

Japanese Aerospace Literature This month: *Aluminium Alloys*

N94-28171 Formation and high mechanical strength of Al-based alloys containing a nanoscale icosahedral phase as a main constituent. A. INOUE, and M. WATANABE, (Akita Univ., Japan.), HISAMICHI, KIMURA and T. MASUMOTO, In *The Science Reports of the Research Institutes*, Tohoku University. Series A: Physics, Chemistry, and Metallurgy. Vol. 38, No. 1: Amorphous Materials 14, pp. 138-160 (SEE N94-28158 07-26) Documents available from Aeroplus Dispatch.

This report reviews recent results on the achievement of high tensile strength and good ductility for rapidly solidified Al-Mn-Ln and Al-Cr-Ln (Ln = lanthanide metal) alloys containing an icosahedral phase as a main constituent phase. The good mechanical properties are attributed to the simultaneous achievement of the following three structural effects resulting from rapid solidification and appropriate alloy design: the formation of a mixed structure consisting of nanoscale icosahedral particles surrounded by Al phase; the formation of the icosahedral phase at low solute concentrations; and the achievement of an ultra-fine mixed state of icosahedral and approximant regions caused by the phase strain-induced approximant transition in the nanoscale icosahedral particles. The utilization of the structural effects is expected to cause high mechanical strengths combined with good ductility for other quasicrystalline alloys. (Author)

N94-28167 Mechanical behavior of amorphous alloys at elevated temperatures. H. OKUMURA, A. INOUE, and T. MASUMOTO, In *The Science Reports of the Research Institutes*, Tohoku University. Series A: Physics, Chemistry, and Metallurgy. Vol. 38, No. 1: Amorphous Materials 14, pp. 88-98 (SEE N94-28158 07-26) Documents available from Aeroplus Dispatch.

Mechanical behavior of amorphous alloys has been investigated through the static and dynamic mechanical measurements. Two stress relaxation systems are observed in the dynamic measurements; the sub-T(sub g) relaxation and the T(sub g) relaxation. These relaxations seem to cause the change in the deformation mode from inhomogeneous to homogeneous deformation which is seen in the static stress-strain curves. The stress relaxation systems also correlate to the ductility of amorphous alloys. The decrease in the stress relaxation resulting from the lack of the sub-T(sub g) relaxation causes embrittlement. (Author)

N94-28162 NMR study of quasicrystal Al(70)Pd(20)T(M10) alloy (T(M):Cr, Mn, Fe, and Co). T. SHINOHARA, and T. SATO, In *The Science Reports of the Research Institutes*, Tohoku University. Series A: Physics, Chemistry, and Metallurgy. Vol. 38, No. 1: Amorphous Materials 14, pp. 34-42 (SEE N94-28158 07-26) Documents available from Aeroplus Dispatch.

Nuclear Magnetic Resonance (Al-27, Mn-55, and Co-59) measurements have been made on quasicrystalline phases of the Al70Pd20T(sub M)10 alloy (T(sub M): Cr, Mn, Fe and Co) in the temperature range between 5 K and room temperature. There is no marked temperature dependence in peak shift and line width of either the Al-27 or Co-59 NMR spectra, except for the Al-27 and Mn-55 spectra in the Al70Pd20Mn10. However, the peak shift of these spectra depends upon the constituent transition element. For the Al70Pd20Mn10, the negative Al-27 Knight shift and line broadening at low temperatures indicate that there exist two classes of Mn atoms, magnetic and nonmagnetic ones. (Author)

N94-26477 Toward insulating quasicrystalline alloy in Al-Pd-Re icosahedral phase. H. AKIYAMA, Y. HONDA, T. HASHIMOTO, K. EDAGAWA, and S. TAKEUCHI, Documents available from Aeroplus Dispatch.

The resistivities in Al70Pd20Re10 alloy of the icosahedral phase are quite sample-dependent, possibly due to slight variation of the alloy composition. In some samples, the resistivity at room temperature is approximately 0.01 omega cm and that at 4.2 K is as high as approximately 0.1 omega cm; these values are much higher than any reported values so far for quasi-crystals. The temperature dependence of the conductivity is almost linear above 4.2 K and the magnetoconductivity is negative. These dependencies are interpreted by the theory of weak localization which takes into account the spin-orbit scattering. (Author)

N94-26071 Formation of three types of quasi-crystals in Al-Pd-Mg system. N. KOSHIKAWA, K. EDAGAWA, Y. HONDA, and S. TAKEUCHI, Documents available from Aeroplus Dispatch.

