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(54) **MAGNESIUM ALLOY, MAGNESIUM ALLOY MEMBER AND METHOD FOR MANUFACTURING SAME, AND METHOD FOR USING MAGNESIUM ALLOY**

MAGNESIUMLEGIERUNG, MAGNESIUMLEGIERUNGSELEMENT UND VERFAHREN ZUR HERSTELLUNG DAVON SOWIE VERFAHREN ZUR VERWENDUNG DER MAGNESIUMLEGIERUNG

ALLIAGE DE MAGNÉSIUM, ÉLÉMENT EN ALLIAGE DE MAGNÉSIUM ET PROCÉDÉ DE FABRICATION DE CE DERNIER, ET PROCÉDÉ D'UTILISATION DE L'ALLIAGE DE MAGNÉSIUM

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(56) References cited:
EP-A1- 2 319 949 JP-A- 2008 214 668
JP-A- 2013 129 914 JP-B- S 477 973
JP-B- S4 431 694

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• **YASUMASA CHINO ET AL.: 'Mg-Ce-kei**
Magnesium Gokin Atsuenzai no Seikeisei to
Soshiki no Kankei' ABSTRACTS OF THE JAPAN
INSTITUTE OF METALS 27 March 2007, page 452,
XP008174188
• **YASUMASA CHINO ET AL.: 'Mg-0.2mass%Ce**
Gokin no Joon. Koon Asshuku Henkei Tokusei'
ABSTRACTS OF THE JAPAN INSTITUTE OF
METALS 19 September 2007, page 149,
XP008174187
• **YASUMASA CHINO ET AL.: 'Compressive**
deformation behavior at room temperature-773 K
in Mg-0.2 mass% (0.035at.%)Ce alloy' ACTA
MATERIALIA vol. 56, no. 3, February 2008, pages
387 - 394, XP022419142

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Description

Technical Field

[0001] The present invention relates to magnesium alloy members comprising trace amounts of yttrium that allow for easy plastic working in cold and room temperature ranges.

[0002] The present invention also relates to a method for manufacturing a magnesium alloy member that allows for easy cold working, and that is preferred for use in applications such as in automobiles, railcars, aerospace flying objects, and housings of electronic devices.

Background Art

[0003] These types of magnesium alloys are desired in applications where light structural members are needed. Examples of such structural member applications include automobiles, railcars, aerospace flying objects, and housings of electronic devices. However, use of magnesium alloys as structural members has not been realized because of the considerable difficulties involved in the plastic working in cold and room temperature ranges. Wrought magnesium alloys produced by processes such as press-rolling and extrusion are also problematic in terms of yielding stress anisotropy, because the basal plane {0001} crystal orientation becomes in line with the working direction, and creates a large difference between the tensile and compression yielding stresses. As used herein, "cold temperature" means ordinary temperature or a temperature below the recrystallization temperature of the material. The cold working temperatures of magnesium alloys are typically 200°C or less.

[0004] PTL 1 and PTL 2 disclose wrought magnesium alloys that contain 0.1 to 1.5 mol% of yttrium. These wrought magnesium alloys advantageously overcome the yielding stress anisotropy problem, and have excellent cold workability. A problem, however, is that these materials contain yttrium, and are vulnerable to the rising price of yttrium.

[0005] PTL 3 and PTL 4 disclose rolled magnesium alloys that contain 0.01 to 0.5 mol% of yttrium. The advantage of these rolled magnesium alloys is the low yttrium content. However, the basal plane is in line with the press-roll direction (PTL 4, FIG. 1), and it is not difficult to imagine that a large difference occurs between the tensile and compression yielding stresses.

[0006] PTL 5 and PTL 6 disclose rolled magnesium alloys that contain only trace amounts of yttrium for easy workability. These rolled magnesium alloys contain 6 to 16 mass% of lithium, and the β phase of the BCC (body-centered cubic lattice) structure is dispersed in the α phase of the HCP (hexagonal close-packed) structure to improve workability. However, the use of the active element lithium severely impairs the corrosion resistance of the material, and poses a safety problem.

[0007] PTL 7 discloses a magnesium alloy in which quasicrystal grains are dispersed in the magnesium matrix in order to reduce yielding stress anisotropy. However, this magnesium alloy is a Mg-Zn-Re alloy, containing rare earth elements in a content of 0.2 to 1.5 mol%. A problem, then, is that the material is vulnerable to the rising price of rare earths. There is indeed a need to reduce the rare earth content.

[0008] PTL 8 discloses a wrought magnesium alloy that contains 0.03 to 0.54 mol% of yttrium. This wrought magnesium alloy has an average magnesium crystal grain diameter of 1.5 μm or less, and a high concentration of yttrium is segregated in the vicinity of the grain boundary to improve material strength. The solute element remains at high concentration in the vicinity of the grain boundary when the size of matrix is fine and the percentage volume of the grain boundary is high. However, the solute element exists in a solid solution state not in the vicinity of the crystal grain boundary but inside the size of matrix in applications where the crystals have coarse grain diameters (for example, 10 μm or more). The material cannot have high strength in this case.

[0009] PTL9 discloses Mg-based alloy members and exemplifies various Mg-Y alloys having a level between 0.1 and 3.0 at% Y.

Citation List

Patent Literature

[0010]

PTL 1: WO2010/010965

PTL 2: WO2008/117890

PTL 3: JP-A-2010-13725

PTL 4: JP-A-2008-214668

PTL 5: JP-A-2003-226929

PTL 6: JP-A-9-41066

PTL 7: JP-A-2010-222645

PTL 8: Japanese Patent No. 4840751

PTL 9: EP2319949 A1

Summary of Invention

Technical Problem

[0011] In magnesium alloys, strength and ductility are improved by making fine grains using press-rolling, extrusion, and other processes that apply strain, as with the case of other metallic materials. However, the basal plane {0001} becomes in line with the working direction, specifically a basal plane texture is formed during the hot working for reasons attributed to the magnesium crystal structure. For example, the crystal orientation of the basal plane of press-rolled or extruded magnesium aligns parallel to the press-roll or extrusion direction. This is problematic in terms of yielding stress anisotropy, because the compression yielding stress is only 50% to 60% of the tensile yielding stress. There have been attempts to overcome this problem by dispersing quasicrystal grains (PTL 7) or producing alloys (PTLs 1 to 6). However, all of these techniques involve addition of 0.1 mol% or more of rare earth elements, and are vulnerable to the rising price of rare earths.

Solution to Problem

[0012] According to a first aspect of the present invention, there is provided a magnesium alloy member that comprises 0.025 mol% or more and less than 0.05 mol% of yttrium, Mg and unavoidable impurities accounting for the remainder.

[0013] The magnesium alloy has a homogenous composition, and a homogenous crystal structure with an average grain size of several micrometers and several ten micrometers.

[0014] In a second aspect of the invention the magnesium alloy member of the first aspect has an average grain size of 10 μm or more.

[0015] According to a third aspect of the present invention, there is provided a method for producing a magnesium alloy member having a crystal structure which is an equiaxial grain structure, the method comprising: hot plastic working of a magnesium alloy comprising 0.025 mol% or more and less than 0.05 mol% of yttrium, Mg and unavoidable impurities accounting for the remainder in a temperature range of 200°C to 550°C, followed by an isothermal heat treatment performed in a temperature range of 300°C to 600°C.

[0016] The isothermal heat treatment is a process by which a magnesium alloy sample is placed in a maintained constant temperature bath, maintained for a predetermined time period, and slowly cooled in air outside of the bath. The magnesium alloy member may be a wrought magnesium member such as a plate member, a rod member, and a pipe member.

