep state to the superplastic state is associated with a kinetic (nonequilibrium) grain boundary phase transformation of the first kind. As a result of the phase transformation, the grains lose the long-range order and become amorphous. This result indicates that superplasticity can be treated as a special physical state of a material.

**A92-18300** Determination of single-phase liquid solution boundaries in the system Al-Mg-Sc-Zr (Postroenie granits odnofaznogo zhidkogo rastvora v sisteme Al-Mg-Sc-Zr). L. L. ROKHLIN, A. S. FRIDMAN, T. V. DOBATEKINA, and D. G. ESKIN, *Metally* (ISSN 0568-5303), Nov.-Dec. 1991, pp. 158-160. Refs.

The boundaries of the phase volume of an aluminum-base melt were determined at 700, 750, and 800 C for alloys of the system Al-6 pct Mg-Sc-Zr (up to 0.7 percent Sc and up to 0.5 percent Zr). By applying the linear regression method to the experimental results, an equation is obtained which describes the liquidus surface in the system studied. Computer-generated three-dimensional images of the liquidus surface and isotherms are presented.

**A92-18295** Behavior of D16 and V65 alloys under dynamic aging (Povedenie splavov D16 i B65 pri dinamicheskom starenii). V. F. GAIDUCHENIA and A. M. SHNEIBERG, *Metally* (ISSN 0568-5303), Nov.-Dec. 1991, pp. 107-111. Refs.

The dynamic aging kinetics of two heat-treatable aluminum alloys, D16 and V65, was investigated experimentally at various temperatures. The experiments included measuring hardness after aging and determining the activation energy during the aging treatment. The increase in hardness observed after aging is attributed to the formation of Guinier-Preston zones at dislocations, whose nucleation is initiated by the applied stress.

**A92-18288** Some characteristics of the pulsed laser hardening of titanium alloys (Nekotorye osobennosti impul'snogo lazernogo uprochneniia titanovykh splavov). A. P. LIUBCHENKO, E. A. SATANOVSKII, V. N. PUSTOVOIT, G. I. BROVER, V. N. VARAVKA, and E. A. KATSNEL'SON, *Fizika i Khimiia Obrabotki Materialov* (ISSN 0015-3214), Nov.-Dec. 1991, pp. 130-134. 3 Refs.

The characteristic features of the pulsed laser treatment of titanium alloys are examined with particular reference to experimental results obtained for VT3-1 alloy. It is found that laser treatment leads to the formation of a hardened surface layer 70-100 microns deep whose hardness exceeds that of the base metal by a factor of 1.1-1.6. The observed hardening effect is attributed to the concentration and morphological inhomogeneity of the solid solutions, formation of the alpha prime martensitic phase, and saturation by nitrogen and carbon from the air and from the coatings.

**A91-50801** The effect of high-temperature melt-processing on the structure of single crystals of heat-resistant alloys (Vlianie vysokotemperaturnoi obrabotki rasplava na strukturu monokristallov zharoprochnykh splavov). P. D. RODIONOV, E. A. KULESHOVA, V. A. SAZONOVA, N. I. VINOGRADOVA, D. P. RODIONOV, and V. N. LARIONOV, *Fizika Metallov i Metallovedenie* (ISSN 0015-3230), April 1991, pp. 95-102. 5 Refs.

The effect of the type of heat-processing of two heat-resistant Ni-base alloys on the structure and the strength of 100-line-oriented single crystals of these alloys was investigated using results of electron microscopy, XRD, and metallographic examinations. Results are presented on the effect of temperature on the structural refinement, the parameters of the cell-dendrite-structure growth, the morphology and dispersivity of the gamma-prime phase, the coherence on the boundary between the gamma and the gamma-prime phases, and the relationships of these phases with the long-time strength of the alloys. The nominal compositions of the two alloys were (in wt pct): (1) Ni-0.14C-5.0Cr-9.0Co-13.1(W+Mo+V)-8.1(Ti+Al+Nb)-0.015B; and (2) Ni-0.16C-5.0Cr-9.0Co-15.0(W+Mo+V+Re)-11.6(Al+Nb+Ta)-0.015 B.

**A92-18286** Synthesis of titanium nitride coatings in an electron-beam plasma (Sintez nitrid-titanovykh pokrytii v elektronno-puchkovoi plazme). V. L. BYCHKOV, M. N. VASIL'EV, and A. S. KOROTEEV, *Fizika i Khimiia Obrabotki Materialov* (ISSN 0015-3214), Nov.-Dec. 1991, pp. 77-83. 13 Refs.

In the experiments reported here, titanium nitride coatings were synthesized on the surface of titanium alloys in a plasma generated by a stationary electron beam injected into nitrogen gas. The composition of the surface layer was investigated by electron spectroscopy. A theoretical model is proposed which can be used for calculating the process characteristics from the specified electron beam and gas parameters.

**A92-16211** Two-stage transformation in (alpha + beta)-titanium alloys on non-equilibrium heating. P. E. MARKOVSKII, *Scripta Metallurgica et Materialia* (ISSN 0956-716X), Vol. 25, Dec. 1991, pp. 2705-2710. 9 Refs.

An experimental investigation is reported on the two-stage transformations where the alpha-phase undergoes a diffusionless alpha-to-beta shift at a specific maximum temperature or where such a shift is not completed. Two (alpha + beta)-Ti alloys are employed to prepare samples with starting alpha-crystals of varying sizes. A laser is used to heat the samples at about 10 exp 6 deg C/s, and TEM is used to examine both the initial and quenched states of the samples. The data demonstrate that the absence of preferential growth directions for martensitic crystals in globular initial structures accounts for the difference in lamellar initial structures. An analysis of the results forms the basis for a proposed distribution of beta-stabilizer elements in the high-temperature beta-phase caused by rapid heating in both cases of transformation.