In the Al-Pd-Mg system, a Mackay-Icosahedron (MI) type Icosahedral (I) phase with the F-type superlattice order and a Decagonal (D) phase were found to form in a melt-quenched state, in addition to the Frank-Kasper (FK) type stable I-phase reported previously. This is the first example in which the three types of quasi-crystalline phases are formed in the same alloy system. The formation range of the FK-type I-phase in melt-quenched state is rather wide: 5-20 at percent Pd and 20-45 at percent Mg. In contrast, the MI-type, I-phase and D-phase are formed in small composition ranges around Al52Pd31Mg17 and Al74Pd21Mg5, respectively. Electron diffraction studies showed that the period along the tenfold axis of the D-phase is about 1.6 nm. The formation and stability of the MI-type and FK-type I-phases were discussed in terms of a Hume-Rothery rule. (Author)

N94-25577 Study on improvement in physical analysis method of metallic materials (Kinzoku zairyo no butsuri bunseki shuho no kodoka ni kansuru kenkyu). Y. TAMURA, T. OKOSHI, K. HONMA, T. KIMURA,

K. OGAWA, H. DOI, and Y. ISODA, In *Bulletin of National Research Institute for Metals in Fiscal Year 1993*, No. 14, pp. 309-321 (SEE N94-25544 07-26) Documents available from Aeroplus Dispatch.

Refinement of technology for crystal structures was investigated with the purpose of improvement in physical analysis. The research had two themes. One is an analysis by x ray diffraction. The x ray diffraction determining the long periodical structures of binary alloys was extended in order to determine site locations and the mutual substitution amount between Ti and Al elements of ternary TiAl-X alloys. These alloys were produced by adding V, Mn, Zr, or Nb to binary TiAl alloys. It was found that V and Mn atoms were chiefly solid solutionized to Al sites, and Zr and Nb atoms to Ti sites. The mutual substitution amount between Al and Ti atoms decreased as the density of V and Mn increased. The other theme is an analysis by high resolution electron microscopy. Fe 30 mol percent FeO, composed by sintering carbonyl and FeO powders, was observed at Fe/FeO interfaces by a high resolution electron microscope. The results were compared with the composition analysis results of oxidized crystals obtained by Auger electron spectroscopy. Migration areas of distorted FeO cubes with decreased oxygen were generated at (111) Fe/(110) FeO interfaces. Excess oxygen was diffused from FeO in the areas with decreased oxygen, and those areas played a significant role to the joint of Fe/FeO phases. (Author)

N94-25573 Study on solidification of non-homogeneous melting/solidification materials (Fukinshitsu yokai gyokozai no gyoko ni kansuru kenkyu). G. OMORI, O. NAKANO, T. MITSUI, H. SUGE, N. SAKUMA, and K. TOGANO, In *Bulletin of National Research Institute for Metals in Fiscal Year 1993*, No. 14, pp. 269-273 (SEE N94-25544 07-26) Documents available from Aeroplus Dispatch.

An attempt was made to produce homogeneous cast lumpby quick solidification from a uniform liquid state. Al-Pb alloys were used for this experiment, and fundamental data were obtained along with property evaluation. The purpose is the production of homogeneous cast lumps of monotectic alloys with big differences in melting points, specific gravities, and little solubility limits with each other. First, Al-Pb alloys up to 30 mass percent on the excess monotectic side were prepared as an amount for Pb in order to obtain fundamental data for alloy production. The factor influencing the texture homogenization was considered to be the cooling rate at two liquid phase separation areas, and Pb diffusion conditions in Al base were studied with the correlation between the cooling rate and textures. At rapid solidification, the cooling rate at two liquid phase separation areas became slower as the alloy mass and Pb density increased. The cooling rate much influenced the solidified textures, and faster cooling rates caused fine, uniform Pb grain diffusion. ZnCl2 and SnCl2 were effective as fusing agents for hot Pb galvanizing. Among various plating methods, excellent wetness and coherency are obtained with the method in which a fusing agent is applied to Al-Pb alloy base and it is solidified by cooling, and then melting Pb is dripped. (Author)

N94-25572 Study on production of materials with one direction solidification texture (Ichihoko gyoko soshiki zairyo no sosei ni kansuru kenkyu). A. SATO, T. NAMAI, Y. OSAWA, and G. ARAGANE, In *Bulletin of National Research Institute for Metals in Fiscal Year 1993*, No. 14, pp. 259-268 (SEE N94-25544 07-26) Documents available from Aeroplus Dispatch.

