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(54) **FINE CRYSTALLITE HIGH-PERFORMANCE METAL ALLOY MEMBER AND METHOD FOR MANUFACTURING SAME**

(57) Provided by the present invention are a fine crystallite high-function metal alloy member, a method for manufacturing the same, and a business development method thereof, in which a crystallite of a metal alloy including a high-purity metal alloy whose crystal lattice is a face-centered cubic lattice, a body-centered cubic lat-

tice, or a close-packed hexagonal lattice is made fine with the size in the level of nanometers (10^{-9} m to 10^{-6} m) and micrometers (10^{-6} m to 10^{-3} m), and the form thereof is adjusted, thereby remedying drawbacks thereof and enhancing various characteristics without losing superior characteristics owned by the alloy.

FIG. 1

Name	Crystal lattice	Composition (%)	Average crystallite size
Au type	Face-centered cubic lattice	Au 99.95	27
		Au 90-Ag 10	15
		Au 50-Ag 50	19
		Au 10-Ag 90	23
Ag 99.95		8	
Ag 90-Pd 10		19	
Ag 50-Pd 50		23	
Ag 10-Pd 90		25	
Pt 99.95		11	
Pt 90-Pd 10		19	
Pt 50-Cu 50		17	
Pt 10-Cu 90		22	
Pd 99.95		15	
Al type		Al 99.95	6
		Al 90-Mg 10	13
		Al 50-Mg 50	27
Mg type	Al 10-Mg 90	19	
	Mg 99.95	12	
Cu type	Cu 99.95	17	
	Cu 90-Zn 10	7	
	Cu 65-Zn 35	21	
	Cu 10-Ag 90	13	
Fe type	Body-centered cubic lattice	Fe 99.95	7
		Fe 99.0-Si 1	27
		Fe 75.0-Ni 17-Al 8	18
Ti type	Close-pack hexagonal lattice	Ti 99.95	7
		Ti 99.8-Pd 0.2	27

Description

TECHNICAL FIELD

[0001] The present invention relates to a high-performance elastic limit metal alloy member and a method for manufacturing the same, in which the said alloy member is suitable for an electronic member, a car and an aerial member, a physicochemical member, a medical care member, a jewelry member, a musical instrument members, a tableware member, a structural member, and the like.

BACKGROUND ART

[0002] In the past, gold (Au), platinum (Pt), silver (Ag), copper (Cu), iron (Fe), aluminum (Al), magnesium (Mg), titanium (Ti), and the like have been known as a metal material; and they have been used in many fields.

[0003] The present invention is characterized in providing fine crystallite high-function alloy of a metal and a precious metal which are novel modified metal alloys with free of toxicity, not only having improved various characteristics but also being capable of adjusting these characteristics without losing the superior characteristics of a metal alloy and a precious metal alloy.

[0004] Especially, the present invention is characterized in providing, by adjusting the fine crystallite, a fine crystallite high-function metal alloy having strength, Young's modulus, elongation, heat resistance, corrosion resistance, and spring property, wherein sustainability thereof and so forth may be controlled easily while having easy processability and good workability.

[0005] In order to utilize the excellent characteristics of an alloy material itself, the present invention provides a fine crystallite high-function metal alloy member and a method for manufacturing the same, in which the said alloy member has enhanced functional characteristics whereby enhancing sustainability and processability with easy operation and no uselessness, while keeping or enhancing hardness, tensile strength, Young's modulus, elongation, corrosion resistance, discoloration, high-temperature characteristics, and workability.

[0006] Existing metal materials do not necessarily have sufficient mechanical properties, physical properties, chemical properties, and so forth when used in various use fields. In addition, there is a problem of poor workability. An object of the present invention is to solve and remedy these problematic properties for betterment while keeping the above-mentioned characteristics of the metal materials thereby obtaining a novel fine crystallite high-function metal alloy member that has been wanted.

[0007] In the present invention, it was found that a novel fine crystallite high-function metal alloy member having superior characteristics including physical, electrical, mechanical, and chemical characteristics, and also having excellent performance, quality, function, processability, workability, and so on, could be obtained by making

the crystallite fine (to the size of 10^{-9} m to 10^{-3} m) and by controlling the size and the form thereof; and based on this finding, a method for manufacturing the same could be established.

[0008] The fine crystallite metal alloy member of the present invention is characterized in that by controlling the size and the form of a newly developed fine crystallite, not only various characteristics of existing metal alloys such as hardness, tensile strength, elongation, Young's modulus, resisting force, softening property, electrical conductivity, thermal conductivity, processability, and workability may be kept or enhanced, but also these various characteristics may be controlled, so that unnecessary in function, performance, quality, process, operation, and so forth may be cut away.

[0009] In the fine crystallite metal alloy of the present invention, 90% or more thereof may be processed without annealing. This alloy shows characteristics including not causing cracks even if the rolling direction is changed.

[0010] This metal alloy is easy to be processed and is not easily deformed, while having sustainability; and thus, this is suitable for the purpose to reduce the size and weight upon commercialization thereof.

[0011] The fine crystallite high-function alloy of a metal and a precious metal in the present invention has superior characteristics as to hardness, tensile strength, Young's modulus, resisting force, elastic limit, elongation, spring property, and so forth; and in addition, this can be processed easily with good workability. This is highly pure, a crystallite thereof is fine, and the volume-occupation rate of an added element is small; and thus, an electronic material having high electrical conductivity and thermal conductivity may be obtained. These characteristics can be enhanced without deteriorating Young's modulus, so that a covering range of its commercial deployment is wide. When this is used to make a musical instrument, a creative tone and an acoustic effect may be obtained. Because the spring property can be enhanced, a wire rod and a plate material having flexibility and toughness can be obtained. Because heat resistance can be enhanced, its application is wide. A material having superior physical, mechanical, electrical, and chemical characteristics can be obtained.

[0012] In the fine crystallite high-function metal alloy of the present invention, the characteristics that various properties can be enhanced without substantial deterioration of electrical conductivity and Young's modulus were found and established.

[0013] In addition, this is characterized by free of toxicity.

[0014] In the fine crystallite high-function metal alloy of the present invention, similar high function characteristics can be obtained also in thin films of a spatter film, a vapor-deposited film, and a plated film, because the crystallite is in the size of nanometers (10^{-9} m to 10^{-6} m) or the size of micrometers (10^{-6} m to 10^{-3} m).

SUMMARY OF THE INVENTION

[0015] The present invention was made in view of the needs from the market as mentioned above; and an object thereof is to provide a fine crystallite high-function metal alloy member and a method for manufacturing the same, in which the said metal alloy keeps, enhances, and adjusts mechanical, physical, and chemical properties while having desired function, performance, and quality, with good workability and free of toxicity.

[0016] In the present invention, a novel method for making the crystallite fine, which is the most important to enhance and keep various characteristics such as mechanical characteristics, electrical characteristics, physical characteristics, and chemical characteristics of a metal alloy, was found and established.

[0017] In addition, the present invention has objects to provide: a fine crystallite high-function metal alloy member having also excellent corrosion resistance and discoloration resistance and a method for manufacturing this; and a fine crystallite metal alloy member having excellent various properties not only at normal temperature but also at high temperature and a method for manufacturing this.

[0018] To solve drawbacks of a precious metal alloy, proposals have been made in PCT/JP96/00510, PCT/JP97/02014, PCT/JP00/04411, PCT/JP03/01993, and PCT/JP2007/073133. The present invention develops to a further wider range. In a fine crystallite high-function precious metal alloy and a fine crystallite high-function metal alloy, a new phenomenon was found, whereby establishing the commercial viability thereof.

BRIEF DESCRIPTION OF THE DRAWINGS

[0019]

FIG. 1:

This shows the average crystallite size of the 0.2 mm thickness plate obtained by the process wherein gadolinium (Gd) was added and dissolved into a metal alloy including a high-purity metal alloy of gold (Au), silver (Ag), platinum (Pt), palladium (Pd), aluminum (Al), magnesium (Mg), copper (Cu), iron (Fe), and titanium (Ti), and then the resulting mixture was cast-molded to a thick plate having the widths of 30 mm and 10 mm; and then, this plate was solution-treated, aged, and then roll-processed to a thick plate having the thickness of 0.2 mm.

It was found that the crystallite size could be adjusted by a cast molding method, a processing method, and a heat-treatment method.

Because the crystallite size could be made fine to the order of nanometers as shown in FIG. 1, the size thereof could be adjusted in the range of 10^{-9} m to 10^{-3} m, and in addition, the texture

form thereof could be adjusted.

Regardless of whether the crystal lattice thereof was a face-centered cubic lattice, a body-centered cubic lattice, or a close-packed hexagonal lattice, size of the crystallite could be made fine, and the texture form thereof could be adjusted. It was found that the size thereof could be made fine, and that the texture form thereof could be adjusted even when the element therein was changed.

FIG. 2:

This shows the increase rate of electrical conductivity, Young's modulus, hardness, tensile strength, resisting force, elongation, and softening point, as well as corrosion resistance, with regard to the respective lattices of the fine crystallite high-function metal alloy of the present invention.

This shows that without deteriorating Young's modulus and electrical conductivity, hardness, tensile strength, resisting force, elongation, and softening point thereof can be enhanced significantly, and that these characteristics can be adjusted.