**A92-10798** Effect of copper on alpha phase precipitation in concentrated titanium-niobium and titanium-vanadium alloys (Vlianie medi na vydelenie alpha-fazy v kontsentrirrovannykh splavakh titan-niobii i titan-vanadii). V. A. VOZILKIN and T. L. TRENOGINA, *Fizika Metallov i Metallovedenie* (ISSN 0015-3230), June 1991, pp. 181-185. 8 Refs.

The structure and phase composition of several copper-containing Ti-Nb and Ti-V alloys were investigated by transmission electron microscopy and X-ray diffraction analysis. In alloys containing 60-65 percent niobium or vanadium, the addition of 1-3 percent Cu leads to the decomposition of the stabilized bcc beta solid solution and alpha phase precipitation. The susceptibility to solid solution decomposition significantly decreases with an increase in the content of the beta-stabilizing element (niobium or vanadium). The decomposition process also becomes more active with an increase in Cu content from 1 to 3 percent.

**A91-55411** Increasing the wear resistance of titanium alloys at high contact loads (Povyshenie iznosostoikosti titanovykh splavov pri vysokikh kontaktnykh nagruzkakh). O. M. IVASISHIN, P. E. MARKOVSKII, O. V. MIKULIAK, and V. E. PANARIN, *Metallovedenie i Termicheskaiia Obrabotka Metallov* (ISSN 0026-0819), No. 8, 1991, pp. 46, 47. 8 Refs.

The objective of the study was to investigate the possibility of obtaining eutectic alloy coatings on titanium that would provide a high wear resistance at contact pressures up to 300 N/sq mm. The coatings were deposited by ion plasma spraying and were based on the Fe-Cr-Ni-V-Ti system with interstitial phases (carbides, nitrides, and borides). Results of friction tests for coated VT23 titanium alloy show that the ion-plasma coatings significantly increase the wear resistance of the alloy at high contact loads.

**A91-52686** Structure and properties of welded joints of different titanium alloys (Struktura i svoistva svarnykh soedinenii iz razlichnykh titanovykh splavov). A. A. POPOV, A. G. ILLARIONOV, M. A. KHOREV, and N. A. DROZDOVA, *Metallovedenie i Termicheskaiia Obrabotka Metallov* (ISSN 0026-0819), No. 7, 1991, pp. 23-25. 4 Refs.

Changes in the structure, phase composition, microhardness, and alloying element distribution in the base metal, heat affected zone, and deposited metal of weld joints of different titanium alloys were investigated by X-ray diffraction, metallographic, and electron probe analyses and microhardness measurements. Results are presented for VT6-OT4, VT6-VT20, VT23-OT4, VT23-VT6, VT23-VT19, and VT23-VT32 welds. Recommendations concerning the heat treatment of such welds are given.

**A91-49408** Characteristics of solid solution hardening in alloys based on aluminum, nickel, and iron with additions of transition metals (Ob osobennostiakh tverdostvornogo uprochneniia v splavakh na osnove aluminia, nikelia i zheleza, legirovannykh perekhodnymi metallami). V. O. ABRAMOV and O. V. ABRAMOV, *Akademiia Nauk SSSR, Doklady* (ISSN 0002-3264), Vol. 318, No. 4, 1991, pp. 883-887. 6 Refs.

The objective of the study was to evaluate the effect of the chemical nature of the alloying element on the mechanical properties and structural stability of aluminum, nickel, and iron alloys. The alloying elements, 3-d, 4-d, and 5-d transition metals and, in some cases, Cu and Zn, were used in amounts of 0.5 at. pct (for aluminum) and 1-8 at. pct (for nickel). For nickel alloys and Fe-B system, the degree of solid solution hardening correlates with the lattice spacing of the alloying element atom and its radius. The strength of aluminum alloys increases with the atomic number of the 3-d metal, with a maximum observed in Al-Co alloys; after that, the strength decreases.

**A92-15069 Structure and properties of a rapidly solidified Al-Li alloy following compaction and aging (Struktura i svoystva bystrozakristallizovannogo Al-Li-splava posle kompaktirovaniia i starenii).** V. O. ABRAMOV, O. V. ABRAMOV, M. M. KAMALOV, V. V. KULESHOV, M. M. MYSLIAEV, and V. M. PANOVKO, *Metallovedenie i Termicheskaiia Obrabotka Metallov* (ISSN 0026-0819), No. 11, 1991, pp. 30-32. 8 Refs.

A study is made of the aging behavior of Al-Li P/M alloys produced by two process routes. In particular, the possibility of compaction by extrusion without preheating is discussed. It is shown that the compaction of rapidly solidified Al-2.6 pct Li specimens at temperatures lower than the usual compaction temperature makes it possible to largely retain the structural state characteristic of the powdered alloy. Aging of the alloy without prior heat treatment leads to lithium diffusion in aluminum and formation of a delta prime hardening phase.