[0017] The method of the third aspect of the present invention produces a magnesium alloy member in which the crystal structure of the member is an equiaxial grain structure with no texture. Equiaxial grain means a three-dimensionally isotropic crystal grain structure that does not stretch or flatten unidirectionally. Texture, or crystal texture as it is also called, refers to a distribution state of the crystal lattice orientation (crystal orientation) of each crystal grain present in a polycrystalline material such as metal. For example, solidifying a cubical crystal metal forms a preferred orientation [100]. In the case of magnesium, the basal plane {0001} tends to align in the strain applying direction, as noted above.

[0018] The magnesium alloy member produced according to the method of the third aspect may have an average grain size of 10 μm or more.

[0019] A fourth aspect of the present invention is a method according to the third aspect in which a compressional nominal strain of 0.4 or more is applied by cold working performed in a temperature range of from room temperature (here and below, room temperature means 15°C to 35°C) to 150°C.

[0020] A fifth aspect of the present invention is a method according to any of the third or fourth aspects in which the average grain size of the magnesium alloy after cold working performed in a temperature range of from room temperature to 150°C is 80% or less of the initial average grain size (undeformed magnesium alloy).

[0021] A sixth aspect of the present invention is a method according to the third aspect in which the strength and hardness of the member after applying nominal strain by cold working performed in a temperature range of from room temperature to 150°C are 15% greater than strength and hardness of the undeformed ones.

Advantageous Effects of Invention

[0022] The present invention induces room temperature recrystallization (grain refining) by controlling the dispersion state of yttrium, scandium in a magnesium alloy. This makes it possible to develop excellent compressional deformation

characteristics. The magnesium alloy member of the present invention overcomes the yielding stress anisotropy problem with its random crystal orientation distribution (after working), and has the same yielding stress for the tensile and compressional deformation with the maintained high strength. Further, the magnesium alloy member of the present invention does not break even under a large applied compressional strain in excess of 50%, and has excellent deformability. Because of the considerably low yttrium content, the magnesium alloy of the present invention is less vulnerable to the material price of yttrium, scandium, and lanthanoid rare earth elements as compared to conventional rare earth-containing magnesium alloys.

Brief Description of Drawings

[0023]

[FIG. 1] FIG. 1 is a photographic representation showing the appearance of a material when the hot working temperature is in the appropriate range.

[FIG. 2] FIG. 2 represents the nominal stress-nominal strain curve obtained after the room-temperature tensile and compression testing of extruded material Mg-0.05Y and extruded and heat-treated material Mg-0.05Y.

[FIG. 3] FIG. 3 represents the nominal stress-nominal strain curve obtained after the room-temperature compression testing of extruded material Mg-Y alloy.

[FIG. 4] FIG. 4 represents the nominal stress-nominal strain curve obtained after the room-temperature compression testing of extruded and heat-treated material Mg-Y alloy.

[FIG. 5] FIG. 5 represents the nominal stress-nominal strain curve obtained after the room-temperature compression testing of cast and heat-treated material Mg-1 mol% Y.

[FIG. 6] FIG. 6 is a photographic representation of the observed scanning electron micrograph/electron backscatter diffraction image of extruded and heat-treated material Mg-0.03Y.

[FIG. 7] FIG. 7 shows a pole figure image of the region observed in FIG. 5, in which ED and TD are directions parallel to and perpendicular to extrusion direction, respectively.

[FIG. 8] FIG. 8 is a photographic representation of extruded and heat-treated material Mg-0.03Y as observed by scanning electron microscopy/electron backscatter diffraction after applying 20% compressional strain.

[FIG. 9] FIG. 9 is a photographic representation of extruded and heat-treated material Mg-0.03Y as observed by scanning electron microscopy/electron backscatter diffraction after applying 50% compressional strain.

[FIG. 10] FIG. 10 is a photographic representation showing the appearance of a material at a low hot working temperature.

Description of Embodiments

[0024] The magnesium alloy of the present invention contains yttrium, Mg and unavoidable impurities accounting for the remainder. A magnesium alloy containing yttrium, and an alloy member of such an alloy will be described below as embodiments of the magnesium alloy and the magnesium alloy member of the present invention.

[0025] For the magnesium alloy member of the present invention to exhibit effect, hot plastic working (hereinafter, also referred to as "hot working") of a magnesium alloy is required to segregate yttrium to a grain boundary, and the yttrium needs to be diffused in the grain interior by isothermal heat treatment. The procedures are as follows.

[0026] For the magnesium alloy member of the present invention to exhibit effect, the magnesium alloy contains yttrium in 0.025 mol% or more and less than 0.05 mol%, and magnesium and unavoidable impurities accounting for the remainder. When the yttrium content is 0.02 mol%, the yttrium exists at 19.5×10^{-10} m radius intervals. This value corresponds to the magnitude about three times the Burgers vector of magnesium, and represents a value that limits the interactions of lattice defects such as dislocations in terms of atomic binding theory. The grain size that allows the yttrium to homogeneously segregate to a grain boundary by the hot working becomes coarser as the yttrium content decreases. It is, however, difficult to obtain the effect because the estimated average grain size after the hot working is 10 μ m or more. Here, the Burgers vector represents the distorted direction of atoms around a dislocation line introduced as a crystallographic linear crystal defect. In edge dislocations, the dislocation line and the Burgers vector are perpendicular to each other, whereas these are parallel to each other in screw dislocations.

[0027] The hot plastic working temperature is conducted at a temperature of 200°C to 550°C, more preferably 250°C to 350°C. When the working temperature is below 200°C, the low working temperature makes dynamic recrystallization less likely to occur. FIG. 1 is a photographic representation showing the appearance of a material when the hot working temperature is in the appropriate range. FIG. 10 is a photographic representation showing the exterior of a material at a low hot working temperature. By comparing FIG. 1 and FIG. 10, it can be seen that an appropriate magnesium alloy member can be produced by setting the hot working temperature in the appropriate temperature range. Above 550°C, the high working temperature makes it difficult to produce an average grain size of 10 μ m or less. There is also a potential

problem in mold lifetime such as in extrusion. The hot working is typically extrusion, forging, press-rolling, or drawing. However, any plastic working may be used, as long as strain can be applied. The equivalent plastic strain during strain application is 1.5 or more, preferably 2.0 or more. When the equivalent plastic strain is less than 1.5, a sufficient strain cannot be applied, and a mixed structure of coarse grains and fine grains appears, making it difficult to homogeneously segregate the yttrium in the vicinity of the grain boundary. With the isothermal heat treatment of a cast material alone without the hot working, the yttrium does not homogeneously diffuse and disperse in the grain interior, and fracture occurs at a nominal strain of about 0.3 as shown in FIG. 5. That is, the effects of the present invention cannot be obtained.

[0028] The temperature of the isothermal heat treatment is preferably equal to or greater than the hot working temperature, so that the yttrium segregated at the grain boundary can diffuse in the grain interior. Specifically, temperature of the isothermal heat treatment is 300°C to 600°C, more preferably 350°C to 450°C. A heat treatment temperature above 600°C may cause the material to burn during the heat treatment. The retention time, which varies with the heat treatment temperature, is preferably 3 minutes to 24 hours. A retention time longer than 24 hours has the possibility of causing abnormal grain growth during the heat treatment.

[0029] The magnesium alloy member having an equiaxial grain structure with no texture can be obtained in this manner. It is also possible to obtain a magnesium alloy member having an average grain size of 10 μm or more, for example 30 μm to 50 μm.