It was found that the corrosion resistance could be improved thereby increasing the prevention effect of metal corrosion.

MODES FOR CARRYING OUT THE INVENTION

[0020] A fine crystallite high-function metal alloy member according to a first embodiment of the present invention comprises a metal alloy containing 5 to 30000 ppm of gadolinium (Gd) in a gold (Au) alloy including a high-purity gold (Au) alloy.

[0021] The fine crystallite high-function gold (Au) alloy member according to the first embodiment of the present invention was obtained as following: gadolinium (Gd) was added to a metal alloy containing 99.95% by weight of gold (Au) so that the resultant metal alloy has gadolinium (Gd) content of 500 ppm, and then, the mixture thereof was cast-molded to a thick plate having the widths of 30 mm and 10 mm; and then, this plate was solution-treated, aged, and then roll-processed to a thick plate having the thickness of 0.3 mm.

[0022] Next, 500 g of gadolinium (Gd) was added to a gold alloy comprising 90% by weight of gold (Au) and 10% by weight of silver (Ag), and then, the mixture thereof was cast-molded to a thick plate having the widths of 30 mm and 10 mm; and then, this plate was solution-treated, aged, and then roll-processed to a thick plate having the thickness of 0.3 mm.

[0023] Further, 500 g of gadolinium (Gd) was added to a gold (Au) alloy comprising 50% by weight of gold (Au) and 50% by weight of silver (Ag), and then, the mixture thereof was cast-molded to a thick plate having the

widths of 30 mm and 10 mm; and then, this plate was heat-treated, and then roll-processed to a thick plate having the thickness of 0.3 mm.

[0024] Lastly, 500 g of gadolinium (Gd) was added to a gold alloy comprising 10% by weight of gold (Au) and 90% by weight of silver (Ag), and then, the mixture thereof was cast-molded to a thick plate having the widths of 30 mm and 10 mm; and then, this plate was solution-treated, aged, and then roll-processed to a thick plate having the thickness of 0.3 mm.

[0025] The foregoing finishing-processed thick plates having the thickness of 0.3 mm were analyzed by the X-ray analysis; and the average crystallite diameters obtained by the Scherrer's equation were 27 nm, 15 nm, 19 nm, and 23 nm, respectively. The crystallite size thereof could be newly adjusted in the level of nanometers (10^{-9} m to 10^{-6} m) and micrometers (10^{-6} m to 10^{-3} m).

[0026] Without substantial deterioration of electrical conductivity and Young's modulus, hardness, tensile strength, and 0.2% resisting force could be increased by 2 to 3 times. It was found that also elongation could be increased by 2 to 3 times. Softening point could be increased by 2.3 times. Roll-process could be carried out without heat treatment; and in addition, cross process could be carried out. Furthermore, processability and the various characteristics could be enhanced so that it became possible to balance these characteristics.

[0027] These effects could be realized in plates, wires, thin films, and powders.

[0028] Next, a method for manufacturing the metal alloy member having the afore-mentioned characteristics will be explained.

[0029] Firstly, in the case of the cast-molded alloy, the alloy material with the afore-mentioned composition is cast-molded, then, if necessary, the material is solution-treated in which rapid cooling is conducted after heating to a prescribed temperature, and further, if necessary, an ageing treatment is conducted thereafter at a prescribed temperature.

[0030] In the case of the processed alloy, the alloy material with the afore-mentioned composition is cast-molded, then, if necessary, the material is solution-treated in which rapid cooling is conducted after heating to a prescribed temperature, and then the material is processed to a prescribed form, wherein if necessary, the material is aged before or after this process.

[0031] After cast-molding of the gold alloy material, the solution treatment may be done in the temperature range of 500 to 2700°C, and the ageing treatment may be done in the temperature range of 100 to 700°C.

[0032] To obtain a high-function gold alloy, especially preferable production conditions are the temperature range of 600 to 1000°C for the solution treatment, and the temperature range of 150 to 550°C for the ageing treatment.

[0033] In any case by the above-mentioned processing method, the addition effect of gadolinium (Gd) could be seen eminently.

[0034] The same effect could also be obtained when the solution treatment and the ageing treatment were conducted.

[0035] When evaluation was done as to the sample which was prepared by adding 5 to 30000 ppm of gadolinium (Gd) to the gold (Au) alloy including a high-purity gold (Au) alloy whose crystal lattice is a face-centered cubic lattice, the same addition effect of gadolinium (Gd) was obtained.

[0036] The addition effect appears from 5 ppm, and the characteristics thereof decreases when the content thereof is 30000 ppm or more.

[0037] In the gold (Au) alloy having gadolinium (Gd) contained in the range of 5 to 30000 ppm in a metal alloy that is constituted by gold (Au) and at least one element selected from the group consisting of rare earth metals other than gadolinium (Gd), alkaline earth metals, zirconium (Zr), tin (Sn), indium (In), copper (Cu), silver (Ag), platinum (Pt), palladium (Pd), aluminum (Al), iron (Fe), nickel (Ni), manganese (Mn), cobalt (Co), and gallium (Ga), eminent enhancement of the function characteristics could be seen.

[0038] A fine crystallite high-function metal alloy member according to the second embodiment of the present invention comprises a metal alloy containing 5 to 30000 ppm of gadolinium (Gd) in a silver (Ag) alloy including a high-purity silver (Ag) alloy.

[0039] The fine crystallite high-function silver (Ag) alloy member according to the second embodiment of the present invention was obtained as following: gadolinium (Gd) was added to a metal alloy containing 99.95% by weight of silver (Ag) so that the resultant metal alloy has gadolinium (Gd) content of 500 ppm, and then, the mixture thereof was cast-molded to a thick plate having the widths of 30 mm and 10 mm; and then, this plate was solution-treated, aged, and then roll-processed to a thick plate having the thickness of 0.3 mm.

[0040] Next, 500 g of gadolinium (Gd) was added to a silver (Ag) alloy comprising 90% by weight of silver (Ag) and 10% by weight of palladium (Pd), and then, the mixture thereof was cast-molded to a thick plate having the widths of 30 mm and 10 mm; and then, this plate was solution-treated, aged, and then roll-processed to a thick plate having the thickness of 0.3 mm.

[0041] Further, 500 g of gadolinium (Gd) was added to a silver (Ag) alloy comprising 50% by weight of silver (Ag) and 50% by weight of palladium (Pd), and then, the mixture thereof was cast-molded to a thick plate having the widths of 30 mm and 10 mm; and then, this plate was heat-treated, and then roll-processed to a thick plate having the thickness of 0.3 mm.

[0042] Lastly, 500 g of gadolinium (Gd) was added to a silver (Ag) alloy comprising 10% by weight of silver (Ag) and 90% by weight of palladium (Pd), and then, the mixture thereof was cast-molded to a thick plate having the widths of 30 mm and 10 mm; and then, this plate was solution-treated, aged, and then roll-processed to a thick plate having the thickness of 0.3 mm.

[0043] The foregoing finishing-processed thick plates having the thickness of 0.3 mm were analyzed by the X-ray analysis; and the average crystallite diameters obtained by the Scherrer's equation were 8 nm, 19 nm, 23 nm, and 25 nm, respectively. The crystallite size could be newly adjusted in the level of nanometers (10^{-9} m to 10^{-6} m) and micrometers (10^{-6} m to 10^{-3} m).

[0044] Without substantial deterioration of electrical conductivity and Young's modulus, hardness, tensile strength, and 0.2% resisting force could be increased by 2 to 3 times. It was found that also elongation could be increased by 2 to 3 times. Softening point could be increased by 2.2 times. Roll-process could be carried out without heat treatment; and in addition, cross process could be carried out. It was further found that processability was enhanced. These characteristics could be balanced.

[0045] The various characteristics could be enhanced so that it became possible to balance these characteristics.

[0046] These effects could be realized in plates, wires, thin films, and powders.

[0047] Next, a method for manufacturing the metal alloy member having the afore-mentioned characteristics will be explained.

[0048] Firstly, in the case of the cast-molded alloy, the alloy material with the afore-mentioned composition is cast-molded, then, if necessary, the material is solution-treated in which rapid cooling is conducted after heating to a prescribed temperature, and further, if necessary, an ageing treatment is conducted thereafter at a prescribed temperature.

[0049] In the case of the processed metal alloy, the alloy material with the afore-mentioned composition is cast-molded, then, if necessary, the material is solution-treated in which rapid cooling is conducted after heating to a prescribed temperature, and then the material is processed to a prescribed form, wherein if necessary, the material is aged before or after this process.

[0050] In the silver (Ag) alloy, the solution treatment may be done in the temperature range of 450 to 2200°C, and the ageing treatment may be done in the temperature range of 100 to 600°C. Especially preferable conditions are the temperature range of 500 to 1550°C for the solution treatment, and the temperature range of 150 to 500°C for the ageing treatment. Processing efficiency during the time of processing is arbitrary, while the preferable range thereof is the same as that of the first embodiment.

[0051] It was found that by adding gadolinium (Gd), tensile strength, hardness, resisting force, elongation, and heat resistance could be enhanced, and that sulfurization and oxidation could be delayed, without substantial deterioration of electrical conductivity and Young's modulus, even the latter being slightly enhanced.