**A92-13760 Effect of the depth of gas-saturated layer removal on the repeated static life and ductility of OT4 and VT6ch titanium alloys (O vliianii glubiny s'ema gazonasyschennogo sloia na povtorno-statsicheskuiu dolgovечnost' i plastichnost' titanovykh splavov OT4 i VT6ch).** A. B. KOLOMENSII, B. A. KOLACHEV, A. V. DEGTIAREV, and A. N. ROSHCHUPKIN, *Fiziko-Khimicheskaiia Mekhanika Materialov* (ISSN 0430-6252), Vol. 27, May-June 1991, pp. 25-28. 4 Refs.

Experiments were conducted on 0.8-3.0-mm-thick sheets of VT6ch and OT4 titanium alloys to investigate the effect of the incomplete etching of the gas-saturated surface layer on the ductile characteristics of the alloys and their life under repeated static loading. It is found that controlled incomplete removal of the gas-saturated surface layer may have a positive effect on the life of titanium sheets under repeated static loading without any deterioration of the ductile properties. The method is recommended for low- and medium-strength titanium alloys.

**A92-13759 Effect of plasma coatings on the fatigue strength of aluminum alloys (Vliianie plazmennyykh pokrytii na ustalostnuiu prochnost' aluminievyykh splavov).** N. S. SUROV and S. V. BABIN, *Fiziko-Khimicheskaiia Mekhanika Materialov* (ISSN 0430-6252), Vol. 27, May-June 1991, pp. 21-24. 7 Refs.

Results of an experimental study of the effect of plasma-sprayed coatings on the fatigue strength of specimens of D1ch and D16A-T alloys are reported. It is found that thermally sprayed coatings reduce the strength of D15A-T alloy by 30 percent and that of D1ch alloy by 85 percent. Following hardening and artificial aging, the fatigue strength of D1ch alloys with a plasma-sprayed PN70YU30 coating is shown to increase on the average by 100 percent; the strength of coated D16A-T alloy increases by more than 50 percent.

**A92-12849 Effect of additions of vanadium, molybdenum, and zirconium on the solvus of the phase (Nb, Ti)Cr<sub>2</sub> in the system Nb-Ti-Al-Cr (Vliianie dobavok vanadiia, molibdena i tsirkoniia na sol'vus fazy (Nb, Ti)Cr<sub>2</sub> v sisteme Nb-Ti-Al-Cr).** A. M. ZAKHAROV, A. V. PAVLOV, G. V. KARSANOV, and L. L. VERGASOVA, *Metally* (ISSN 0568-5303), Sept.-Oct. 1991, pp. 208-211. Refs.

The individual and combined effect of additions of 3 pct V, 3 pct Mo, and 1.5 pct Zr on the solidus temperature of alloys in the system Nb-Ti-Al-Cr and chromium solubility in the niobium beta solid solution were investigated experimentally for constant contents of Ti (32 percent) and Al (5 percent) using the Pirani-Alterum method, and metallographic and X-ray diffraction analyses. It is shown that the addition of 3 pct V to Nb-Ti-Al-Cr alloys reduces chromium solubility in the Nb beta solid solution by 4-5 percent. A similar effect is observed in the case of the combined addition of 3 pct Mo and 1.5 pct Zr. The addition of 3 pct Mo, on the other hand, has no noticeable effect on chromium solubility.

**A92-12846 Effect of the conditions of directional solidification and heat treatment on the porosity of single crystals of high-temperature nickel alloys (Vliianie rezhimov napravlennoi kristallizatsii i termooobrabotki na poristost' v monokristallakh nikel'nykh zharoprochnykh splavov).** V. N. TOLORAIIA, A. G. ZUEV, and I. L. SVETLOV, *Metally* (ISSN 0568-5303), Sept.-Oct. 1991, pp. 70-76. Refs.

The number and morphology of voids in single crystals of a high-temperature nickel alloy are investigated experimentally using directionally solidified 18-mm-diameter cylindrical specimens with the 001-line orientation. In the as-cast condition, the voids have the form of cracks along the interface between the gamma-gamma prime eutectic and the gamma matrix. Following heat treatment, the voids become rounded in shape, and their volume fraction increases. The volume fraction of voids decreases with the increasing temperature gradient and increases with the increasing growth rate. In 001-line-oriented specimens, cracks propagate in the direction normal to the axis; the crack propagation rate is anisotropic.

**A92-10927 Morphological changes of the gamma prime phase in single crystals of Ni-Si-Al nickel alloys (Morfologicheskie izmeneniia gamma-prime-fazy v monokristallakh nikel'nykh splavov Ni-Si-Al).** D. M. MANSUROV, O. M. BARABASH, and S. P. OSHKADEROV, *Metallofizika* (ISSN 0204-3580), Vol. 13, May 1991, pp. 89-94. Refs.

Experiments were carried out on model Ni-Si-Al alloys to determine the factors affecting the morphology of the gamma prime phase precipitating in these alloys. A direct relationship is established between the morphology of the gamma prime phase and the lattice misfit parameter. It is shown that, in the case of a negative misfit parameter, octets of cuboidal particles are formed at the late stages of decomposition.