[0030] The magnesium alloy member may be subjected to cold plastic working (hereinafter, also referred to as "cold working") in a temperature range of from room temperature to 150°C. For example, a compressional nominal strain of 0.4 or more can be applied. The upper limit is 1.5. The cold working refines the crystal grains of the magnesium alloy member. For example, the size of matrix can be refined to 80% or less of the average grain size of the magnesium alloy member after the cold working. The lower limit is 5%, though it is not particularly limited.

[0031] Refining of the crystal grains by cold working can increase the hardness and strength of the magnesium alloy member. For example, the hardness of the magnesium alloy member can be increased 15% or more after the cold working. The strength of the magnesium alloy member also can be increased 15% or more after the cold working.

[0032] As described above, in the present embodiment, the dispersion state of yttrium is controlled by hot working the magnesium alloy to segregate yttrium at a grain boundary, and performing an isothermal heat treatment to diffuse the yttrium in the grain interior. The subsequent cold working refines the grains, and improves the hardness and strength of the magnesium alloy member.

[0033] Controlling the dispersion state of yttrium induces room temperature recrystallization (grain refining), and excellent compressional deformation characteristics can be developed.

[0034] The foregoing embodiments described the yttrium-containing magnesium alloy, and the alloy member of such a magnesium alloy. However, the present invention is not limited to the embodiments.

Examples

[0035] Yttrium (Y) and pure magnesium (Mg; purity 99.95%) were completely melted in an argon atmosphere, and cast into an iron mold to fabricate five types of Mg-Y alloy cast materials with the target Y contents of 0.01 mol%, 0.02 mol%, 0.03 mol%, 0.04 mol%, and 0.05 mol%. The target Y contents of 0.03 mol%, 0.04 mol%, and 0.05 mol% fall within the range of the present invention (Examples). The target Y contents of 0.01 mol% and 0.02 mol% fall outside of the range of the present invention (Comparative Examples). The Y content, and the concentrations of other composition elements were evaluated by ICP atomic emission spectrometry after a 2-hour solution treatment of the cast material at 500°C. The results of the composition analysis are presented in Table 1. The five alloys were produced by using the following procedures under the following conditions.

[Table 1]

	Y	Fe	Si	Mn	Cu
Mg-0.05Y	0.16 (=0.044)	0.002	0.002	0.003	<0.001
Mg-0.04Y	0.13 (=0.036)	0.002	0.002	0.004	<0.001
Mg-0.03Y	0.09 (=0.025)	0.002	0.002	0.004	<0.001
Mg-0.02Y	0.06 (=0.016)	0.002	0.002	0.003	<0.001
Mg-0.01Y	0.02 (=0.005)	0.002	0.002	0.003	<0.001
Figures in parentheses are mol%. Other figures are mass%.					

[0036] The cast material was maintained in a furnace at a temperature of 500°C for 2 hours, and then water cooled as a solution treatment. The product was then machined to produce a columnar extrusion billet measuring 40 mm in

diameter and 70 mm in height. The same unit billet was maintained for 30 minutes in a container maintained at the extrusion temperature shown in Table 2, and subjected to a hot strain applying process, which was performed by extruding the material at an extrusion ratio of 25:1. The resulting product will be called "extruded material." The average equivalent plastic strain was 3.7 as determined from the percentage reduction of a cross section. The extruded material was isothermally maintained in a 400°C furnace for 15 minutes, and allowed to cool in air to prepare a sample. This product will be called "extruded and heat-treated material."

[Table 2]

		Y concentration, mol%	Extrusion temperature, degrees	Heat treatment temperature, degrees	Heat treatment time, min	grain size, μm	Tys, MPa	Cys, MPa	Fracture strain
	Mg-0.05Y	0.044	306	----	----	5	278	140	0.15
		0.044	306	400	15	32	91	65	>0.50
	Mg-0.04Y	0.036	302	----	----	5	252	148	0.15
		0.036	302	400	15	38	91	65	>0.50
	Mg-0.03Y	0.025	315	----	----	5	207	134	0.14
		0.025	315	400	15	40	85	65	>0.50
	Mg-0.02Y	0.016	304	----	----	75	94	68	0.17
		0.016	304	400	15	94	84	34	0.31
		0.016	212	----	----	5	116	103	0.38
		0.016	212	400	15	44	100	47	0.36
	Mg-0.01Y	0.005	317	----	----	75	92	47	0.27
		0.005	317	400	15	>100		32	0.32
		0.005	238	----	----	30	97	65	0.35
		0.005	238	400	15	65	80	34	0.33

Tys: Tensile yielding stress, Cys: Compressional yielding stress

[0037] Mg-Y alloy samples collected from the extruded materials and the extruded and heat-treated materials were subjected to a room-temperature tensile and compression test at a strain rate of $1 \times 10^{-3} \text{s}^{-1}$. All test samples were collected in a direction parallel to the extrusion direction. FIGS. 2 to 4 represent the nominal stress-nominal strain curves obtained after the room-temperature tensile and compression test. It can be seen that fracture occurs in the extruded materials in the nominal strain range of 0.2 to 0.3, irrespective of the amounts of yttrium added. Here, "fracture" is defined as at least 20% reduction in stress, and denoted as BK in the figures. A fracture occurred in the extruded and heat-treated materials Mg-0.01Y and Mg-0.02Y in the nominal strain range of 0.2 to 0.3 as in the extruded materials. However, no fracture occurred in the extruded and heat-treated materials Mg-0.03Y, Mg-0.04Y, and Mg-0.05Y even under the applied nominal strain of 0.5. These results suggest that the extruded and heat-treated materials Mg-0.03Y, Mg-0.04Y, and Mg-0.05Y are highly suited for cold working. As Comparative Example, a Mg-1 mol% Y alloy was fabricated by casting, and subjected to a room-temperature compression test after a solution treatment, without performing hot working. The result is shown in FIG. 5. It can be seen that fracture occurs at a nominal strain as low as about 0.3, despite the high yttrium content. The post-casting hot strain applying process can thus be said as essential for the present invention to exhibit effect.

[0038] FIG. 6 shows an example of the observed scanning electron micrograph/electron backscatter diffraction image of the extruded and heat-treated material Mg-0.03Y. The symbols ED and TD represent directions parallel and perpendicular to the extrusion direction, respectively. It can be seen that the material does not tensile in the extrusion direction: ED, and has an equiaxial structure. The average diameter of grains with 15° or greater misorientation was 40 μm. FIG. 7 shows a pole figure image of the region observed in FIG. 6. Each point corresponds to the crystal orientation of the measured crystal grain. It can be seen that the material has a random texture without accumulation of basal plane in the specific direction (extrusion direction).

[0039] FIG. 8 shows an example of the microstructure of the extruded and heat-treated material Mg-0.03Y observed by scanning electron microscopy/electron backscatter diffraction after applying 20% compressional nominal strain (= 0.20). In contrast to the undeformed material of FIG. 6, refining of the grains can be observed. The average diameter of the grains with 15° or greater misorientation was 30 μm, 75% of the initial grain diameter before the room temperature recrystallization. In the figure, the symbol "LG" represents a low-angle grain boundary with less than 15° misorientation. This is considered to be largely due to the room temperature recrystallization forming a low-angle boundary of about 5°

in the grains. FIG. 9 shows an example of the microstructure of the extruded and heat-treated material Mg-0.03Y observed by scanning electron microscopy/electron backscatter diffraction after applying 50% compressional nominal strain (= 0.50). In contrast to the undeformed material of FIG. 6, refining of the grains can be observed. The average diameter of the crystal grains with 15° or greater misorientation was 11 μm, 25% of the initial grain diameter.