[0052] In any case by the above-mentioned processing method, the addition effect of gadolinium (Gd) could be seen eminently.

[0053] The same effect could also be obtained when the solution treatment and the ageing treatment were conducted.

[0054] When evaluation was done as to the sample which was prepared by adding 5 to 30000 ppm, of gadolinium (Gd) to the silver (Ag) alloy including a high-purity silver (Ag) alloy whose crystal lattice is a face-centered cubic lattice, the same addition effect of gadolinium (Gd) was obtained.

[0055] When evaluation was done as to the samples of the foregoing silver (Ag) alloy compositions, the same addition effect of gadolinium (Gd) was obtained. After addition of gadolinium (Gd), characteristics with regard to hardness, tensile strength, Young's modulus, and heat resistance were enhanced; and it showed the spring property. This could be easily processed, and workability thereof could be improved. Deterioration of electrical conductivity was hardly observed.

[0056] In the silver (Ag) alloy having gadolinium (Gd) contained in the range of 5 to 30000 ppm in a metal alloy that is constituted by silver (Ag) and at least one element selected from the group consisting of rare earth metals other than gadolinium (Gd), alkaline earth metals, zirconium (Zr), tin (Sn), indium (In), copper (Cu), palladium (Pd), aluminum (Al), zinc (Zn), nickel (Ni), and gallium (Ga), eminent enhancement of the characteristics could be seen.

[0057] A fine crystallite high-function metal alloy member according to a third embodiment of the present invention comprises a metal alloy containing 5 to 30000 ppm of gadolinium (Gd) in a platinum (Pt) alloy including a high-purity platinum (Pt) alloy.

[0058] The fine crystallite high-function platinum (Pt) alloy according to the third embodiment of the present invention was obtained as following: gadolinium (Gd) was added to a metal alloy containing 99.95% by weight of platinum (Pt) so that the resultant metal alloy has gadolinium (Gd) content of 500 ppm, and then, the mixture thereof was cast-molded to a thick plate having the widths of 30 mm and 10 mm; and then, this plate was solution-treated, aged, and then roll-processed to a thick plate having the thickness of 0.3 mm.

[0059] Next, 500 g of gadolinium (Gd) was added to a platinum (Pt) alloy comprising 90% by weight of platinum (Pt) and 10% by weight of palladium (Pd), and then, the mixture thereof was cast-molded to a thick plate having the widths of 30 mm and 10 mm; and then, this plate was solution-treated, aged, and then roll-processed to a thick plate having the thickness of 0.3 mm.

[0060] Further, 500 g of gadolinium (Gd) was added to a platinum (Pt) alloy comprising 50% by weight of platinum (Pt) and 50% by weight of copper (Cu), and then, the mixture thereof was cast-molded to a thick plate having the widths of 30 mm and 10 mm; and then, this plate was heat-treated, and then roll-processed to a thick plate having the thickness of 0.3 mm.

[0061] Lastly, 500 g of gadolinium (Gd) was added to a platinum (Pt) alloy comprising 10% by weight of plati-

num (Pt) and 90% by weight of copper (Cu), and then, the mixture thereof was cast-molded to a thick plate having the widths of 30 mm and 10 mm; and then, this plate was solution-treated, aged, and then roll-processed to a thick plate having the thickness of 0.3 mm.

[0062] The foregoing finishing-processed thick plates having the thickness of 0.3 mm were analyzed by the X-ray analysis; and the average crystallite diameters obtained by the Scherrer's equation were 11 nm, 19 nm, 17 nm, and 22 nm, respectively. The crystallite size could be adjusted in the level of nanometers (10^{-9} m to 10^{-6} m) and micrometers (10^{-6} m to 10^{-3} m).

[0063] Without substantial deterioration of electrical conductivity and Young's modulus, hardness, tensile strength, and 0.2% resisting force could be increased by 2 to 3 times. It was found that also elongation could be increased by 2 to 3 times. Softening point could be increased by 2 or more times. Roll-process could be carried out without heat treatment; and in addition, cross process could be carried out. It was further found that processability was enhanced. These characteristics could be balanced.

[0064] The various characteristics could be enhanced so that it became possible to balance these characteristics.

[0065] These effects could be realized in plates, wires, thin films, and powders.

[0066] Next, a method for manufacturing the metal alloy member having the afore-mentioned characteristics will be explained.

[0067] Firstly, in the case of the cast-molded alloy, the alloy material with the afore-mentioned composition is cast-molded, then, if necessary, the material is solution-treated in which rapid cooling is conducted after heating to a prescribed temperature, and further, if necessary, an ageing treatment is conducted thereafter at a prescribed temperature.

[0068] In the case of the processed metal alloy, the alloy material with the afore-mentioned composition is cast-molded, then, if necessary, the material is solution-treated in which rapid cooling is conducted after heating to a prescribed temperature, and then the material is processed to a prescribed form, wherein if necessary, the material is aged before or after this process.

[0069] This comprises a precious metal alloy containing 5 to 30000 ppm of gadolinium (Gd) in a platinum (Pt) alloy including a high-purity platinum (Pt) alloy.

[0070] In the platinum (Pt) alloy, the solution treatment may be done in the temperature range of 600 to 2800°C, and the ageing treatment may be done in the temperature range of 150 to 1400°C. Especially preferable conditions are the temperature range of 500 to 1600°C for the solution treatment, and the temperature range of 150 to 1000°C for the ageing treatment. Processing efficiency during the time of processing is arbitrary, while the preferable range thereof is the same as that of the first embodiment.

[0071] In any case by the above-mentioned processing

method, the addition effect of gadolinium (Gd) could be seen eminently.

[0072] The same effect could also be obtained when the solution treatment and the ageing treatment were conducted.

[0073] When evaluation was done as to the sample which was prepared by adding 5 to 30000 ppm of gadolinium (Gd) to the platinum (Pt) alloy including a high-purity platinum (Pt) alloy whose crystal lattice is a face-centered cubic lattice, the same addition effect of gadolinium (Gd) was obtained.

[0074] When evaluation was done as to the sample of the blended platinum (Pt) alloy having the respective foregoing compositions, the same addition effect of gadolinium (Gd) was obtained.

[0075] After addition of gadolinium (Gd), characteristics with regard to hardness, tensile strength, elongation, resisting force, and heat resistance were enhanced; and it showed the spring property. This could be easily processed, and workability thereof could be improved. Deterioration of Young's modulus and electrical conductivity was hardly observed.

[0076] In the platinum alloy having gadolinium (Gd) contained in the range of 50 to 15000 ppm in a metal alloy that is constituted by platinum (Pt) and at least one element selected from the group consisting of rare earth metals other than gadolinium (Gd), alkaline earth metals, zirconium (Zr), tin (Sn), indium (In), copper (Cu), palladium (Pd), nickel (Ni), tungsten (W), iridium (Ir), rhodium (Rh), ruthenium (Ru), osmium (Os), and gallium (Ga), eminent enhancement of the characteristics and balance characteristics could be seen.

[0077] A fine crystallite high-function metal alloy member according to a fourth embodiment of the present invention comprises a metal alloy containing 5 to 30000 ppm of gadolinium (Gd) in a palladium (Pd) alloy including a high-purity palladium (Pd) alloy.

[0078] The fine crystallite high-function palladium (Pd) alloy member according to the fourth embodiment of the present invention was obtained as following: gadolinium (Gd) was added to a metal alloy containing 99.95% by weight of palladium (Pd) so that the resultant metal alloy has gadolinium (Gd) content of 500 ppm, and then, the mixture thereof was cast-molded to a thick plate having the widths of 30 mm and 10 mm; and then, this plate was solution-treated, aged, and then roll-processed to a thick plate having the thickness of 0.3 mm.

[0079] The foregoing finishing-processed thick plate having the thickness of 0.3 mm was analyzed by the X-ray analysis; and the average crystallite diameter obtained by the Scherrer's equation was 15 nm. The crystallite size could be adjusted in the level of nanometers (10^{-9} m to 10^{-6} m) and micrometers (10^{-6} m to 10^{-3} m).

[0080] Without substantial deterioration of electrical conductivity and Young's modulus, hardness, tensile strength, and 0.2% resisting force could be increased by 2 to 3 times. It was found that also elongation could be increased by 2 to 3 times. Softening point could be in-

creased by 2.3 times. Roll-process could be carried out without heat treatment; and in addition, cross process could be carried out. It was further found that processability was enhanced. These characteristics could be balanced.

[0081] The various characteristics could be enhanced so that it became possible to balance these characteristics.

[0082] These effects could be realized in plates, wires, thin films, and powders.

[0083] Next, a method for manufacturing the metal alloy member having the afore-mentioned characteristics will be explained.

[0084] Firstly, in the case of the cast-molded alloy, the alloy material with the afore-mentioned composition is cast-molded, then, if necessary, the material is solution-treated in which rapid cooling is conducted after heating to a prescribed temperature, and further, if necessary, an ageing treatment is conducted thereafter at a prescribed temperature.

[0085] In the case of the processed metal alloy, the alloy material with the afore-mentioned composition is cast-molded, then, if necessary, the material is solution-treated in which rapid cooling is conducted after heating to a prescribed temperature, and then the material is processed to a prescribed form, wherein if necessary, the material is aged before or after this process.