**A92-12900 Equipment for the experiments on material sciences and the technological possibilities of Soviet unmanned spacecraft. L. L. REGEL', V. P. SHALIMOV, A. M. TURCHANINOV, A. A. VEDERNIKOV, M. B. SHCHERBINA-SAMOILOVA, G. P. ANSHAKOV, and V. D. KOZLOV, *Proceedings of the 1st AIAA/IKI Microgravity Science Symposium*, Moscow, USSR, May 13-17, 1991, (A92-12851 02-29). Washington, DC, American Institute of Aeronautics and Astronautics, 1991, pp. 324-330.**

The development of scientific equipment is reviewed emphasizing the study of space materials aboard automated spacecraft with the possibility of payload retrieval. The projects considered are based on the design and fabrication of universal multiobjective furnaces including the ChSK-3 automatic crystal processor, the ABC furnace for large specimens, and the RGA system for studying crystal growth in solutions. The ChSK-3 is a furnace which operates at 1200 C and can process glass and composite specimens, semiconductor materials, and metal and other alloys. The ABC can be operated at up to 1500 C and has several independently controlled heaters; a cooling system is included in the system to permit a stable temperature gradient. Three unmanned spacecraft - the 'Photon', 'Resurs-F', and the 'Nika-T' - are described in detail with respect to supporting potential experiments in materials sciences.

**A92-12891 Microgravity influence on unidirectional crystallization of metallic eutectics.** V. V. ZUBENKO, I. V. TELEGINA, L. L. REGEL', and O. V. RADKEVICH, *Proceedings of the 1st AIAA/IKI Microgravity Science Symposium*, Moscow, USSR, May 13-17, 1991, (A92-12851 02-29). Washington, DC, American Institute of Aeronautics and Astronautics, 1991, pp. 252-256. 24 Refs.

The unidirectional solidification of two alloys (Al-CuAl<sub>2</sub> and Al-NiAl<sub>3</sub>) is achieved in space, and the effects of microgravity on the crystallization structure is examined. The alloys are solidified at different rates under known thermal conditions, and SEM and X-rays are used to analyze the microstructures longitudinally and in cross section. The regions with regular lamellar structure are identified for the Al-AlCu<sub>2</sub> alloy under certain conditions and are found to be enlarged when produced in microgravitational conditions. As the growth rate increases for the Al-CuAl<sub>2</sub> eutectic the lamellar structure becomes finer. The fiberlike structure of Al-NiAl<sub>3</sub> is larger when produced under microgravitational conditions, but lamellar structures are not reported for this alloy and experimental condition.

**A92-12848 Equilibrium and metastable phase diagrams of Ni-Al-Mo (Ravnovesnaia i metastabil'naia diagrammy sostoiianiia Ni-Al-Mo).** S. B. MASLENKOV, N. N. BUROVA, V. A. RODIMKINA, M. D. BESPALOVA, and O. O. OLDAKOVSKAIA, *Metally* (ISSN 0568-5303), Sept.-Oct. 1991, pp. 192-198. Refs.

Results of an experimental study of the phase diagram of the system Ni-Al-Mo in the equilibrium and metastable states are reported. It is shown, in particular, that the concentration and temperature intervals of the gamma region decrease and the boundaries of the gamma-gamma prime regions shift toward a region with a lower molybdenum content as the content of aluminum increases. Attention is also given to the shift of phase equilibria during rapid solidification as well as changes in the structure and phase composition of the alloys following 4-hour anneals in the temperature range 1200-1000 C.

**A91-50803 Investigation of the nature of alpha-phase 'coarse precipitates' in titanium alloys and the conditions of their formation during deformation and heat treatment (Izuchenie prirody 'grubyykh vydelenii' alpha-fazy v strukture titanovykh splavov i uslovii ikh obrazovaniia pri deformatsii i termooobrabotke).** G. V. SHAKHANOVA, M. IA. BRUN, and I. V. SOLDATENKO, *Fizika Metallov i Metallovedenie* (ISSN 0015-3230), April 1991, pp. 133-137.

Quantitative metallographic methods involving layer-by-layer etching were used to investigate the characteristics and the conditions of formation of the alpha-phase 'coarse precipitates' in the alpha + beta structure of VT3-1-type Ti alloys which are chemically identical to the base alloy. It was found that coarse alpha-phase precipitates are readily formed during prolonged (more than 5 hrs) isothermal heating at the alpha + beta temperatures, as well as during low-rate (slower than 1 C/min) cooling in a narrow temperature interval corresponding to the high-temperature interval of alpha + beta region.

**A91-47472 Structure and properties of Al-Cu-Mg alloys containing Fe and Si (Svoystva i struktura splavov sistemy Al-Cu-Mg s dobavkami zheleza i kremniia).** L. N. LESHCHINER and T. P. FEDORENKO, *Metallovedenie i Termicheskaiia Obrabotka Metallov* (ISSN 0026-0819), No. 5, 1991, pp. 38-41. 9 Refs.

The effect of phase compositions in an alloy on its structure (in particular, on the volume fraction of excess phases), the safety margin, and the mechanical properties of the alloy during stretching was investigated using rolled plates made of naturally aged commercial 1163T alloy. Results of fractographic and electron-microscope observations combined with analyses of compositional analyses showed that the alloy contained two types of particles: (1) particles containing Fe, Cu, and Mg and having a complex structure and (2) particles containing only Cu and Mg. Results of mechanical tests showed that plates containing less than 0.1 percent Fe and less than 4.3 percent Cu and with less than 1.8 vol pct excess phases displayed the highest resistance to low-cycle fatigue. The levels of crack resistance at low strain coefficients did not depend on the phase composition.

**A92-12775 Liquidus surface and crystallization pattern of Ti-Ni-Zr alloys containing up to 50 percent Ni (Poverkhnost' likvidusa i skhema kristallizatsii splyavov sistemy Ti-Ni-Zr, soderzhashchikh do 50 percent Ni).** V. N. EREMENKO, E. L. SEMENOVA, and L. A. TRET'ACHENKO, *Poroshkovaia Metallurgiya* (ISSN 0032-4795), Aug. 1991, pp. 49-54. 3 Refs.