By utilizing the solidification process of metal alloys, investigation was made focusing on the following four items with the purposes of producing materials with one directional solidification texture and developing new structured materials. Moldless upward continuous casting: Al-Cu and Al-Si alloy rods with a wide range of freezing points were produced. The crystals of these rods were completely in one direction lengthwise. It was also clarified that pure aluminum rods with various surface shapes could be produced by refractory molding tools. Composite material production by centrifugal casting: Research was conducted to improve wear resistance and heat dilatation at specific areas of materials by controlling the distribution of the primary Si crystals resulting from centrifugal segregation. The primary Si crystals tend to segregate around the outer circumference of test samples due to centrifugal force. This segregated distribution changes the material properties. Supersonic oscillation application to melting metals: Two methods were investigated to apply supersonic oscillation to melting metals. One was to transmit oscillation by melting metals, and the other to use Al coated film steel horns. Both methods were effective in preventing steel loss from melting steels and grain refinement of solidified texture. Fundamental studies of materials with one direction solidification: It was confirmed that the dendrite became coarse when the solidification rate and solute density were lowered while the temperature was kept constant. (Author)

N94-25553 Inner fiber observation for metal matrix composites under the stress load condition utilizing Synchrotron Orbital Radiation (SR) by X-ray CT (Shinkuroton hoshako (SR) o riyo shita x sen CT bu yoru oryoku fuka jotai ni okeru fukugo zairyo no naibu kansatsy). C. MASUDA, Y. TANAKA, P. MAHAJAN, K. USAMI, (Hitachi Ltd., Tokyo, Japan.), and T. HIRANO, (Hitachi Ltd., Tokyo, Japan.) In *Bulletin of National Research Institute for Metals in Fiscal Year 1993*, No. 14, pp. 97-106 (SEE N94-25544 07-26) Documents available from Aeroplus Dispatch.

Observations were made of inner fiber damage in metal matrix composites (MMC) by using stress load equipment in concert with X-ray CT (Computer

Tomography) equipment. A layer of test samples was prepared from long fiber strengthened MMC's, and a stress load was applied to observe the breaking process. The X-ray images of SiC (C)/C/A6N01 material and B (W)/A6N01 material after the stress load process showed different break structures. Inner fiber ruptures and strengthened fiber slippings that were observed should contribute useful information to clarify the relationship between the surface and dynamic characteristics. By observing particle dispersion strengthened MCC's by means of X-ray CT, it was found that the accompanying void generation, up to the maximum tension force, remained almost unchanged, like that with no load; although, the void size increased as the load increased. Voids were also generated just before the sample failed. In conclusion, it is possible to measure and analyze the damage in MMC's due to strain load tension processes. It is also possible to gather data on broken fiber length as it relates to rupture characteristics. It was also confirmed that the equipment developed in this research was effective. (Author)

A94-25082 Effect of Zr, Sn and Al addition on mechanical properties of metastable beta titanium alloys. S. ISIYAMA, (Nippon Stainless Steel Co., Ltd., Jyotsu, Japan), and S. HANADA, In *Titanium '92: Science and technology; Proceedings of the Symposium*, World Titanium Conference, 7th, San Diego, CA, June 29–July 2, 1992. Vol. 2 (A94-24901 06-26), Warrendale, PA, Minerals, Metals, and Materials Society, 1993, pp. 1,947–1,954. 11 Refs. Documents available from Aeroplus Dispatch.

Mechanical properties of metastable beta titanium alloys were investigated using Ti-16V and Ti-7Cr base alloys doped with Sn, Zr and Al as ternary or quaternary additions. Zr addition had little influence on the mechanical properties, while Sn addition decreased flow stress and increased elongation markedly. In Al added alloys, rapid work hardening followed by secondary yielding was observed after extremely low yielding. This tendency became clear with increasing Al content, which resulted in a remarkable deterioration in elongation. These results are explained by considering the effect of Zr, Sn, and Al addition on deformation modes and beta phase stability. (Author)

A94-25074 Improvement of hydrogen embrittlement of beta Ti alloy. A. NOZUE, T. OKUBO, Y. SAITA, and S. HYOE, In *Titanium '92: Science and technology; Proceedings of the Symposium*, World Titanium Conference, 7th, San Diego, CA, June 29–July 2, 1992. Vol. 2 (A94-24901 06-26), Warrendale, PA, Minerals, Metals, and Materials Society, 1993, pp. 1,867–1,873. 6 Refs. Documents available from Aeroplus Dispatch.