[0086] The metal alloy member comprises a precious metal alloy containing 5 to 30000 ppm of gadolinium (Gd) in a palladium (Pd) alloy including a palladium (Pd) alloy.

[0087] In the palladium (Pd) alloy, the solution treatment may be done in the temperature range of 500 to 2700°C, and the ageing treatment may be done in the temperature range of 150 to 1300°C. Especially preferable conditions are the temperature range of 550 to 1500°C for the solution treatment, and the temperature range of 150 to 900°C for the ageing treatment. Processing efficiency during the time of processing is arbitrary, while the preferable range thereof is the same as that of the first embodiment.

[0088] In any case by the above-mentioned processing method, the addition effect of gadolinium (Gd) could be seen eminently.

[0089] The same effect could also be obtained when the solution treatment and the ageing treatment were conducted.

[0090] When evaluation was done as to the sample which was prepared by adding 5 to 30000 ppm of gadolinium (Gd) to the palladium (Pd) alloy including a high-purity palladium (Pd) alloy, whose crystal lattice is a face-centered cubic lattice, the same addition effect of gadolinium (Gd) was obtained.

[0091] When evaluation was done as to the sample of the blended palladium (Pd) alloy having the respective foregoing compositions, the same addition effect of gadolinium (Gd) was obtained.

[0092] After addition of gadolinium (Gd), characteristics with regard to hardness, tensile strength, resisting

force, heat resistance, and so forth were enhanced; and it showed the spring property. This could be easily processed, and workability thereof could be improved. Deterioration of Young's modulus and electrical conductivity was hardly observed.

[0093] In the palladium (Pd) alloy having gadolinium (Gd) contained therein in the range of 5 to 30000 ppm, eminent enhancement of the characteristics and balance characteristics could also be seen.

[0094] A fine crystallite high-function metal alloy member according to a fifth embodiment of the present invention comprises a metal alloy containing 5 to 30000 ppm of gadolinium (Gd) in an aluminum (Al) alloy including a high-purity aluminum (Al) alloy.

[0095] The fine crystallite high-function aluminum (Al) alloy member according to the fifth embodiment of the present invention was obtained as following: gadolinium (Gd) was added to a metal alloy containing 99.95% by weight of aluminum (Al) so that the resultant metal alloy has gadolinium (Gd) content of 500 ppm, and then, the mixture thereof was cast-molded to a thick plate having the widths of 30 mm and 10 mm; and then, this plate was solution-treated, aged, and then roll-processed to a thick plate having the thickness of 0.3 mm.

[0096] Next, 500 g of gadolinium (Gd) was added to an aluminum (Al) alloy comprising 90% by weight of aluminum (Al) and 10% by weight of magnesium (Mg), and then, the mixture thereof was cast-molded to a thick plate having the widths of 30 mm and 10 mm; and then, this plate was solution-treated, aged, and then roll-processed to a thick plate having the thickness of 0.3 mm.

[0097] Further, 500 g of gadolinium (Gd) was added to an aluminum (Al) alloy comprising 50% by weight of aluminum (Al) and 50% by weight of magnesium (Mg), and then, the mixture thereof was cast-molded to a thick plate having the widths of 30 mm and 10 mm; and then, this plate was heat-treated, and then roll-processed to a thick plate having the thickness of 0.3 mm.

[0098] Lastly, 500 g of gadolinium (Gd) was added to an aluminum (Al) alloy comprising 10% by weight of aluminum (Al) and 90% by weight of magnesium (Mg), and then, the mixture thereof was cast-molded to a thick plate having the widths of 30 mm and 10 mm; and then, this plate was solution-treated, aged, and then roll-processed to a thick plate having the thickness of 0.3 mm.

[0099] The foregoing finishing-processed thick plates having the thickness of 0.3 mm were analyzed by the X-ray analysis; and the average crystallite diameters obtained by the Scherrer's equation were 6 nm, 13 nm, 27 nm, and 19 nm, respectively. The crystallite size could be adjusted in the level of nanometers (10^{-9} m to 10^{-6} m) and micrometers 10^{-6} m to 10^{-3} m).

[0100] The foregoing finishing-processed thick plates having the thickness of 0.3 mm were analyzed by the X-ray analysis; and the average crystallite diameters obtained by the Scherrer's equation were 8 nm, 13 nm, 27 nm, and 19 nm, respectively. The crystallite size could be adjusted in the level of nanometers (10^{-9} m to 10^{-6} m)

and micrometers (10^{-6} m to 10^{-3} m).

[0101] Without substantial deterioration of electrical conductivity and Young's modulus, hardness, tensile strength, and 0.2% resisting force could be increased by 2 to 3 times. It was found that also elongation could be increased by 2 to 3 times. Softening point could be increased by 2.4 times. Roll-process could be carried out without heat treatment; and in addition, cross process could be carried out. It was further found that processability was enhanced. These characteristics could be balanced.

[0102] The various characteristics could be enhanced so that it became possible to balance these characteristics.

[0103] The aluminum (Al) alloy member comprises the aluminum (Al) alloy containing 5 to 30000 ppm of gadolinium (Gd).

[0104] In the aluminum (Al) alloy, the solution treatment may be done in the temperature range of 300 to 2000°C, and the ageing treatment may be done in the temperature range of 50 to 450°C. Especially preferable conditions are the temperature range of 500 to 1600°C for the solution treatment, and the temperature range of 50 to 400°C for the ageing treatment. Processing efficiency during the time of processing is arbitrary, while the preferable range thereof is the same as that of the first embodiment.

[0105] It was found that by adding gadolinium (Gd), the member having high function and sustainability, capable of being readily processed, could be obtained.

[0106] In any case by the above-mentioned processing method, the addition effect of gadolinium (Gd) could be seen eminently.

[0107] The same effect could also be obtained when the solution treatment and the ageing treatment were conducted.

[0108] When evaluation was done as to the sample which was prepared by adding 5 to 30000 ppm of gadolinium (Gd) to the aluminum (Al) alloy including a high-purity aluminum (Al) alloy whose crystal lattice is a face-centered cubic lattice, the same addition effect of gadolinium (Gd) was obtained.

[0109] When evaluation was done as to the sample of the blended aluminum (Al) alloy having the respective foregoing compositions, the same addition effect of gadolinium (Gd) was obtained.

[0110] A fine crystallite high-function metal alloy member according to a sixth embodiment of the present invention comprises a metal alloy containing 5 to 30000 ppm of gadolinium (Gd) in a magnesium (Mg) alloy including a high-purity magnesium (Mg) alloy.

[0111] The fine crystallite high-function magnesium (Mg) alloy member according to the sixth embodiment of the present invention was obtained as following: gadolinium (Gd) was added to a metal alloy containing 99.95% by weight of magnesium (Mg) so that the resultant metal alloy has gadolinium (Gd) content of 500 ppm, and then, the mixture thereof was cast-molded to a thick plate hav-

ing the widths of 30 mm 10 mm; and then, this plate was solution-treated, aged, and then roll-processed to a thick plate having the thickness of 0.3 mm.

[0112] The foregoing finishing-processed thick plate having the thickness of 0.3 mm was analyzed by the X-ray analysis; and the average crystallite diameter obtained by the Scherrer's equation was 12 nm. The crystallite size could be adjusted in the level of nanometers (10^{-9} m to 10^{-6} m) and micrometers (10^{-6} m to 10^{-3} m).

[0113] Without substantial deterioration of electrical conductivity and Young's modulus, hardness, tensile strength, and 0.2% resisting force could be increased by 2 to 3 times. It was found that also elongation could be increased by 2 to 3 times. Softening point could be increased by 2 or more times. Roll-process could be carried out without heat treatment; and in addition, cross process could be carried out. It was further found that processability was enhanced. These characteristics could be balanced.

[0114] The various characteristics could be enhanced so that it became possible to balance these characteristics.

[0115] The fine crystallite high-function magnesium alloy comprises the magnesium (Mg) bare metal containing 5 to 30000 ppm of gadolinium (Gd) or the magnesium (Mg) alloy containing the same.

[0116] Without substantial deterioration of electrical conductivity and Young's modulus, hardness, tensile strength, and 0.2% resisting force could be increased by 2 to 3 times. It was found that also elongation could be increased by 2 or more times. Roll-process could be carried out without heat treatment; and in addition, cross process could be carried out. It was further found that processability was enhanced. These characteristics could be balanced.

[0117] These effects could be realized in plates, wires, thin films, and powders.

[0118] Next, a method for manufacturing the metal alloy member having the afore-mentioned characteristics will be explained.

[0119] Firstly, in the case of the cast-molded alloy, the alloy material with the afore-mentioned composition is cast-molded, then, if necessary, the material is solution-treated in which rapid cooling is conducted after heating to a prescribed temperature, and further, if necessary, an ageing treatment is conducted thereafter at a prescribed temperature.

[0120] In the case of the processed metal alloy, the alloy material with the afore-mentioned composition is cast-molded, then, if necessary, the material is solution-treated in which rapid cooling is conducted after heating to a prescribed temperature, and then the material is processed to a prescribed form, wherein if necessary, the material is aged before or after this process.