[0040] Hardness measurement was performed for the extruded and heat-treated material Mg-0.03Y (undeformed sample) and the sample to which 50% compressional nominal strain (= 0.50) was applied. Hardness was 30.5 Hv for the undeformed sample, and 36.5 Hv for the 50% deformed sample. The improved hardness over the undeformed material is attributed to the finer grain size imparted after the room temperature working. It can be seen from these results that the material of the present invention improves hardness and strength after the room-temperature plastic working.

Comparative Example

[0041] When the working temperature is below 200°C, the low working temperature makes dynamic recrystallization less likely to occur. FIG. 10 is a photographic representation showing the appearance of the material of Comparative Example, representing the situation where dynamic recrystallization is limited by low working temperature. The limited dynamic recrystallization makes the material of Comparative Example less usable in producing a good material.

Industrial Applicability

[0042] The present invention induces room temperature recrystallization (grain refining), and develops excellent compressional deformation characteristics by controlling the dispersion state of one or more elements selected from yttrium, scandium, and lanthanoid rare earth elements in a magnesium alloy. The magnesium alloy member of the present invention has a random crystal orientation distribution (after working), and the same yielding stress for the tensile and compressional deformation with the maintained high strength. The magnesium alloy member of the present invention can thus be used as a wrought magnesium member such as a plate member, a rod member, and a pipe member. In a three-dimensional structure using such a wrought magnesium member, any external force acting on the structure deforms the magnesium alloy member near isotropically, and the strengths against the locally acting tensile and compressional loads become essentially the same. Further, the magnesium alloy member of the present invention does not break even under a large applied compressional strain in excess of 50%, and has excellent deformability. The magnesium alloy member of the present invention can thus be used as a structural member or a shock absorbing material in applications such as automobiles, railcars, aerospace flying objects, and portable electronic devices.

Claims

1. A magnesium alloy member comprising 0.025 mol% or more and less than 0.05 mol% of yttrium, Mg and unavoidable impurities accounting for the remainder.
2. A magnesium alloy member as claimed in claim 1, wherein the average grain size is 10 μm or more.
3. A method for producing a magnesium alloy member having a crystal structure which is an equiaxial grain structure, the method comprising:
 - hot plastic working of a magnesium alloy comprising 0.025 mol% or more and less than 0.05 mol% of yttrium, Mg and unavoidable impurities accounting for the remainder in a temperature range of 200°C to 550°C; and
 - an isothermal heat treatment of the magnesium alloy in a temperature range of 300°C to 600°C after the hot plastic working.
4. A method as claimed in claim 3 including an additional step of applying by cold working a compressional nominal strain of 0.4 or more in a temperature range of from room temperature to 150°C.
5. A method as claimed in claim 3 or claim 4, wherein the average grain size of the magnesium alloy member after cold working performed in a temperature range of from room temperature to 150°C is 80% or less of the average grain size of an unworked magnesium alloy member.
6. A method as claimed in claim 3, wherein the strength and hardness of the member after applying nominal strain by cold working performed in a temperature range of from room temperature to 150°C are 15% greater than strength

and hardness of the undeformed ones.

Patentansprüche

1. Magnesiumlegierungselement, umfassend 0,025 Mol-% oder mehr und weniger als 0,05 Mol-% Yttrium, Mg und unvermeidliche Verunreinigungen, die den Rest darstellen.
2. Magnesiumlegierungselement nach Anspruch 1, wobei die mittlere Korngröße 10 µm oder mehr beträgt.
3. Verfahren zur Herstellung eines Magnesiumlegierungselements mit einer Kristallstruktur, welche eine gleichachsige Kornstruktur ist, wobei das Verfahren umfasst:
 heißplastische Bearbeitung einer Magnesiumlegierung, umfassend 0,025 Mol-% oder mehr und weniger als 0,05 Mol-% Yttrium, Mg und unvermeidliche Verunreinigungen, die den Rest darstellen, in einem Temperaturbereich von 200°C bis 550°C; und
 eine isotherme Wärmebehandlung der Magnesiumlegierung in einem Temperaturbereich von 300°C bis 600°C nach der heißplastischen Bearbeitung.
4. Verfahren nach Anspruch 3, welches einen zusätzlichen Schritt des durch Kaltbearbeitung Anlegens einer Nenn-Kompressionsbelastung von 0,4 oder mehr in einem Temperaturbereich von Raumtemperatur bis 150°C beinhaltet.
5. Verfahren nach Anspruch 3 oder Anspruch 4, wobei die mittlere Korngröße des Magnesiumlegierungselements nach Kaltbearbeitung, durchgeführt in einem Temperaturbereich von Raumtemperatur bis 150°C, 80% oder weniger als die mittlere Korngröße eines unbearbeiteten Magnesiumlegierungselements beträgt.
6. Verfahren nach Anspruch 3, wobei die Stärke und Härte des Elements nach Anlegen von Nennbelastung durch Kaltbearbeitung, durchgeführt in einem Temperaturbereich von Raumtemperatur bis 150°C, 15% größer als die Stärke und Härte der nicht verformten sind.

Revendications

1. Membre en alliage de magnésium comprenant 0,025 % en moles ou plus et moins de 0,05 % en moles d'yttrium, du Mg et des impuretés inévitables représentant le reste.
2. Membre en alliage de magnésium tel que revendiqué dans la revendication 1, dans lequel la taille de grain moyenne est de 10 µm ou plus.
3. Procédé de production d'un membre en alliage de magnésium ayant une structure cristalline qui est une structure de grain équiaxiale, le procédé comprenant :
 un travail plastique à chaud d'un alliage de magnésium comprenant 0,025 % en moles ou plus et moins de 0,05 % en mol d'yttrium, du Mg et des impuretés inévitables représentant le reste dans une plage de température de 200 °C à 550 °C ; et
 un traitement thermique isotherme de l'alliage de magnésium dans une plage de température de 300 °C à 600 °C après le travail plastique à chaud.
4. Procédé tel que revendiqué dans la revendication 3 incluant une étape additionnelle d'application par travail à froid d'une contrainte nominale de compression de 0,4 ou plus dans une plage de température allant de la température ambiante à 150 °C.
5. Procédé tel que revendiqué dans la revendication 3 ou la revendication 4, dans lequel la taille de grain moyenne du membre en alliage de magnésium après le travail à froid effectué dans une plage de température allant de la température ambiante à 150 °C est de 80 % ou moins de la taille de grain moyenne d'un membre en alliage de magnésium non travaillé.

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6. Procédé tel que revendiqué dans la revendication 3, dans lequel la force et la dureté du membre après l'application d'une contrainte nominale par travail à froid effectué dans une plage de température allant de la température ambiante à 150 °C sont 15% supérieures à la force et à la dureté de ceux non déformées.