A new heat treatment process has been developed to reduce the hydrogen embrittlement of a beta Ti-15V-3Cr-3Sn-3Al alloy. The new process involves solution treatment at 1223 K, aging at 783 K for 14.4 ks, and then aging at 713 K for 10.8 ks. After the first aging, precipitate-free zones are formed around grain boundaries, and the specimens contain a small fraction of alpha precipitates within the grains. After the second aging, the specimens contain a relatively high fraction of the alpha phase precipitates within the grains while still retaining the precipitate-free zones. The new process makes it possible to obtain the desirable mechanical properties in this alloy.

A94-25071 Fatigue crack propagation in Ti-6Al-4V alloys containing retained metastable beta phase. M. NIINOMI, T. KOBAYASHI, and A. SHIMOKAWA, In *Titanium '92: Science and technology; Proceedings of the Symposium*, World Titanium Conference, 7th, San Diego, CA, June 29–July 2, 1992. Vol. 2 (A94-24901 06-26), Warrendale, PA, Minerals, Metals, and Materials Society, 1993, pp. 1,835–1,842. 6 Refs. Documents available from Aeroplus Dispatch.

Fatigue crack propagation characteristics in solutionized specimens and aged specimens of Ti-6Al-4V forged bars and rolled plates were investigated. Fatigue crack propagation rate of the IIb region in solutionized specimens is greater than that in aged ones, particularly in the case of rolled Ti-6Al-4V plates. Crack closure of solutionized specimens is greater than that of aged ones in both forged bars and rolled plates of Ti-6Al-4V alloys. Deformation induced twins or martensite are thought to induce crack closure and retard the fatigue crack propagation rate in rolled plates of Ti-6Al-4V alloys. (Author revised)

A94-25070 High cycle fatigue properties of Ti-6Al-4V alloys at cryogenic temperatures. K. NAGAI, T. YURI, O. UMEZAWA, T. OGATA, K. ISHIKAWA, (National Research Inst. for Metals, Tsukuba, Japan), Y. ITO, and T. NISHIMURA, (Kobe Steel, Ltd., Japan). In *Titanium '92: Science and technology; Proceedings of the Symposium*, World Titanium Conference, 7th, San Diego, CA, June 29–July 2, 1992. Vol. 2 (A94-24901 06-26), Warrendale, PA, Minerals, Metals, and Materials Society, 1993, pp. 1,827–1,834. 12 Refs. Documents available from Aeroplus Dispatch.

The high cycle fatigue properties of Ti-6Al-4V alloys with 0.054, 0.104, and 0.135 mass percent oxygen were investigated at 293, 77, and 4 K using both as-forged and rolled material. The mean primary alpha size of the lowest oxygen alloy was the smallest. Although rolling did not always produce the finer alpha grain size, the process changed the morphology of alpha grains from plate-like to globular. The fatigue strength of the alloys increased as the test temperature decreased. The fatigue strength of rolled material was higher than that of the forged material, especially at 4 K.

A94-24982 Improvement in mechanical properties of alpha + beta type titanium alloys by microstructural control using thermochemical processing. M. NIINOMI, (Toyoashi Univ. of Technology, Japan), B. GONG,

(Toyoashi Univ. of Technology, Japan; Northeast Univ. of Technology, Shenandoah, China), T. KOBAYASHI, and Y. OHYABU, (Toyoashi Univ. of Technology, Japan). In *Titanium '92: Science and technology; Proceedings of the Symposium*, World Titanium Conference, 7th, San Diego, CA, June 29–July 2, 1992. Vol. 1 (A94-24901 06-26), Warrendale, PA, Minerals, Metals, and Materials Society, 1993, pp. 853–860. 7 Refs. Documents available from Aeroplus Dispatch.

Hydrogen behavior and microstructural modification of Ti-6Al-4V alloys during thermochemical processing (TCP) were investigated. The newly proposed and conventional TCP were conducted in order to refine the microstructure of Ti-6Al-4V and Ti-5Al-2.5Fe alloys. Tensile properties and fracture toughness were measured on the TCP Ti-6Al-4V and Ti-5Al-2.5Fe materials. Newly proposed below-transus hydrogenation TCP was found to be effective in achieving good balance of strength and elongation in Ti-6Al-4V and Ti-5Al-2.5Fe alloys. Fracture toughness of the TCP Ti-6Al-4V alloys was fairly low. (Author)

A94-24964 Effect of stress on hydride formation behavior of Ti-6Al-4V alloy. K. NAKASA, and J. LIU, (Hiroshima Univ., Higashi-Hiroshima, Japan). In *Titanium '92: Science and technology; Proceedings of the Symposium*, World Titanium Conference, 7th, San Diego, CA, June 29–July 2, 1992. Vol. 1 (A94-24901 06-26), Warrendale, PA, Minerals, Metals, and Materials Society, 1993, pp. 619–626. 10 Refs. Documents available from Aeroplus Dispatch.