The liquidus surface and the solidification diagram are presented for the system Ti-Ni-Zr in the region Ti-TiNi-ZrNi-Zr. Nonvariant equilibria (at 880, 830, and 770 °C) determining phase relations in this composition region are identified. The transition of binary systems to the ternary system is associated with a change in the process type along two boundary curves; a change from a congruent process to an incongruent process is observed at 925 °C with an increase in titanium content. Simultaneous solidification of two phases is observed along other boundary curves.

**A92-10924 Temperature dependence of the Young modulus of commercial beryllium in the temperature range 30-300 K (Temperaturnaya zavisimost' modulia lunga tekhnicheskogo berillia v intervalle temperatur 30-300 K).** F. F. LAVRENT'EV, O. P. SALITA, S. V. SOKOL'SKII, and O. V. MATSIEVSKII, *Metallfizika* (ISSN 0204-3580), Vol. 13, May 1991, pp. 38-44. Refs.

An apparatus is described which makes it possible to measure the longitudinal modulus of elasticity,  $E$ , at low temperatures by using the method of transverse static bending. Results of a study of the temperature dependence of the modulus of elasticity at 30-300 K are presented for three grades of commercial beryllium. It is suggested that the temperature dependence of  $E$  is largely determined by changes in the linear expansion coefficient with temperature. The effect of the grain size and orientation on the elastic modulus of the alloys is demonstrated.

**A92-10847 Effect of interstitial impurities on the fracture toughness of ductile titanium alloys. II (Vliianie primesei vnedreniia na treshchinostoiost' plastichnykh titanovykh splyavov. II).** V. T. TROSHCHENKO, V. V. POKROVSKII, and V. L. IARUSEVICH, *Problemy Prochnosti* (ISSN 0556-171X), Aug. 1991, pp. 30-36. Refs.

The fracture toughness of 2V titanium alloy containing 0.05-0.35 percent nitrogen and oxygen is investigated using an approach based on the J-integral. The optimal concentrations of nitrogen and oxygen, corresponding to an optimum combination of fracture toughness and strength, are determined. Expressions are obtained for calculating the resistance to microfracture from the geometrical parameters of the plate-like alpha phase. The approach makes it possible to estimate the fracture toughness of the alloy with sufficient accuracy over the full range of impurity concentrations using empirical expressions.

**A92-10846 Effect of interstitial impurities on the fracture toughness of ductile titanium alloys. I (Vliianie primesei vnedreniia na treshchinostoiost' plastichnykh titanovykh splyavov. I).** V. T. TROSHCHENKO, V. V. POKROVSKII, V. L. IARUSEVICH, V. I. MIKHAILOV, and V. A. SHER, *Problemy Prochnosti* (ISSN 0556-171X), Aug. 1991, pp. 23-30. Refs.

A study is made of the effect of nitrogen and oxygen impurities in concentrations of 0.05-0.35 percent on the mechanical properties and fracture toughness of a ductile titanium alloy, 2V. It is found that the fracture toughness characteristics of the alloy change nonmonotonically with nitrogen and oxygen contents. A quantitative relation is established between impurity contents and geometrical parameters of the lamellar structure. Expressions are obtained which make it possible to estimate the fracture toughness of the alloy from the known hardness and geometrical parameters of the structure.

**A91-50914 Effect of molybdenum on the phase composition of Nb-Ti-Al alloys at 1400-600 °C (Vliianie molibdena na fazovyi sostav splyavov sistemy Nb-Ti-Al pri 1400-600 °C).** A. M. ZAKHAROV, A. V. PAVLOV, and T. L. KAGANOVA, *Akademiia Nauk SSSR, Izvestiia, Metally* (ISSN 0568-5303), May-June 1991, pp. 102-106. 10 Refs.

The effect of additions of up to 10 wt pct Mo on the phase compositions of Nb-based alloys containing 20-35 wt pct Ti and 6 wt pct Al at 600-1400 °C was investigated using metallographic and X-ray observations and XRD analyses. It was found that, depending on the alloy composition and temperature, the Nb-Ti-Al alloys contain the beta-solid solution based on Nb as well as the intermediate phases sigma (Nb,Ti)2Al alpha-2 Ti2NbAl or Ti2.4Nb(0.6)Al, having bcc, tetragonal, or ordered rhombic lattices, respectively. It was found that Mo additions shift the concentration minimum of Ti for the formation of the sigma phase from greater than 31-32 percent to a lower level.

**A91-52674 Effect of iron on the structure of silicon-containing Al-Zn-Mg-Cu alloys (Vliianie zheleza na strukturu splyavov Al-Zn-Mg-Cu s primes'iu kremniia).** A. A. AKSENOV, N. A. BELOV, and V. S. ZOLOTOROVSKII, *Akademiia Nauk SSSR, Izvestiia, Metally* (ISSN 0568-5303), July-Aug. 1991, pp. 209-211. 6 Refs.

The effect of iron on the structure and properties of silicon-containing Al-Zn-Mg-Cu alloys was investigated metallographically and by electron probe microanalysis. For iron and silicon contents of 1-1.7 and 0.25-0.4 percent, respectively, it is shown that these elements may be completely bound in the phase alpha(Fe2SiAl8) within the disperse eutectic which is susceptible to fragmentation to individual inclusions during heating at 520 °C. Since the phase Mg2Si is not formed in this case, the presence of Si

does not lead to a reduction in strength characteristics.