[0121] In the magnesium (Mg) alloy, the solution treatment may be done in the temperature range of 250 to 1050°C, and the ageing treatment may be done in the

temperature range of 110 to 500°C. Especially preferable conditions are the temperature range of 500 to 1000°C for the solution treatment, and the temperature range of 50 to 450°C for the ageing treatment. Processing efficiency during the time of processing is arbitrary, while the preferable range thereof is the same as that of the first embodiment.

[0122] It was found that by adding gadolinium (Gd), the member having high function and durability, capable of being readily processed, could be obtained.

[0123] In any case by the above-mentioned processing method, the addition effect of gadolinium (Gd) could be seen eminently.

[0124] The same effect could also be obtained when the solution treatment and the ageing treatment were conducted.

[0125] When evaluation was done as to the sample which was prepared by adding 5 to 30000 ppm of gadolinium (Gd) to the magnesium (Mg) alloy including a high-purity magnesium (Mg) alloy whose crystal lattice is a face-centered cubic lattice, the same addition effect of gadolinium (Gd) was obtained.

[0126] When evaluation was done as to the sample of the blended magnesium (Mg) alloy having the respective foregoing compositions, the same addition effect of gadolinium (Gd) was obtained.

[0127] After addition of gadolinium (Gd), characteristics with regard to hardness, tensile strength, resisting force, elongation, and heat resistance were enhanced; and this could be easily processed, and workability thereof could be improved. Deterioration of Young's modulus and electrical conductivity was hardly observed.

[0128] A fine crystallite high-function metal alloy member according to a seventh embodiment of the present invention comprises a metal alloy containing 5 to 30000 ppm of gadolinium (Gd) in a copper (Cu) alloy including a high-purity copper (Cu) alloy.

[0129] The fine crystallite high-function copper (Cu) alloy member according to the seventh embodiment of the present invention was obtained as following: gadolinium (Gd) was added to a metal alloy containing 99.95% by weight of copper (Cu) so that the resultant metal alloy has gadolinium (Gd) content of 500 ppm, and then, the mixture thereof was cast-molded to a thick plate having the widths of 30 mm and 10 mm; and then, this plate was solution-treated, aged, and then roll-processed to a thick plate having the thickness of 0.3 mm.

[0130] Next, 500 g of gadolinium (Gd) was added to a copper (Cu) alloy comprising 90% by weight of copper (Cu) and 10% by weight of zinc (Zn), and then, the mixture thereof was cast-molded to a thick plate having the widths of 30 mm and 10 mm; and then, this plate was solution-treated, aged, and then roll-processed to a thick plate having the thickness of 0.3 mm.

[0131] Further, 500 g of gadolinium (Gd) was added to a copper (Cu) alloy comprising 65% by weight of copper (Cu) and 35 by weight of zinc (Zn), and then, the mixture thereof was cast-molded to a thick plate having

the widths of 30 mm and 10 mm; and then, this plate was heat-treated, and then roll-processed to a thick plate having the thickness of 0.3 mm.

[0132] Lastly, 500 g of gadolinium (Gd) was added to a copper (Cu) alloy comprising 10% by weight of copper (Cu) and 90% by weight of silver (Ag), and then, the mixture thereof was cast-molded to a thick plate having the widths of 30 mm and 10 mm; and then, this plate was solution-treated, aged, and then roll-processed to a thick plate having the thickness of 0.3 mm.

[0133] The foregoing finishing-processed thick plates having the thickness of 0.3 mm were analyzed by the X-ray analysis; and the average crystallite diameters obtained by the Scherrer's equation were 17 nm, 7 nm, 21 nm, and 13 nm, respectively. The crystallite size could be adjusted in the level of nanometers (10^{-9} m to 10^{-6} m) and micrometers (10^{-6} m to 10^{-3} m).

[0134] Without substantial deterioration of electrical conductivity and Young's modulus, hardness, tensile strength, and 0.2% resisting force could be increased by 2 to 3 times. It was found that also elongation could be increased by 2 to 3 times. Softening point could be increased by 2.3 times. Roll-process could be carried out without heat treatment; and in addition, cross process could be carried out. It was further found that processability was enhanced. These characteristics could be balanced.

[0135] The various characteristics could be enhanced so that it became possible to balance these characteristics.

[0136] These effects could be realized in plates, wires, thin films, and powders.

[0137] Next, a method for manufacturing the metal alloy member having the afore-mentioned characteristics will be explained.

[0138] Firstly, in the case of the cast-molded alloy, the alloy material with the afore-mentioned composition is cast-molded, then, if necessary, the material is solution-treated in which rapid cooling is conducted after heating to a prescribed temperature, and further, if necessary, an ageing treatment is conducted thereafter at a prescribed temperature.

[0139] In the case of the processed metal alloy, the alloy material with the afore-mentioned composition is cast-molded, then, if necessary, the material is solution-treated in which rapid cooling is conducted after heating to a prescribed temperature, and then the material is processed to a prescribed form, wherein if necessary, the material is aged before or after this process.

[0140] In the copper (Cu) alloy, the solution treatment may be done in the temperature range of 600 to 2500°C, and the ageing treatment may be done in the temperature range of 150 to 850°C. Especially preferable conditions are the temperature range of 600 to 1600°C for the solution treatment, and the temperature range of 150 to 780°C for the ageing treatment.

[0141] It was found that by adding gadolinium (Gd), the member having high function and durability, capable

of being readily processed, could be obtained.

[0142] In any case by the above-mentioned processing method, the addition effect of gadolinium (Gd) could be seen eminently.

[0143] The same effect could also be obtained when the solution treatment and the ageing treatment were conducted.

[0144] When evaluation was done as to the sample which was prepared by adding 5 to 30000 ppm of gadolinium (Gd) to the copper (Cu) alloy including a high-purity copper (Cu) alloy whose crystal lattice is a face-centered cubic lattice, the same addition effect of gadolinium (Gd) was obtained.

[0145] When evaluation was done as to the sample of the respective copper (Cu) alloy compositions, the same addition effect of gadolinium (Gd) was obtained.

[0146] After addition of gadolinium (Gd), characteristics with regard to hardness, tensile strength, resisting force, elongation, and heat resistance were enhanced; and this could be easily processed, and workability thereof could be improved. Deterioration of Young's modulus and electrical conductivity was hardly observed.

[0147] A fine crystallite high-function metal alloy member according to an eighth embodiment of the present invention comprises a metal alloy containing 5 to 30000 ppm of gadolinium (Gd) in an iron (Fe) alloy including a high-purity iron (Fe) alloy.

[0148] The fine crystallite high-function iron (Fe) alloy member according to the eighth embodiment of the present invention was obtained as following: gadolinium (Gd) was added to a metal alloy containing 99.95% by weight of iron (Fe) so that the resultant metal alloy has gadolinium (Gd) content of 500 ppm, and then, the mixture thereof was cast-molded to a thick plate having the widths of 30 mm and 10 mm; and then, this plate was solution-treated, aged, and then roll-processed to a thick plate having the thickness of 0.3 mm.

[0149] Next, 500 g of gadolinium (Gd) was added to an iron (Fe) alloy comprising 99% by weight of iron (Fe) and 1% by weight of silicon Si, and then, the mixture thereof was cast-molded to a thick plate having the widths of 30 mm and 10 mm; and then, this plate was solution-treated, aged, and then roll-processed to a thick plate having the thickness of 0.3 mm.

[0150] Further, 500 g of gadolinium (Gd) was added to an iron (Fe) alloy comprising 75% by weight of iron (Fe), 17% by weight of nickel Ni, and 8% by weight of aluminum (Al), and then, the mixture thereof was cast-molded to a thick plate having the widths of 30 mm and 10 mm; and then, this plate was heat-treated, and then roll-processed to a thick plate having the thickness of 0.3 mm.

[0151] The foregoing finishing-processed thick plates having the thickness of 0.3 mm were analyzed by the X-ray analysis; and the average crystallite diameters obtained by the Scherrer's equation were 7 nm, 27 nm, and 18 nm, respectively. The crystallite size could be adjusted in the level of nanometers (10^{-9} m to 10^{-6} m) and microm-

eters (10^{-6} m to 10^{-3} m).

[0152] Without substantial deterioration of electrical conductivity and Young's modulus, hardness, tensile strength, and 0.2% resisting force could be increased by 2 to 3 times. It was found that also elongation could be increased by 2 to 3 times. Softening point could be increased by 2 or more times. Roll-process could be carried out without heat treatment; and in addition, cross process could be carried out. It was further found that processability was enhanced. These characteristics could be balanced.

[0153] The various characteristics could be enhanced so that it became possible to balance these characteristics.

[0154] These effects could be realized in plates, wires, thin films, and powders.

[0155] Next, a method for manufacturing the metal alloy member having the afore-mentioned characteristics will be explained.

[0156] Firstly, in the case of the cast-molded alloy, the alloy material with the afore-mentioned composition is cast-molded, then, if necessary, the material is solution-treated in which rapid cooling is conducted after heating to a prescribed temperature, and further, if necessary, an ageing treatment is conducted thereafter at a prescribed temperature.

[0157] In the case of the processed metal alloy, the alloy material with the afore-mentioned composition is cast-molded, then, if necessary, the material is solution-treated in which rapid cooling is conducted after heating to a prescribed temperature, and then the material is processed to a prescribed form, wherein if necessary, the material is aged before or after this process.