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FIG. 1

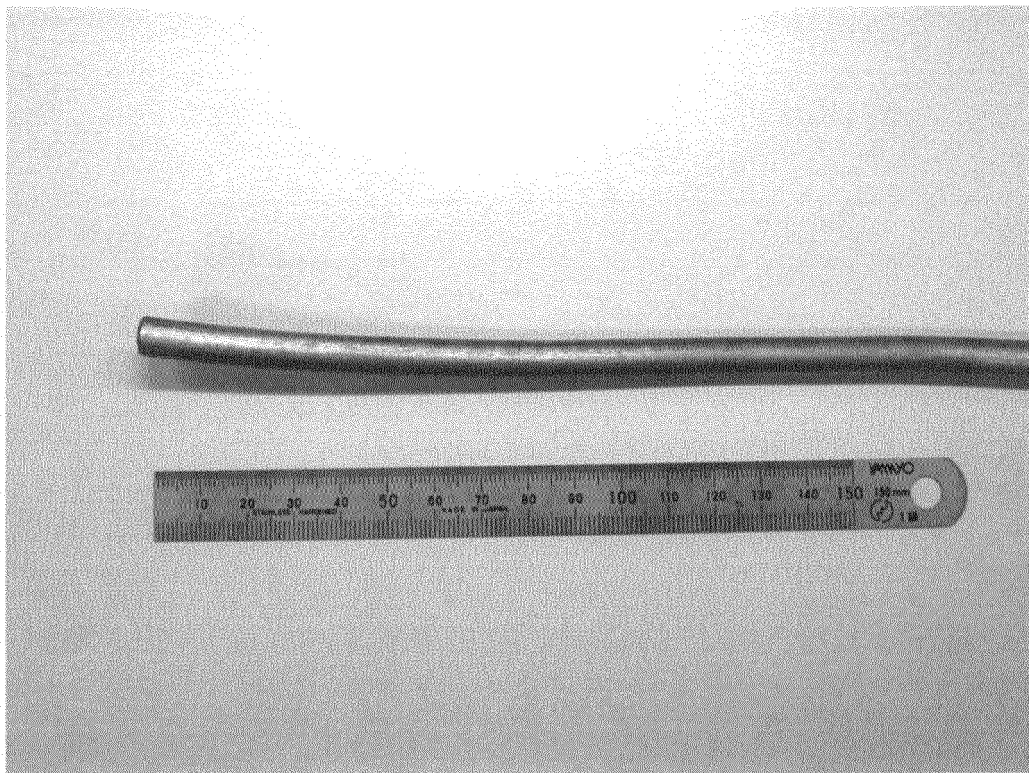


FIG. 2

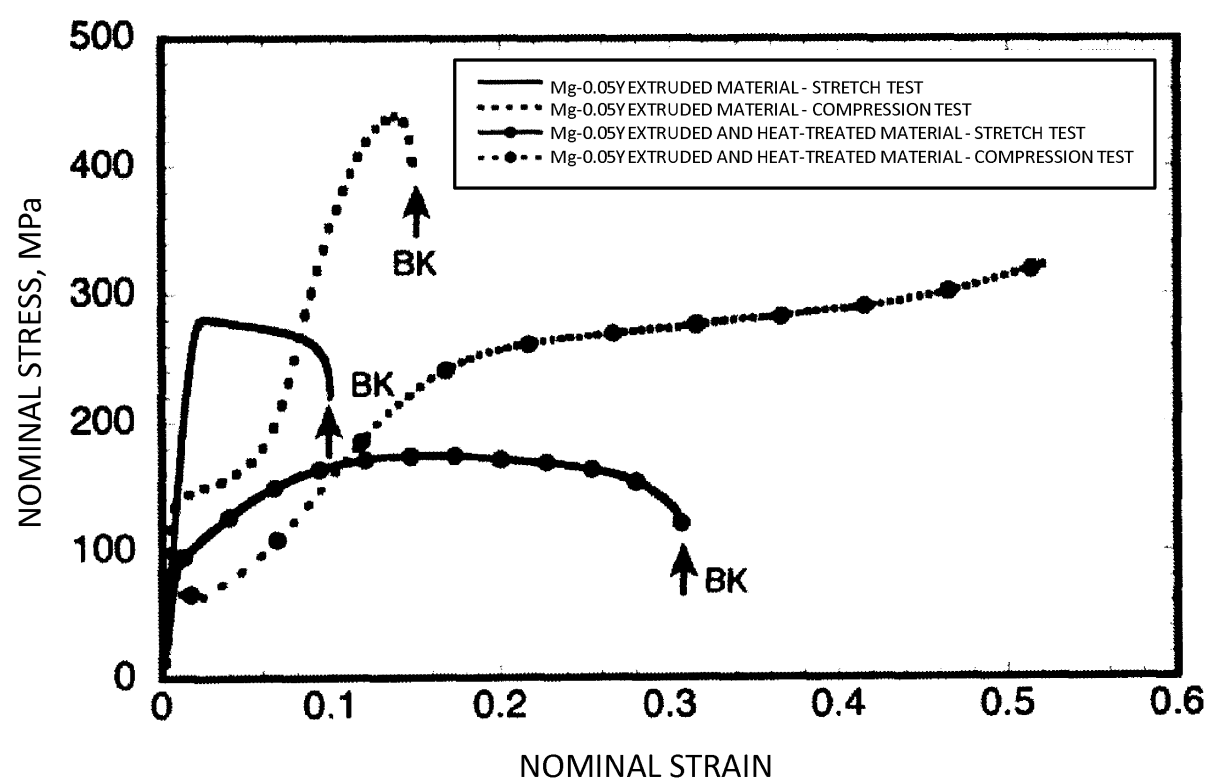


FIG. 3

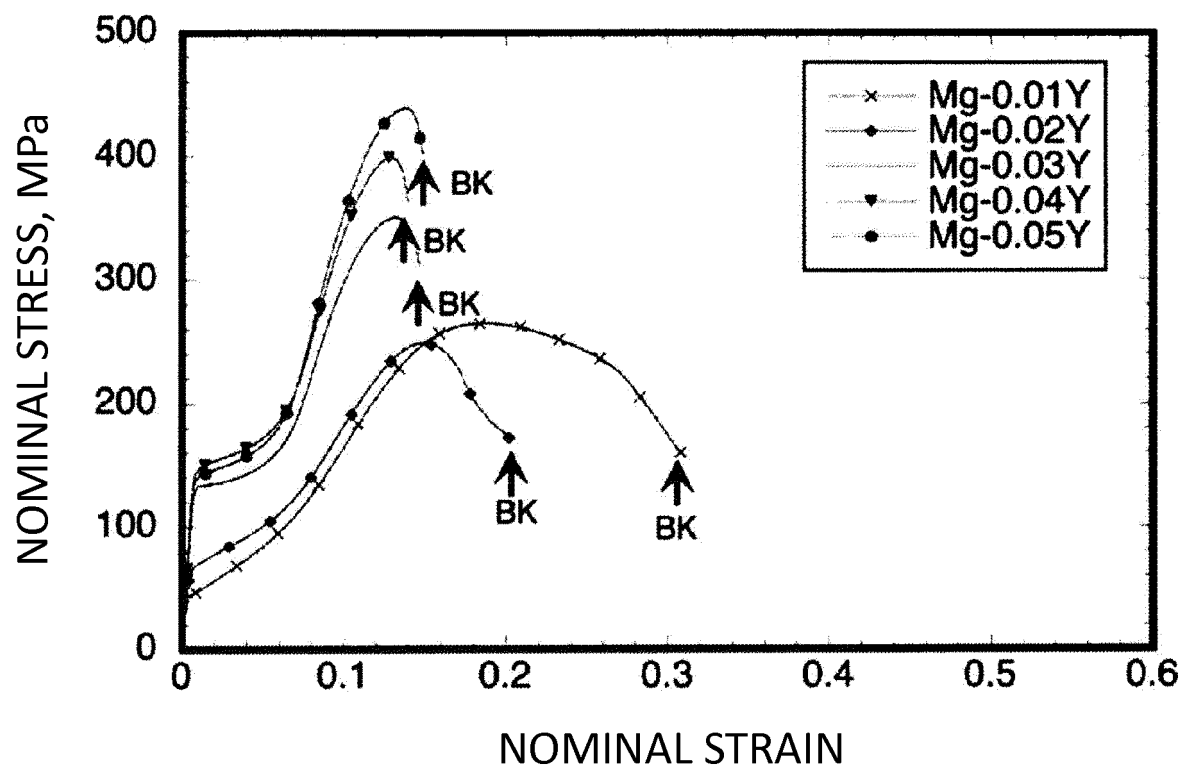