**A92-12185 Effect of heat-resistant coatings on the structure of ZhS6K alloys (Vliianie zharostoikikh pokrytii na strukturu splyavov ZhS6K).** L. P. EFIMENKO, *Metallovedenie i Termicheskaiia Obrabotka Metallov* (ISSN 0026-0819), No. 9, 1991, pp. 24, 25. 5 Refs.

The effect of heat-resistant coatings based on NiAl with additions of Cr, W, Si, and C on the composition and structure of ZhS6K alloy was investigated experimentally in the as-deposited condition and following prolonged high-temperature exposures. It is found that an additional hold at 1100 °C and diffusion of the coating elements into the alloy have a negative effect on the structure and composition of the alloy. The additional hold leads to the precipitation of acicular secondary phases, a process further accelerated by the diffusion of coating elements.

**A91-52684 Mechanism of the formation of hardened surface layers on titanium alloys in a dynamic rarefied nitrogen atmosphere (Mekhanizm formirovaniia pri poverkhnostnykh uprochnennykh sloev na titanovykh splyavakh v razrezhennoi dinamicheskoi atmosfere azota).** G. G. MAKSIMOVICH, V. N. FEDIRKO, and I. N. POGRELIUK, *Fiziko-Khimicheskaiia Mekhanika Materialov* (ISSN 0430-6252), Vol. 27, Mar.-Apr. 1991, pp. 38-42. 6 Refs.

The kinetics of nitriding in a dynamic nitrogen atmosphere rarefied to 10<sup>-0.1</sup> Pa at 850 °C was investigated using 10 x 15 x 1 mm specimens of commercial titanium alloys VT1-0, OT4-1, and VT6s. Kinetic curves obtained at 0.1 Pa are strictly parabolic; as the degree of rarefaction decreases, the kinetic curves deviate from the parabolic shape. The nitride layers formed on titanium during nitriding in a rarefied atmosphere are the product of transformation of titanium oxynitrides of varying composition formed at the initial saturation stages.

**A91-50915 Characteristics of the viscous-brittle transition in the Mo + 4 pct Re, the TsM-10, and the MChVP alloys (Osobennosti viazokhrupkogo perekhoda v splyavakh Mo + 4 pct Re, TsM-10 i MChVP).** A. N. SHCHERBAN', V. F. MOISEEV, E. P. PECHKOVSKII, O. I. BAN'KOVSKII, E. P. POLISHCHUK, and M. E. GOLOVKOVA, *Akademiia Nauk SSSR, Izvestiia, Metally* (ISSN 0568-5303), May-June 1991, pp. 129-133. 11 Refs.

The causes of the lowering of the temperature of the cold brittleness and an increase in plasticity brought about by alloying Mo with 4-6 percent Re were investigated by comparing the mechanical characteristics of three molybdenum-based alloys: Mo-4 percent Re, TsM-10, and MChVP (technical-purity Mo). Results of fractographic studies suggest that small additions of Re result in grain boundaries free from segregations of trace impurities.

**A91-43191 Ceramic materials with an endogenous reinforcement—Structural ceramics (Keramicheskie endogennoarmirovannnye materialy—Konstruktsionnaia keramika).** N. N. RASKATOV, I. I. ZVEZDIN, and A. A. VERTMAN, *Akademiia Nauk SSSR, Doklady* (ISSN 0002-3264), Vol. 317, No. 4, 1991, pp. 913-916. 6 Refs.

Structural ceramics with endogenous reinforcements were produced by the directional solidification of eutectics in the following systems: Al2O3-ZrO2 (Y2O3-stabilized), Al2O3-HfO2, Al2O3-Al2TiO5, Al2O3-TiC, MgO-ZrO2, and MgO-Al2MgO4. Alloys of eutectic and nearly eutectic compositions were solidified by optical zone melting, characterized by high temperature gradients (800 °C/cm) at the solidification front, and by vertical directional solidification in molybdenum containers with relatively low temperature gradients (120-130 °C/cm). The structure of the ceramics and the effect of the solidification conditions on their structural and strength characteristics are discussed.

**A91-41224 Structure, deformation mechanism, and strength characteristics of aging Cu-Ni-Mn alloys (Struktura, mekhanizm deformatsii i prochnostnye svoistva stareiushchikh splyavov Cu-Ni-Mn).** N. A. POLIAKOVA, V. A. UDOVENKO, and E. D. CHICHUA, *Fizika Metallov i Metallovedenie* (ISSN 0015-3230), Jan. 1991, pp. 178-187. 9 Refs.

The effect of isothermal tempering on the structure and deformation mechanisms of single crystals of the quasi-binary section Cu-Ni-Mn with a varying volume fraction of the hardening theta phase was investigated by electron microscopy and electron and neutron diffraction analyses. It is shown that the braking of dislocations by elastic stress fields around coherent precipitates is an effective hardening mechanism in these alloys. The contribution of this hardening mechanism can be varied by varying the volume fraction of the precipitate phase, precipitate size, and ratio between particles of different orientations.

**A91-40089 Effect of the structure on the hardening of high titanium alloys with transition metals (Vliianie struktury na uprochnenie vysokolegirovannykh splyavov titana s perekhodnymi metallami).** L. K. KONDRATENKO and L. N. GUSEVA, *Akademiia Nauk SSSR, Izvestiia, Metally* (ISSN 0568-5303), Mar.-Apr. 1991, pp. 95-98. 5 Refs.