[0158] The solution treatment was done at 820°C for 1 hour; and the ageing treatment was done at 480°C for 3 hours.

[0159] In the iron (Fe) alloy, the solution treatment may be done in the temperature range of 600 to 2800°C, and the ageing treatment may be done in the temperature range of 150 to 700°C. Especially preferable conditions are the temperature range of 600 to 2000°C for the solution treatment, and the temperature range of 150 to 700°C for the ageing treatment. Processing efficiency during the time of processing is arbitrary, while the preferable range thereof is the same as that of the first embodiment.

[0160] It was found that by adding gadolinium (Gd), the member having high function and durability, capable of being readily processed, could be obtained.

[0161] In any case by the above-mentioned processing method, the addition effect of gadolinium (Gd) could be seen eminently.

[0162] The same effect could also be obtained when the solution treatment and the ageing treatment were conducted.

[0163] When evaluation was done as to the sample which was prepared by adding 5 to 30000 ppm of gadolinium (Gd) to the iron (Fe) alloy including a high-purity

iron (Fe) alloy whose crystal lattice was a body-centered cubic lattice, the same addition effect of gadolinium (Gd) was obtained.

[0164] When evaluation was done as to the sample of the respective copper iron (Fe) alloy compositions, the same addition effect of gadolinium (Gd) was obtained.

[0165] After addition of gadolinium (Gd), characteristics with regard to hardness, tensile strength, resisting force, elongation, heat resistance, and so forth were enhanced; and this could be easily processed, and workability thereof could be improved. Deterioration of Young's modulus and electrical conductivity was hardly observed.

[0166] When evaluation was done as to the sample of the respective iron (Fe) alloy compositions, the same addition effect of gadolinium (Gd) was obtained.

[0167] In the iron (Fe) alloy having gadolinium (Gd) contained in the range of 5 to 30000 ppm in a metal alloy that is constituted by iron (Fe) and at least one element selected from the group consisting of rare earth metals other than gadolinium (Gd), alkaline earth metals, silicon (Si), boron (B), zirconium (Zr), tin (Sn), indium (In), lead (Pb), nickel (Ni), manganese (Mn), copper (Cu), vanadium (V), phosphorous (P), and chromium (Cr), eminent enhancement of the elastic limit similar to FIG. 3 could be seen.

[0168] A fine crystallite high-function metal alloy member according to a ninth embodiment of the present invention comprises a metal alloy containing 5 to 30000 ppm of gadolinium (Gd) in a titanium (Ti) alloy including a high-purity titanium (Ti) alloy.

[0169] The fine crystallite high-function titanium (Ti) alloy member according to the ninth embodiment of the present invention was obtained as following: gadolinium (Gd) was added to a metal alloy containing 99.95% by weight of titanium (Ti) so that the resultant metal alloy has gadolinium (Gd) content of 500 ppm and then, the mixture thereof was cast-molded to a thick plate having the widths of 30 mm and 10 mm; and then, this plate was solution-treated, aged, and then roll-processed to a thick plate having the thickness of 0.3 mm.

[0170] Next, 500 g of gadolinium (Gd) was added to a titanium (Ti) alloy comprising 99.8% by weight of titanium (Ti) and 0.2% by weight of palladium (Pd), and then, the mixture thereof was cast-molded to a thick plate having the widths of 30 mm and 10 mm; and then, this plate was solution-treated, aged, and then roll-processed to a thick plate having the thickness of 0.3 mm.

[0171] The foregoing finishing-processed thick plates having the thickness of 0.3 mm were analyzed by the X-ray analysis; and the average crystallite diameters obtained by the Scherrer's equation were 7 nm, and 27 nm, respectively. The crystallite size could be adjusted in the level of nanometers (10^{-9} m to 10^{-6} m) and micrometers (10^{-6} m to 10^{-3} m).

[0172] Without substantial deterioration of electrical conductivity and Young's modulus, hardness, tensile strength, and 0.2% resisting force could be increased by 2 to 3 times. It was found that also elongation could be

increased by 2 to 3 times. Softening point could be increased by 2.1 times. Roll-process could be carried out without heat treatment; and in addition, cross process could be carried out. It was further found that processability was enhanced. These characteristics could be balanced.

[0173] The various characteristics could be enhanced so that it became possible to balance these characteristics.

[0174] These effects could be realized in plates, wires, thin films, and powders.

[0175] Next, a method for manufacturing the metal alloy member having the afore-mentioned characteristics will be explained.

[0176] Firstly, in the case of the cast-molded alloy, the alloy material with the afore-mentioned composition is cast-molded, then, if necessary, the material is solution-treated in which rapid cooling is conducted after heating to a prescribed temperature, and further, if necessary, an ageing treatment is conducted thereafter at a prescribed temperature.

[0177] In the case of the processed metal alloy, the alloy material with the afore-mentioned composition is cast-molded, then, if necessary, the material is solution-treated in which rapid cooling is conducted after heating to a prescribed temperature, and then the material is processed to a prescribed form, wherein if necessary, the material is aged before or after this process.

[0178] In the titanium (Ti) alloy, the solution treatment may be done in the temperature range of 600 to 2700°C, and the ageing treatment may be done in the temperature range of 150 to 500°C. Especially preferable conditions are the temperature range of 500 to 1550°C for the solution treatment, and the temperature range of 300 to 800°C for the ageing treatment. Processing efficiency during the time of processing is arbitrary, while the preferable range thereof is the same as that of the first embodiment.

[0179] The same effect could also be obtained when the solution treatment and the ageing treatment were conducted.

[0180] When evaluation was done as to the sample which was prepared by adding 5 to 30000 ppm of gadolinium (Gd) to the titanium (Ti) alloy including a high-purity titanium (Ti) alloy whose crystal lattice is a close-packed hexagonal lattice, the same addition effect of gadolinium (Gd) was obtained.

[0181] When evaluation was done as to the sample of the respective copper titanium (Ti) alloy compositions, the same addition effect of gadolinium (Gd) was obtained.

[0182] After addition of gadolinium (Gd), characteristics with regard to hardness, tensile strength, resisting force, elongation, heat resistance, and so forth were enhanced; and this could be easily processed, and workability thereof could be improved. Deterioration of Young's modulus and electrical conductivity was hardly observed.

[0183] When evaluation was done as to the sample of

the respective titanium (Ti) alloy compositions, the same addition effect of gadolinium (Gd) was obtained.

[0184] A metal alloy that is constituted by titanium (Ti) and at least one element selected from the group consisting of rare earth metals other than gadolinium (Gd), alkaline earth metals, silicon (Si), boron (B), aluminum (Al), iron (Fe), zirconium (Zr), copper (Cu), tin Sn, indium (In), nickel (Ni), cobalt (Co), vanadium (V), and chromium (Cr), eminent enhancement of the performance characteristics can be seen.

[0185] The metal alloys used in the embodiments are not particularly restricted. Any ingredient other than the above-mentioned function-enhancing additives may be used without specific restrictions provided that it is used in a usual metal alloy.

[0186] In other words, the above-mentioned function-enhancing additives are effective also in an existing general metal alloy. When manufacturing an alloy member according to these embodiments, the same embodiments of the metal alloys shall be applied. In the case of cast-molding, an alloy material with the foregoing composition is cast-molded, and then, the material is solution-treated in which rapid cooling is conducted after heating to a prescribed temperature. Thereafter, if necessary, the material is aged at prescribed temperature. In the case of the processed metal alloy, an alloy material with the afore-mentioned composition is cast-molded, the material is solution-treated in which rapid cooling is conducted after heating to a prescribed temperature, the material is processed to a prescribed form, and further, the material is aged before or after the foregoing process.

[0187] When gadolinium (Gd) solely only an appropriate amount of a function-enhancing additive that is composited with other element is added to a metal alloy (including high-purity alloy) having a face-centered cubic lattice, a body-centered cubic lattice, or a close-packed hexagonal lattice, not only superior high-function characteristics but also superior hardness, Young's modulus, tensile strength, heat-resistance, and workability than ever may be obtained, even in a cast-molded alloy that is not processed.

[0188] In view of volume-occupation rate, gadolinium (Gd) is the most effective element to achieve a high function; and in addition, its effect to enhance heat resistance is eminent. Especially, by adding gadolinium (Gd), marvelously high Young's modulus and elastic limit can be obtained. As can be seen above, gadolinium (Gd) is highly effective to enhance hardness, Young's modulus, and tensile strength; and in addition, eminent enhancement of function characteristics can be obtained. Furthermore, adding amount is small and volume-occupation rate is low; and thus, characteristics unique to a metal alloy can be utilized.

[0189] Effects as the function-enhancing additive can be realized by the sole use of gadolinium (Gd); however, excellent characteristics may also be obtained by a synergy effect that is brought about by adding it compositely with at least one element selected from the aforemen-

tioned elements other than gadolinium (Gd).

[0190] The fine crystallite high-function metal alloy member of the present invention can enhance function characteristics, so that this has strength together with high resisting force, Young's modulus, electrical conductivity, thermal conductivity, softening point, and the like; and in addition, this is not brittle because of the high tensile strength thereof. This is suitable for reduction in the size and weight because of its excellent mechanical characteristics and physical characteristics. This is sustainable. In addition, this has excellent processability and workability.