FIG. 4

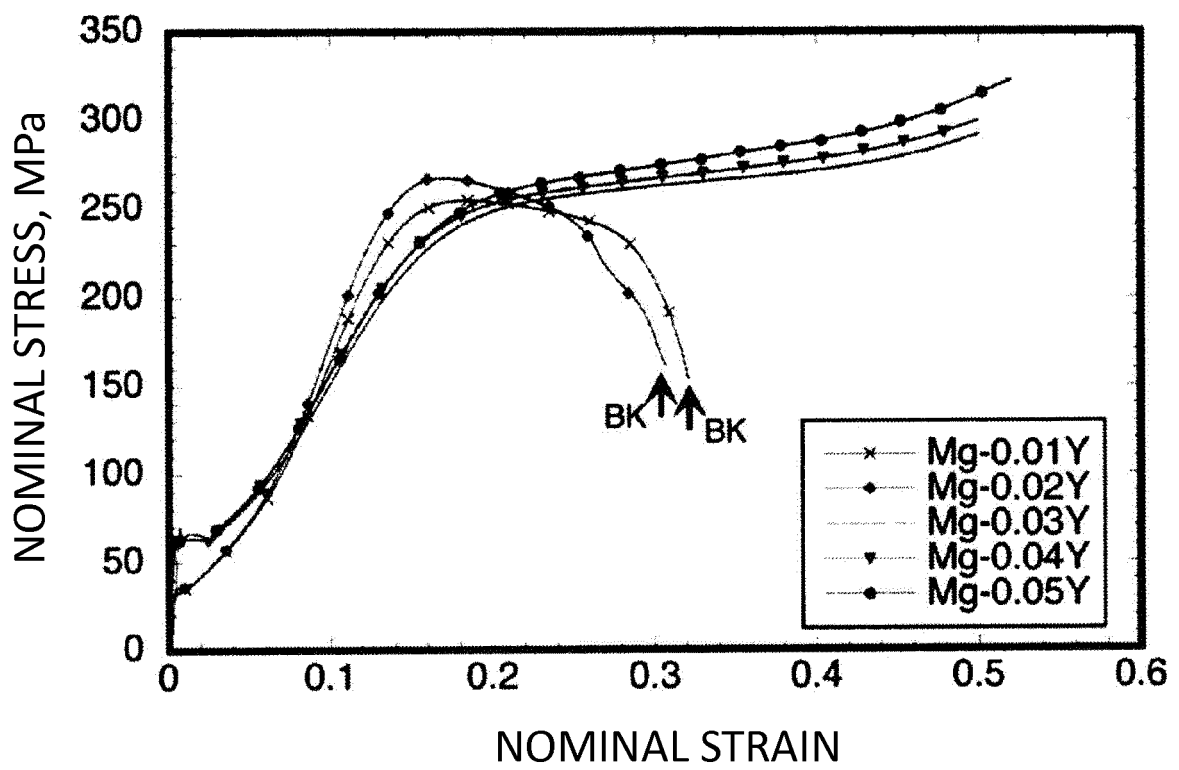


FIG. 5

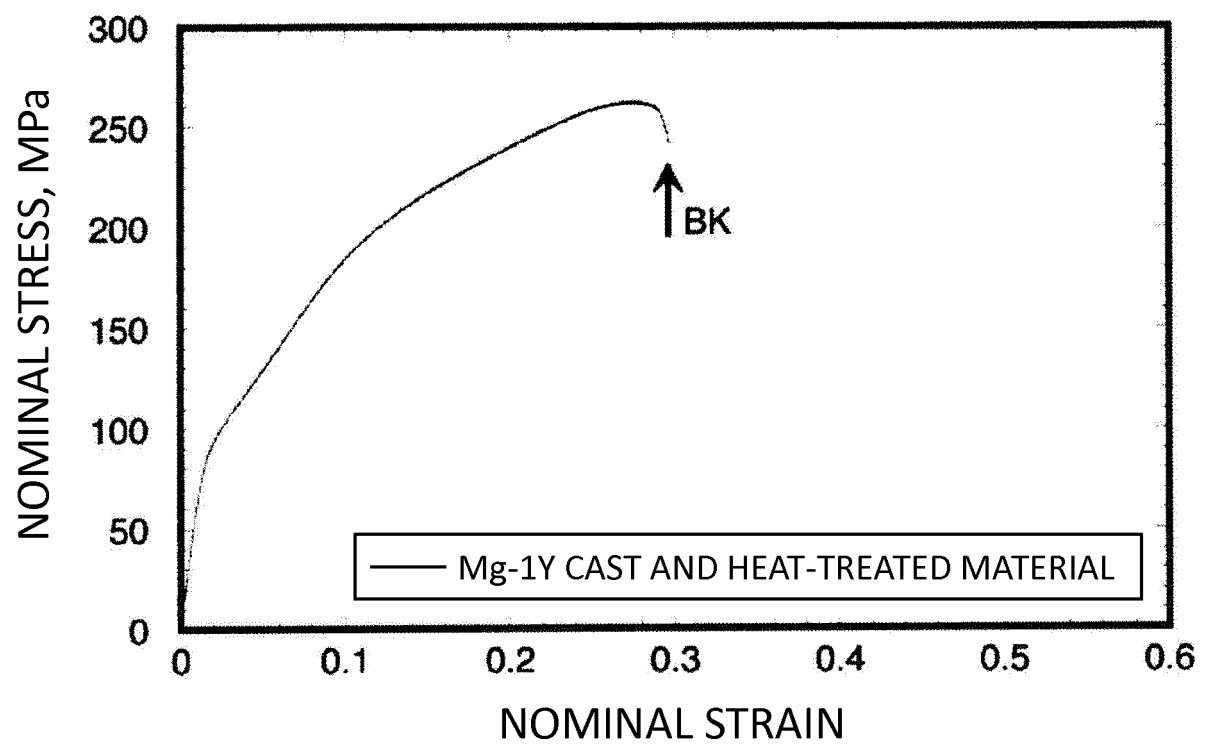


FIG. 6

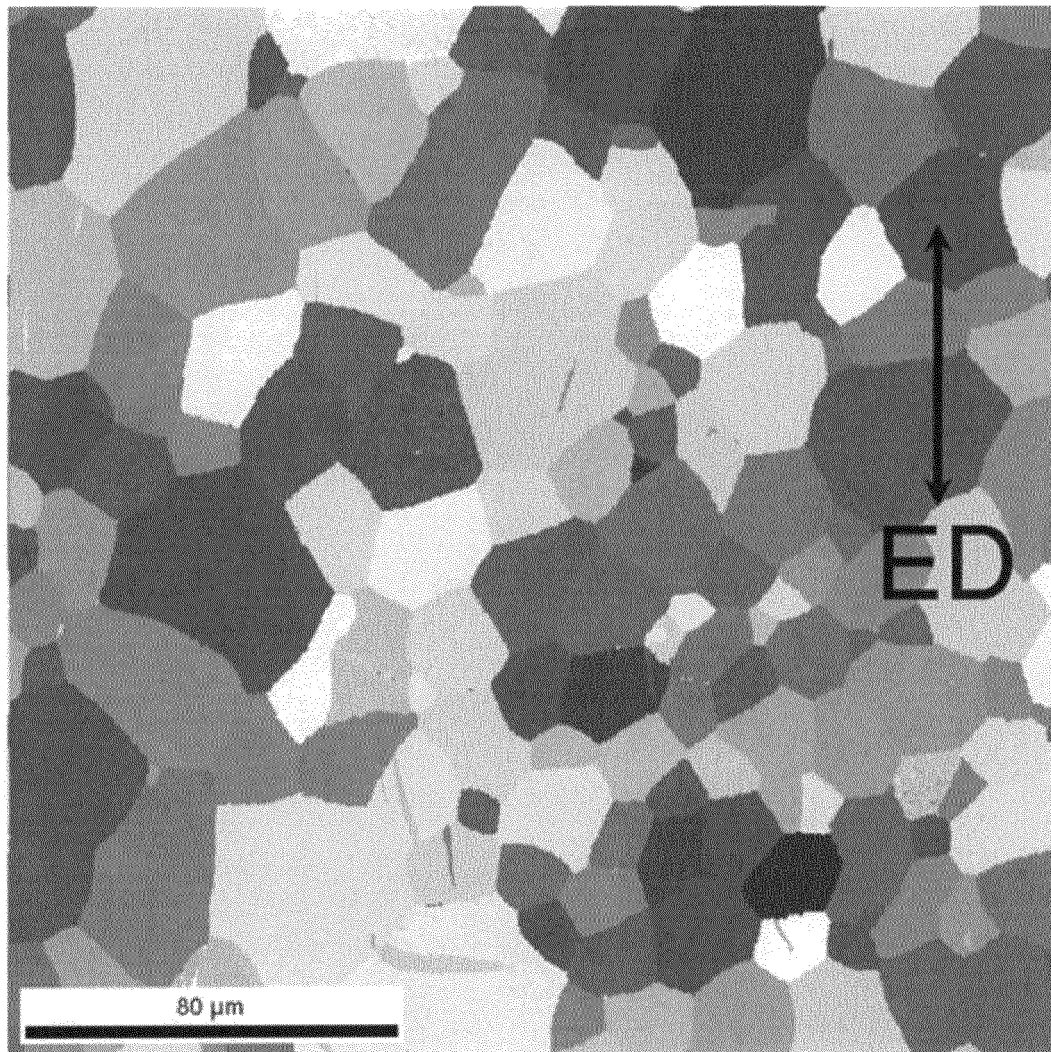


FIG. 7

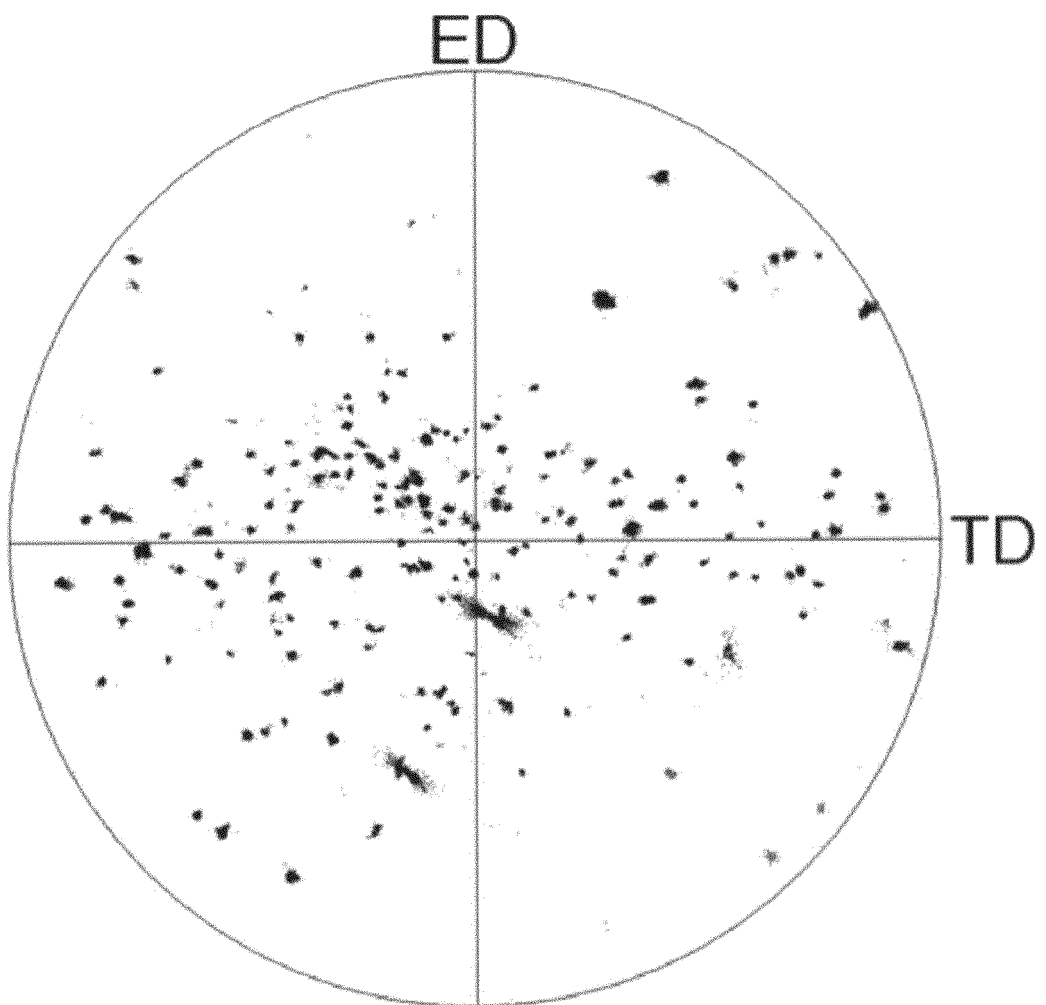


FIG. 8