A study is made of the structural hardening of two-component high titanium alloys with vanadium, niobium, and molybdenum. Changes in the alloy hardness are determined as a function of the composition after quenching from the beta region and aging at 400 °C. Low-temperature aging leads to the complete decomposition of the omega phase and formation of metastable or equilibrium fine-grained alpha and beta phases. Maximum structural hardening is achieved in alloys with the most heterogeneous structure. It is suggested that metastable phase diagrams be used to predict alloy properties.

**A91-48519 TEM study of a superplastically deformed Ni3Al alloy doped with boron.** R. Z. VALIEV, R. M. GAIANOV, H. S. YANG, and A. K. MUKHERJEE, *Scripta Metallurgica et Materialia* (ISSN 0956-716X), Vol. 25, Aug. 1991, pp. 1945-1950. Research supported by AN SSSR. 24 Refs.

The superplastic deformation of a boron-doped Ni3Al alloy at 1373 K was investigated by transmission electron microscopy. It is found that many of the structural changes typical of conventional superplastic metals and alloys are observed during the superplastic deformation of Ni3Al. These include strain induced grain growth, a very small degree of grain elongation, and the presence of a dislocation structure. The superplastic flow of the alloy is associated with grain boundary sliding, intragranular dislocation activity, and diffusion.

**A91-47528 Prospects of using rare-earth gadolinium-dysprosium alloys as the working media of refrigerators (Perspektivnost' ispol'zovaniia redkozemel'nykh splavov gadolinii-disprozi i v kachestve rabochikh tel refrizheratorov).** G. S. BURKHANOV, S. I. U. DAN'KOV, S. A. NIKITIN, A. M. TISHIN, and O. D. CHISTIYAKOV, *Pis'ma v Zhurnal Tekhnicheskoi Fiziki* (ISSN 0320-0116), Vol. 17, May 26, 1991, pp. 7-11. 4 Refs.

A comparison of data for various Dy concentrations in Gd(1-x)Dy(x) compounds indicates that the combination Gd0.59(Gd0.30Dy0.10)0.41 will make a suitable working medium for refrigeration systems. This combination can be an effective cooling agent for magnetic refrigerators operating at room temperature.

## Japanese Aerospace Literature This month: Alloys

**A92-32693 Mechanical properties of aluminum borate whisker reinforced aluminum alloys and interface structure.** K. SUGANUMA, G. SASAKI, T. FUJITA, and N. SUZUKI, *Proceedings of the 8th International Conference on Composite Materials, Composites (ICCM/8)*, Honolulu, HI, July 15-19, 1991. Section 12-21 (A92-32535 13-39). Covina, CA, Society for the Advancement of Material and Process Engineering, 1991, pp. 19-D-1 to 19-D-12. 5 Refs.

Specimens of aluminum alloys reinforced by aluminum borate whiskers fabricated by squeeze casting were tested mechanically, and the fiber-matrix interface was examined by transmission electron microscopy. A comparison of the mechanical properties of 6061 alloy matrix composites reinforced with aluminum borate and other types (i.e., silicon carbide, silicon nitride, and potassium titanate) whiskers demonstrates the advantages of the new whiskers. The aluminum borate/aluminum composites have high strength at elevated temperatures, high Young's modulus, and low thermal expansion coefficient. The reaction between aluminum borate whiskers and aluminum alloy is not severe. A thin amorphous-like layer is formed at the whisker-matrix interface.

**A92-29569 Ni-base oxide dispersion strengthened alloys for turbine applications.** JUN-JI TSUJI, TAKAHITO HOSOKAWA, NORIYASU OGURI, KAZUAKI MINO, and KOICHI ASAKAWA, *Ishikawajima-Harima Engineering Review* (ISSN 0578-7904), Vol. 31, Nov. 1991, pp. 447-451. 3 Refs.

A study has been made on the development of oxide dispersion strengthened (ODS) alloy technologies. An ODS alloy is a hopeful candidate material for turbine components with largely increased inlet temperatures. It is necessary to improve the creep properties at intermediate temperatures as well as high temperatures and also to develop the forming and manufacturing technologies for the practical use of ODS alloys. Various properties, which are important in selecting as a turbine component material, of ODS alloys newly developed were compared with those of single crystals currently in use. Also described were the developmental studies on isothermal forging treatment for directional recrystallization and diffusion bonding technologies which are necessary to produce complicated air-cooled blade and vane structures.

**A92-29526 Effect of alloy composition on age-hardening behavior of rapidly solidified Al-Mn-Cr alloys.** HEE T. SHIN, JUNICHI KANEKO, and MAKOTO SUGAMATA, *Japan Institute of Metals Journal* (ISSN 0021-4876), Vol. 56, Jan. 1992, pp. 15-22. 18 Refs.

Al-Mn-Cr alloys of various compositions were rapidly solidified into solid solutions of extended solid solubilities, and P/M materials were consolidated from rapidly solidified flakes by cold pressing, vacuum degassing, and hot extrusion. Age hardening behavior was examined for both rapidly solidified flakes and P/M materials. Significant age hardening was observed for the alloys containing 10 mass pct of Mn + Cr. However, extruded P/M materials of these alloys showed higher peak hardness than as rapidly solidified flakes. This thermomechanical effect was observed on age hardening of the alloys containing 10 percent of Mn + Cr, whereas no such effect was observed for the alloys containing 7 percent or less of Mn + Cr. Therefore, the optimum Mn and Cr contents for age hardening of rapidly solidified Al-Mn-Cr alloys are such that the G phase, (Mn, Cr)Al12, is the only constituent phase other than alpha-Al, and thus the Al-8Mn-2Cr alloy showed the highest age hardenability.