[0191] The fine crystallite high-function metal alloy member of the present invention has enhanced functions with superior characteristics including hardness, tensile strength, Young's modulus, resisting force, heat resistance, electrical conductivity, and thermal conductivity; and in addition, this has elongation and the like, so that this is easily processed with good workability. Accordingly, this is different from conventional metal alloy members. Furthermore, an important feature thereof resides in that these characteristics can be adjusted in accordance with preference of a user.

[0192] Accordingly, the most significant feature of the present invention resides in that important functional characteristics of the high-function metal alloy of the foregoing elements can be enhanced so that a unique metal alloy having the characteristics thereof adjusted in accordance with preference of a user can be obtained.

Claims

1. A fine crystallite high-function metal alloy member and a method for producing the same, wherein a metal alloy including a high-purity metal alloy whose crystal lattice is a face-centered cubic lattice, a body-centered cubic lattice, or a close-packed hexagonal lattice is made to contain therein 5 to 30000 ppm of gadolinium (Gd), and the crystallite thereof is made fine with the size in the level of nanometers (10^{-9} m to 10^{-6} m) and micrometers (10^{-6} m to 10^{-3} m).
2. A fine crystallite high-function metal alloy member and a method for producing the same, wherein a metal alloy including a high-purity metal alloy whose crystal lattice is a face-centered cubic lattice is made to contain therein 5 to 30000 ppm of gadolinium (Gd), and the crystallite thereof is made fine with the size in the level of nanometers (10^{-9} m to 10^{-6} m) and micrometers (10^{-6} m to 10^{-3} m).
3. A fine crystallite high-function metal alloy member and a method for producing the same, wherein a metal alloy including a high-purity metal alloy whose crystal lattice is a face-centered cubic lattice, a body-centered cubic lattice, or a close-packed hexagonal lattice is made to contain therein 5 to 30000 ppm of

gadolinium (Gd) solely or gadolinium (Gd) together with at least one element selected from the group consisting of elements other than gadolinium (Gd), and the crystallite thereof is made fine with the size in the level of nanometers (10^{-9} m to 10^{-6} m) and micrometers (10^{-6} m to 10^{-3} m).

4. A fine crystallite high-function metal alloy member and a method for producing the same, wherein a metal alloy including a high-purity metal alloy whose crystal lattice is a face-centered cubic lattice is made to contain therein 5 to 30000 ppm of gadolinium (Gd) solely or gadolinium (Gd) together with at least one element selected from the group consisting of elements other than gadolinium (Gd), and the crystallite thereof is made fine with the size in the level of nanometers (10^{-9} m to 10^{-6} m) and micrometers (10^{-6} m to 10^{-3} m).
5. A fine crystallite high-function metal alloy member and a method for producing the same, wherein a metal alloy including a high-purity metal alloy whose crystal lattice is a face-centered cubic lattice, a body-centered cubic lattice, or a close-packed hexagonal lattice is made to contain therein 5 to 30000 ppm of gadolinium (Gd) solely or gadolinium (Gd) together with at least one element selected from the group consisting of elements other than gadolinium (Gd), the crystallite thereof is made fine with the size in the level of nanometers (10^{-9} m to 10^{-6} m) and micrometers (10^{-6} m to 10^{-3} m), and the form thereof is adjusted, thereby remedying drawbacks thereof and enhancing various characteristics thereof without losing superior characteristics owned by the alloy itself.
6. A fine crystallite high-function metal alloy member and a method for producing the same, wherein a metal alloy including a high-purity metal alloy whose crystal lattice is a face-centered cubic lattice is made to contain therein 5 to 30000 ppm of gadolinium (Gd) solely or gadolinium (Gd) together with at least one element selected from the group consisting of elements other than gadolinium (Gd), the crystallite thereof is made fine with the size in the level of nanometers (10^{-9} m to 10^{-6} m) and micrometers (10^{-6} m to 10^{-3} m), and the form thereof is adjusted, thereby remedying drawbacks thereof and enhancing various characteristics thereof without losing superior characteristics owned by the alloy itself.
7. A business development method for developing, manufacturing, or selling a fine crystallite high-function metal alloy member, wherein a metal alloy including a high-purity metal alloy whose crystal lattice is a face-centered cubic lattice, a body-centered cubic lattice, or a close-packed hexagonal lattice is made to contain therein 5 to 30000 ppm of gadolinium (Gd) solely or gadolinium (Gd) together with at least one element selected from the group consisting of elements other than gadolinium (Gd), and the crystallite thereof is made fine with the size in the level of nanometers (10^{-9} m to 10^{-6} m) and micrometers (10^{-6} m to 10^{-3} m), and the form thereof is adjusted, thereby remedying drawbacks thereof and enhancing various characteristics thereof without losing superior characteristics owned by the alloy itself.

ium (Gd), the crystallite thereof is made fine with the size in the level of nanometers (10^{-9} m to 10^{-6} m) and micrometers (10^{-6} m to 10^{-3} m), and the form thereof is adjusted, thereby remedying drawbacks thereof and enhancing various characteristics thereof without losing superior characteristics owned by the alloy itself.

8. A business development method to for developing, manufacturing, or selling a fine crystallite high-function metal alloy member, wherein a metal alloy including a high-purity metal alloy whose crystal lattice is a face-centered cubic lattice is made to contain therein 5 to 30000 ppm of gadolinium (Gd), the crystallite thereof are made fine with the size in the level of nanometers (10^{-9} m to 10^{-6} m) and micrometers (10^{-6} m to 10^{-3} m), and the form thereof is adjusted, thereby remedying drawbacks thereof and enhancing various characteristics thereof without losing superior characteristics owned by the alloy itself.
9. A fine crystallite high-function metal alloy member and a method for producing the same, wherein a crystallite of a metal alloy including a high-purity metal alloy whose crystal lattice is a face-centered cubic lattice, a body-centered cubic lattice, or a close-packed hexagonal lattice is made fine with the size in the level of nanometers (10^{-9} m to 10^{-6} m) and micrometers (10^{-6} m to 10^{-3} m), and the form thereof is adjusted, thereby remedying drawbacks thereof and enhancing various characteristics thereof without losing superior characteristics owned by the alloy itself.
10. A fine crystallite high-function metal alloy member and a method for producing the same, wherein a crystallite of a metal alloy including a high-purity metal alloy whose crystal lattice is a face-centered cubic lattice is made fine with the size in the level of nanometers (10^{-9} m to 10^{-6} m) and micrometers (10^{-6} m to 10^{-3} m), and the form thereof is adjusted, thereby remedying drawbacks thereof and enhancing various characteristics thereof without losing superior characteristics owned by the alloy itself.
11. A fine crystallite high-function metal alloy member and a method for producing the same, wherein a metal alloy including a high-purity metal alloy whose crystal lattice is a face-centered cubic lattice, a body-centered cubic lattice, or a close-packed hexagonal lattice is made to contain therein 5 to 30000 ppm of gadolinium (Gd) solely or gadolinium (Gd) together with at least one element selected from the group consisting of elements other than gadolinium (Gd), the crystallite thereof is made fine with the size in the level of nanometers (10^{-9} m to 10^{-6} m) and micrometers (10^{-6} m to 10^{-3} m), and the form thereof is adjusted, thereby enhancing tensile strength, elas-

tic limit, heat resistance, corrosion resistance, processability, and elongation.

12. A fine crystallite high-function metal alloy member and a method for producing the same, wherein a metal alloy including a high-purity metal alloy whose crystal lattice is a face-centered cubic lattice is made to contain therein 5 to 30000 ppm of gadolinium (Gd) solely or gadolinium (Gd) together with at least one element selected from the group consisting of elements other than gadolinium (Gd), the crystallite thereof is made fine with the size in the level of nanometers (10^{-9} m to 10^{-6} m) and micrometers (10^{-6} m to 10^{-3} m), and the form thereof is adjusted, thereby enhancing tensile strength, elastic limit, heat resistance, corrosion resistance, processability, and elongation without substantial deterioration of Young's modulus.
13. The method for producing the fine crystallite high-function metal alloy member according to the preceding claims, wherein the solution treatment is conducted by rapidly cooling the metal alloy after heating it in the temperature range of 200 to 2800°C, and the ageing treatment is conducted by heat-treating the crystalline metal alloy in the temperature range of 100 to 1600°C.
14. The method for producing the fine crystallite high-function metal alloy member according to the preceding claims, wherein after the solution treatment, processing treatment and ageing treatment are conducted alternately and repeatedly.
15. A method for producing a fine crystallite high-function metal alloy member comprising the steps of:
 - cast-molding a material of the fine crystallite metal alloy member and the fine crystallite precious metal alloy member according to the preceding claims and
 - subjecting the said material to the solution treatment.
16. A method for producing a fine crystallite high-function metal alloy member comprising the steps of:
 - cast-molding a material of the fine crystallite metal alloy member and the fine crystallite metal alloy member according to the preceding claims, subjecting the said material to the solution treatment, and
 - subjecting the material to the ageing treatment before and after the processing.
17. A method for producing a fine crystallite high-function metal alloy member comprising the steps of:
 - cast-molding a material of the crystalline metal alloy member and the fine crystallite high-function metal alloy member according to the preceding claims,
 - subjecting the said material to the solution treatment,
 - a processing the material to a prescribed form, and
 - subjecting the material to the ageing treatment before and after the processing.
18. The method for producing the fine crystallite high-function metal alloy member according to any method of the preceding claims, wherein temperature of the solution treatment is in the range of 300 to 2800°C and temperature of the ageing treatment is in the range of 100 to 1400°C.
19. The method for producing the fine crystallite high-function metal alloy member according to any method of the preceding claims, wherein temperature of the solution treatment is in the range of 300 to 2700°C and temperature of the ageing treatment is in the range of 50 to 1000°C.
20. The method for producing the fine crystallite high-function metal alloy member according to any method of the preceding claims, wherein temperature of the solution treatment is in the range of 250 to 2500°C and temperature of the ageing treatment is in the range of 100 to 800°C.
21. Use of the high-function metal alloy according to any one of the preceding claims, as a product with reduced size and weight.
22. Use of the fine crystallite high-function metal alloy member according to any one of the preceding claims, as a musical instrument material.
23. Use of the fine crystallite high-function metal alloy member according to any one of the preceding claims, as an electronic material.
24. Use of the fine crystallite high-function metal alloy member according to any one of the preceding claims, as a jewelry material.
25. Use of the fine crystallite high-function metal alloy member according to any one of the preceding claims, as a structural material.
26. Use of the fine crystallite high-function metal alloy member according to any one of the preceding claims, as an automobile part.
27. Use of the fine crystallite high-function metal alloy member according to any one of the preceding