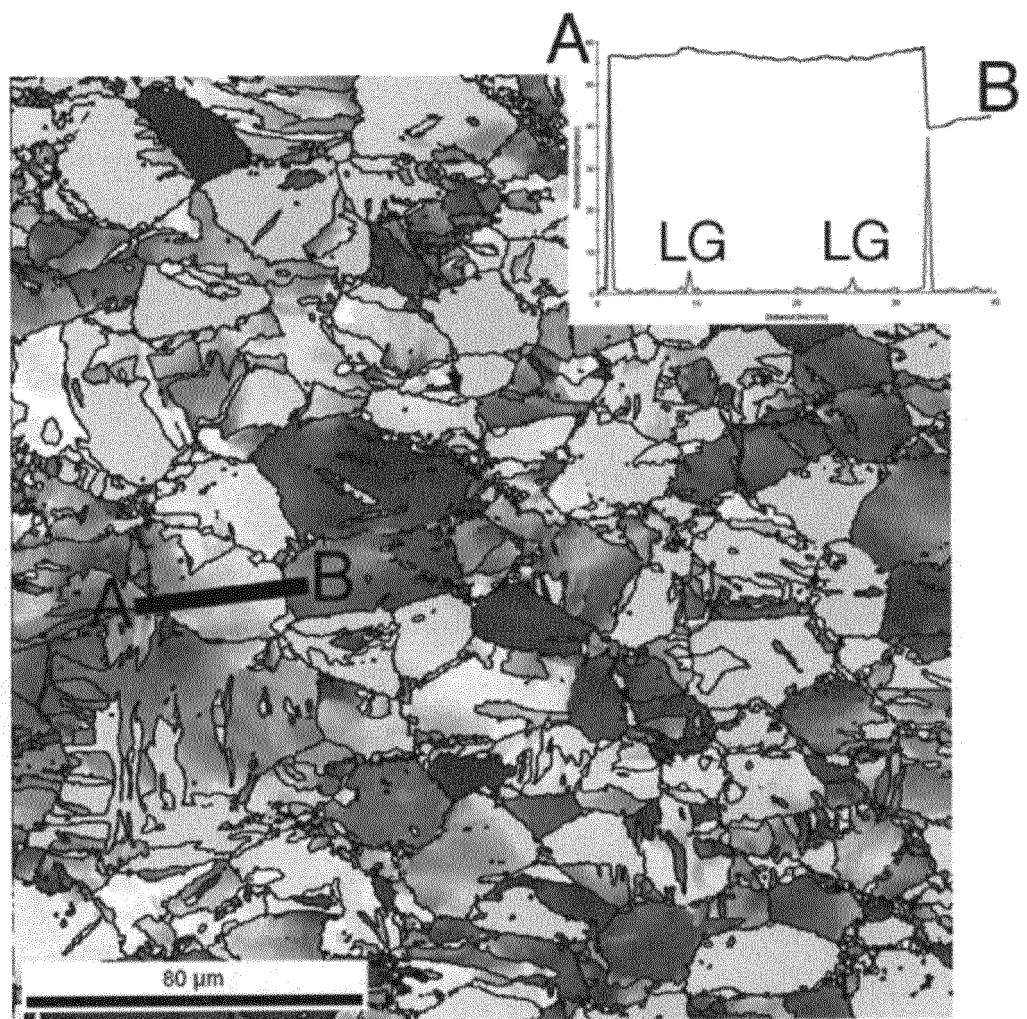


FIG. 9

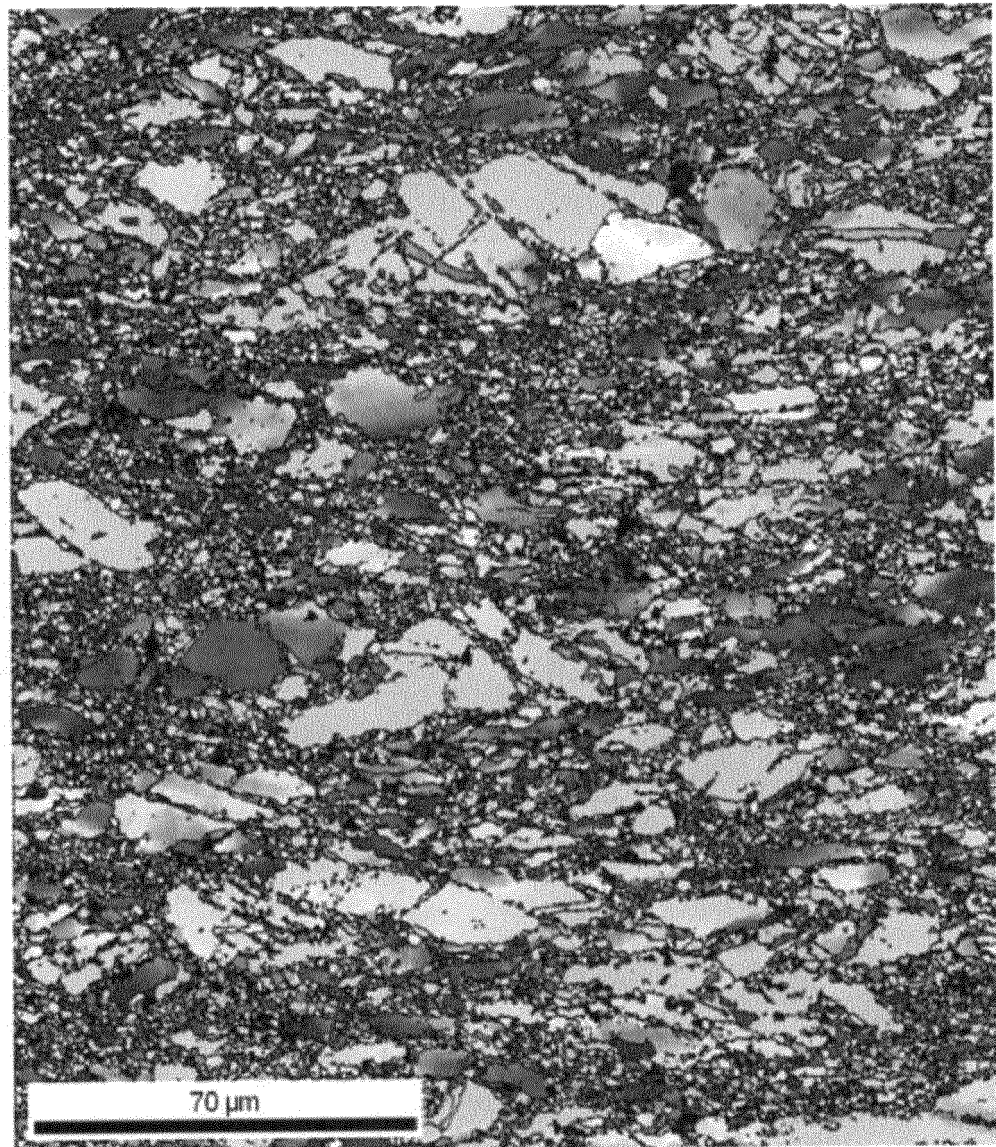
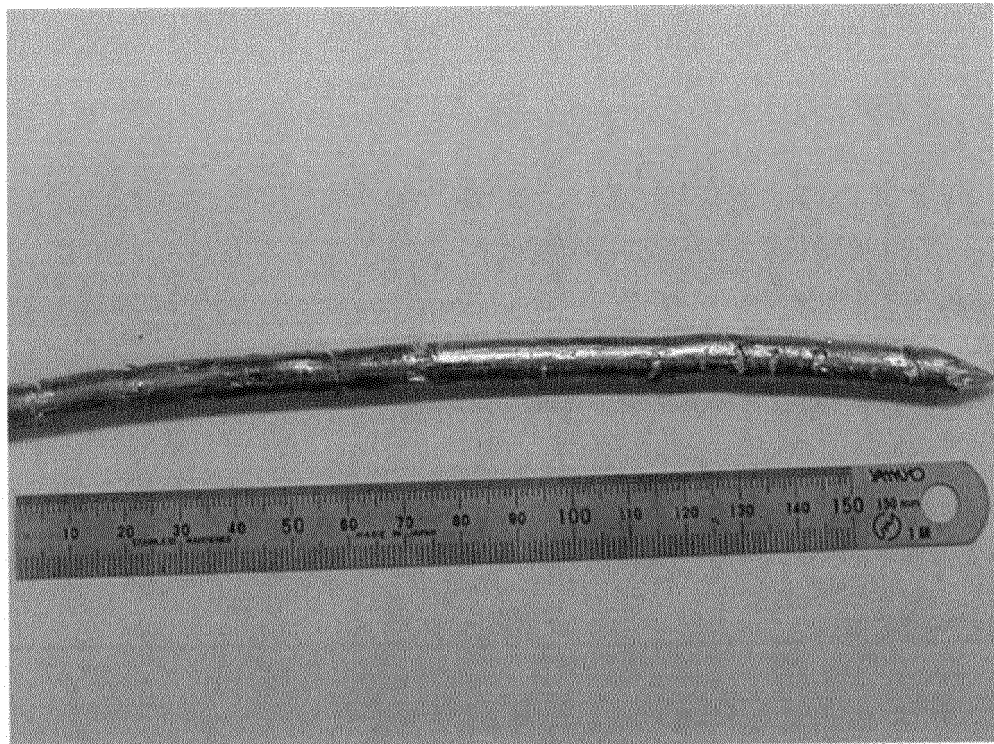


FIG. 10



REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- WO 2010010965 A [0010]
- WO 2008117890 A [0010]
- JP 2010013725 A [0010]
- JP 2008214668 A [0010]
- JP 2003226929 A [0010]
- JP 9041066 A [0010]
- JP 2010222645 A [0010]
- JP 4840751 B [0010]
- EP 2319949 A1 [0010]