**A91-38226 Influence of oxygen content on electrical resistivity and phase constitution in quenched Ti-V alloys.** MASAHIKO IKEDA, SHIN-YA KOMATSU, TAKASHI SUGIMOTO, and KIYOSHI KAMEI, *Japan Institute of Metals Journal* (ISSN 0021-4876), Vol. 55, March 1991, pp. 260-266. 19 Refs.

The effect of oxygen addition on the specific resistivity and hardness of three series of alloys, Ti-10-40 pct V, Ti-20 pct V, and Ti-30 pct V, quenched from beta-phase range temperatures is studied. X-ray diffraction was used to confirm the phase constitution at the RT. The X-ray phase constitution of Ti-V-0.3 pct alloys showed no significant difference from previous alloy series containing about 0.1 pct O.

**A92-29498 Effect of hydrostatic pressures on thermoelastic martensitic transformations in aged Ti-Ni and ausaged Fe-Ni-Co-Ti shape memory alloys.** TOMOYUKI KAKESHITA, KEN'ICHI SHIMIZU, SEI NAKAMICHI, RITSU TANAKA, SHOICHI ENDO, and FUMIHISA ONO, *JIM, Materials Transactions* (ISSN 0916-1821), Vol. 33, Jan. 1992, pp. 1-6. Research supported by Osaka University and MOESC. 18 Refs.

The effect of hydrostatic pressures on thermoelastic martensitic transformations in aged Ti-51 at pct Ni and ausaged Fe-31.9Ni-9.8Co-4.1Ti (at pct) shape memory alloys has been investigated by electrical resistivity measurements under hydrostatic pressures up to 1.5 GPa. The results obtained were as follows: transformation temperatures of the B2 = R transformations for two kinds of Ti-Ni alloys aged for short and long periods were independent of pressure. Ms and As temperatures of the successive R - B19-prime transformations were linearly increased with increasing pressure for the short aged Ti-Ni alloy, but remained constant for the long aged one. On the other hand, the Ms and As temperatures in the ausaged Fe-Ni-Co-Ti alloy were inversely decreased with increasing pressure. A thermodynamic analysis on the pressure dependence of the thermodynamic equilibrium temperature, which was obtained from the measured transformation temperatures, showed that the effect of hydrostatic pressures on the B2 - R and R - B19-prime martensitic transformations in the short aged Ti-Ni alloy was successfully explained by a modified Patel and Cohen's equation, but was not for the gamma - alpha-prime transformation in the ausaged Fe-Ni-Co-Ti alloy.

**A92-28000 Ultra-fine equiaxed grains obtained by process of hydrogenation, aging and dehydrogenation in alpha + beta type titanium alloys.** HIROFUMI YOSHIMURA, KIN'ICHI KIMURA, MASAYUKI HAYASHI, MITSUO ISHII, and JIN-ICHI TAKAMURA, *Japan Institute of Metals Journal* (ISSN 0021-4876), Vol. 55, Dec. 1991, pp. 1375-1381. 13 Refs.

A procedure is described for equiaxed grain refinement in alpha + beta titanium alloys, with particular consideration given to the appearance of two different types of dislocation structures introduced by this procedure. In this procedure, the titanium alloys are hydrogenated with large amounts of hydrogen and dehydrogenated in vacuum at elevated temperatures. Of the two types of dislocation structures, one is introduced by the precipitation of hydrides on aging at relatively low temperature after solution treatment of hydrogenated Ti alloys; the other is introduced by martensitic transformation on cooling from the beta-phase or the alpha + beta two-phase region of hydrogenated titanium alloys. The combination of the two factors results in Ti-6Al-4V alloys exhibiting equiaxed grains of about 1-micron diameter.

**A92-21706 Improvement in oxidation resistance of the Ti-31 to 39 mass pct Al alloys by heat treatment under a low partial pressure oxygen atmosphere.** MICHIO YOSHIHARA, RYOHEI TANAKA, TETSUYA SUZUKI, and MORIYASU GOTO, *JIM, Materials Transactions* (ISSN 0916-1821), Vol. 32, Nov. 1991, pp. 1017-1023. Research supported by MOESC. 13 Refs.

The oxidation behavior of Ti-31 to 39 mass pct Al and Ti-36 mass pct Al, with various oxygen contents, is presently investigated with a view to the effect of heat treatment under low oxygen partial pressure. Cyclic oxidation tests were conducted at 900 and 950 C in an air atmosphere. It is found that nonheat-treated specimen oxidation behavior depends on Al content, with oxidative mass gain decreasing with rising Al content. At 700 C, TiO2 emerged in alloys with higher oxygen content.

**A92-13442 Castability of Al-Li alloys.** SEIJI SAIKAWA, SHIGERU SUGIOKA, KIYOSHI NAKAI, YASUO SUGIURA, and AKIHIKO KAMIO, *Japan Institute of Light Metals Journal* (ISSN 0451-5994), Vol. 41, Sept. 1991, pp. 596-601. 10 Refs.

The casting characteristics of Al-3Si-1Mg-0.15Zr (in percent) containing 1, 2, or 3 percent Li were investigated. It was found that Li losses were about 0.1, 0.2, and 0.4 percent for alloys containing 1, 2, and 3 percent Li, respectively, when the alloys were melted and held for 3 ksec at 973 K in air.