claims, as an aerial part.

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FIG. 1

Name	Crystal lattice	Composition (%)	Average crystallite size
Au type	Face-centered cubic lattice	Au 99.95	27
		Au 90-Ag 10	15
		Au 50-Ag 50	19
		Au 10-Ag 90	23
Ag type		Ag 99.95	8
		Ag 90-Pd 10	19
		Ag 50-Pd 50	23
		Ag 10-Pd 90	25
Pt type		Pt 99.95	11
		Pt 90-Pd 10	19
Pd type		Pt 50-Cu 50	17
		Pt 10-Cu 90	22
		Pd 99.95	15
		Al 99.95	6
Al type		Al 90-Mg 10	13
		Al 50-Mg 50	27
		Al 10-Mg 90	19
		Mg 99.95	12
Mg type		Cu 99.95	17
		Cu 90-Zn 10	7
		Cu 65-Zn 35	21
		Cu 10-Ag 90	13
Cu type		Fe 99.95	7
		Fe 99.0-Si 1	27
		Fe 75.0-Ni 17-Al 8	18
		Ti 99.95	7
Fe type		Body-centered cubic lattice	Ti 99.8-Pd 0.2
Ti type	Close-pack hexagonal lattice		

FIG. 2

Crystal lattice	Crystallite size (m)	Young's modulus increase rate (%)	Electrical conductivity increase rate (%)	Hardness increase rate (%)	Tensile strength increase rate (%)	Resisting force increase rate (%)	Elongation increase rate (%)	Softening point increase rate (%)	Corrosion resistance effect
Face-centered cubic lattice	10^{-9} to 10^{-3}	0 to 13	-4 to 0	0 to 220	0 to 230	0 to 170	0 to 220	0 to 150	Yes
Body-centered cubic lattice	10^{-9} to 10^{-3}	0 to 11	-3 to 0	0 to 205	0 to 210	0 to 160	0 to 204	0 to 142	Yes
Close-pack hexagonal lattice	10^{-9} to 10^{-3}	0 to 10	-2 to 0	0 to 190	0 to 205	0 to 150	0 to 210	0 to 140	Yes

Note: The silver plate of FIG. 1 was allowed to stand in an atmosphere for 5 years, showing no silver oxide and silver sulfide on the surface thereof by the X-ray analysis.

INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2012/060518

A. CLASSIFICATION OF SUBJECT MATTER C22C1/02(2006.01)i, C22C5/02(2006.01)i, C22C5/04(2006.01)i, C22C5/06(2006.01)i, C22C9/04(2006.01)i, C22C14/00(2006.01)i, C22C21/06(2006.01)i, C22C23/00(2006.01)i, C22C38/02(2006.01)i, C22C38/08(2006.01)i, According to International Patent Classification (IPC) or to both national classification and IPC		
B. FIELDS SEARCHED Minimum documentation searched (classification system followed by classification symbols) C22C1/02, C22C5/02, C22C5/04, C22C5/06, C22C9/04, C22C14/00, C22C21/06, C22C23/00, C22C38/02, C22C38/08, C22F1/00 Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched Jitsuyo Shinan Koho 1922-1996 Jitsuyo Shinan Toroku Koho 1996-2012 Kokai Jitsuyo Shinan Koho 1971-2012 Toroku Jitsuyo Shinan Koho 1994-2012 Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)		
C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	JP 2009-30146 A (Kazuo OGASA), 12 February 2009 (12.02.2009), claims 1 to 47; full specification; fig. 1 to 4 (Family: none)	1-27
X	WO 2008/72485 A1 (Kazuo OGASA), 19 June 2008 (19.06.2008), claims 1 to 44; full specification; fig. 1 to 4 (Family: none)	1-27
X	WO 2003/074745 A1 (Kazuo OGASA), 12 September 2003 (12.09.2003), claims 1 to 58; full specification; fig. 1 to 8 & AU 2003211455 A & JP 4417115 B	1-27
☒ Further documents are listed in the continuation of Box C. ☐ See patent family annex.		
* Special categories of cited documents: "A" document defining the general state of the art which is not considered to be of particular relevance "E" earlier application or patent but published on or after the international filing date "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) "O" document referring to an oral disclosure, use, exhibition or other means "P" document published prior to the international filing date but later than the priority date claimed "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art "&" document member of the same patent family		
Date of the actual completion of the international search 04 July, 2012 (04.07.12)		Date of mailing of the international search report 17 July, 2012 (17.07.12)
Name and mailing address of the ISA/ Japanese Patent Office		Authorized officer
Facsimile No.		Telephone No.

Form PCT/ISA/210 (second sheet) (July 2009)

INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2012/060518

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 2002/002834 A1 (Kazuo OGASA), 10 January 2002 (10.01.2002), claims 1 to 77; full descriptions; tables 1 to 4; fig. 1 to 3 & US 2003/0034097 A1 & US 2005/0205173 A1 & EP 1312687 A1 & EP 1693472 A2 & EP 2055794 A1 & CA 2383976 A & AU 5708300 A & CN 1387585 A & CN 1611619 A & AT 328128 T	1-27
X	JP 2001-49364 A (Kazuo OGASA), 20 February 2001 (20.02.2001), claims 1 to 14; full specification; fig. 1 to 4 (Family: none)	1-27
X	WO 1997/047778 A1 (Kazuo OGASA), 18 December 1997 (18.12.1997), claims 1 to 13; full descriptions; fig. 1 to 3 & US 6063213 A & EP 922780 A1 & DE 69715885 D & HK 1020998 A & AT 224961 T & CN 1221459 A	1-27
X	WO 1996/031632 A1 (Kazuo OGASA), 10 October 1996 (10.10.1996), claims 1 to 6; full descriptions; fig. 1 to 4 & US 6045635 A & US 6077366 A & EP 819773 A1 & DE 69618944 D & AU 4844996 A & BR 9604819 A & AU 717376 B & AT 212679 T & ES 2170850 T & CN 1180384 A & JP 9-3612 A	1-27
X	JP 9-3612 A (Kabushiki Kaisha Nishiki Tokushu Kinzoku Kenkyusho), 07 January 1997 (07.01.1997), claims 1 to 6; full specification; table 1 & US 6045635 A & US 6077366 A & EP 819773 A1 & WO 1996/031632 A1 & DE 69618944 D & AU 4844996 A & BR 9604819 A & AU 717376 B & AT 212679 T & ES 2170850 T & CN 1180384 A	1-27
X	JP 8-157983 A (Kabushiki Kaisha Kuwayama Kinzoku), 18 June 1996 (18.06.1996), claims 1, 2; full specification; table 1 (Family: none)	1-27

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INTERNATIONAL SEARCH REPORT

International application No.

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Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

Each of the inventions of claims 1-27 does not have a novel configuration which makes a contribution over the prior art.

Consequently, since it is obvious that respective inventions do not mutually comply with the requirement of unity, it is considered that the number of inventions is twenty seven (27), which is same as the number of claims.

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
2. ☒ As all searchable claims could be searched without effort justifying additional fees, this Authority did not invite payment of additional fees.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

- ☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.
- ☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.
- ☐ No protest accompanied the payment of additional search fees.

Form PCT/ISA/210 (continuation of first sheet (2)) (July 2009)

INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2012/060518

Continuation of A. CLASSIFICATION OF SUBJECT MATTER
(International Patent Classification (IPC))

C22F1/00(2006.01) i

(According to International Patent Classification (IPC) or to both national
classification and IPC)

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

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- JP 9002014 W [0018]
- JP 0004411 W [0018]
- JP 3001993 W [0018]
- JP 2007073133 W [0018]