A microarea XRD analysis was carried out both for bowed-specimen and ball-indentated specimens, which were cathodically hydrogen charged in sulfuric acid solution, in order to investigate the effect of tensile and compressive stresses on the behavior of hydride formation in a Ti-6Al-4V alloy. For the bowed specimen, gamma-hydride (fcc) was formed more easily under tensile stress than under compressive stress. The formation of delta-hydride (fct), on the other hand, was almost insensitive to stress. For the ball-indentated specimen, the amount of gamma- and delta-hydrides showed a minimum in the center of indentation that is concave with the largest compressive stress. The indentation on a plate specimen after hydrogen charging decreased the gamma-hydride but increased the delta-hydride. (Author revised)

A94-24960 Estimation of recrystallized grain size under continuous annealing of cold-rolled beta titanium alloy strips. H. OHYAMA, A. TAKEMURA, T. NISHIMURA, (Kobe Steel, Ltd., Iron and Steel Research Labs., Kakogawa, Japan), and Y. ASHIDA, (Kobe Steel, Ltd., Materials Research Labs., Japan). In *Titanium '92: Science and technology; Proceedings of the Symposium*, World Titanium Conference, 7th, San Diego, CA, June 29–July 2, 1992. Vol. 1 (A94-24901 06-26), Warrendale, PA, Minerals, Metals, and Materials Society, 1993, pp. 579–586. 2 Refs. Documents available from Aeroplus Dispatch.

An investigation is conducted of the recrystallization and grain-growth behavior of a cold-rolled Ti-15V-3Cr-3Sn-3Al alloy strip. A method is proposed for estimating the size of the grain after crystallization by a continuous annealing process. The estimate of the grain size recrystallized via continuous annealing has been conducted by sequentially integrating each increment of isothermal grain growth at each temperature.

A94-24935 Thermodynamics aided design of alpha + alpha(2) high temperature titanium alloys (Ti-Al-Sn-Zr-Nb-Si system). H. ONODERA, S. NAKAZAWA, K. OHNO, T. YAMAGATA, and M. YAMAZAKI, (National Research Inst. for Metals, Tokyo, Japan) In *Titanium '92: Science and technology; Proceedings of the Symposium*, World Titanium Conference, 7th, San Diego, CA, June 29–July 2, 1992. Vol. 1 (A94-24901 06-26), Warrendale, PA, Minerals, Metals, and Materials Society, 1993, pp. 335–342. 13 Refs. Documents available from Aeroplus Dispatch.

In order to construct a design method for alpha + alpha(2) type high temperature titanium alloys, thermodynamic analyses of alpha and alpha(2) phases in the Ti-Al-Sn-Zr-Nb system were performed by means of the two-sublattice model. As the next step, five Ti-Al-Sn-Zr-Nb-Si alloys were designed by this thermodynamic calculation to have the optimum volume fraction of an alpha(2) phase previously proposed. Effects of heat treatments on creep properties were examined by using these alloys. (Author revised)

A94-24914 Effect of heating-rate on the formation of (alpha+beta) microduplex structure in a Ti-15V-3Cr-3Sn-3Al alloy. K. AMEYAMA, (Ritsumeikan Univ., Kyoto, Japan), T. INABA, (Hyogo Prefectural Inst. of Industrial Research, Japan), HIROTA, KENJI (Miki Netsuren Industries Co., Ltd., Hyogo, Japan), K. HIRAI, M. TOKIZANE, (Ritsumeikan Univ., Kyoto, Japan). In *Titanium '92: Science and technology; Proceedings of the Symposium*, World Titanium Conference, 7th, San Diego, CA, June 29–July 2, 1992. Vol. 1 (A94-24901 06-26), Warrendale, PA, Minerals, Metals, and Materials Society, 1993, pp. 169–176. 20 Refs. Documents available from Aeroplus Dispatch.

A beta-metastable Ti alloy is here studied with a view to the effects of cold-rolling and heating-rate effects on alpha-precipitation behavior. With increasing application of cold-rolling, the precipitation of the alpha phase occurred primarily at beta subgrain boundary nodes formed through recovery of the deformed beta phase, either during heating to the aging temperature or in the early stage of aging. In highly cold-rolled samples, an alpha+beta microduplex structure of very fine equiaxed alpha particles and beta subgrains was obtained.