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(54) **COPPER ALLOY MATERIAL FOR ELECTRIC AND ELECTRONIC COMPONENTS**

(57) A copper alloy material for an electric/electronic part, containing Co 0.5 to 2.5 mass% and Si 0.1 to 1.0 mass%, at a ratio of Co/Si of 3 to 5 in terms of mass ratio, with the balance of Cu and inevitable impurities, which is obtained by subjecting to a solution treatment at a tem-

perature (°C) from 800°C to 960°C and lower than $-122.77X^2 + 409.99X + 615.74$, in which X represents the Co content in mass%.

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Description

TECHNICAL FIELD

5 **[0001]** The present invention relates to a copper alloy material applied to electric/electronic parts.

BACKGROUND ART

10 **[0002]** Hitherto, brass (C2600) and phosphor bronze (C5191, C5212, C5210), as well as beryllium copper (C17200, C17530) and Corson alloy (C7025), and the like, have been used for connectors, terminals, relays, switches, and the like, for electronic/electric equipments.

In recent years, since a frequency of electric current applied to the electronic/electric equipments using those alloys becomes high, and a substantial electrical conductivity is lowered due to a skin effect, materials for the parts have been required to have a high electrical conductivity. Although brass and phosphor bronze each originally have a low electrical conductivity and the Corson copper alloy shows a medium electrical conductivity (EC nearly equals to 40 to 50 %IACS) as a connector material, a higher electrical conductivity has been required. Further, beryllium copper has the medium electrical conductivity, but it is expensive. Still further, it is well known that since beryllium is an environment load substance, beryllium copper has been studied to be replaced with another copper alloy, and the like. On the other hand, pure copper (C1100), tin bearing copper (C14410), and the like, which have a high electrical conductivity, have a drawback that their mechanical strength is low. Thus, a copper alloy has been desired which has an electrical conductivity higher than that of a conventional Corson copper, and a tensile strength and a bending property at the same level of those of the conventional Corson copper.

The CXXXXX denotes types of copper alloys specified in JIS, and "%IACS" is an abbreviation of "International Annealed Copper Standard" and is a unit which indicates an electrical conductivity of a material.

25 **[0003]** In general, electrical conductivity and mechanical strength are incompatible properties. Examples of a method for enhancing the strength, include solid-solution strengthening, working strengthening, precipitation strengthening, and the like. Among them, it is known that the precipitation strengthening is a promise as a method for enhancing the strength of the copper alloy without deteriorating the electrical conductivity. In this precipitation strengthening, an alloy, to which an element(s) which precipitates is added, is heat-treated at a high temperature, so as to cause solid solution of the element(s) in a copper matrix, and then, the resultant alloy is heat-treated at a temperature lower than said high temperature, thereby to precipitate the element(s) of the solid solution. For example, this strengthening method is adopted for beryllium copper, the Corson alloy, and the like.

30 **[0004]** Meanwhile, there are known alloys containing an intermetallic compound of cobalt (Co) and silicon (Si) in copper, besides the beryllium copper, the Corson alloy, and the like. Further, there is a copper alloy containing Co and Si, and Mg, Sn and Zn, from which a material having a high strength and a high electrical conductivity can be produced at a low cost. The copper alloy contains Co and Si each at a lower concentration than that of a conventional copper alloy containing Co and Si each at a high concentration (Co content: 2 to 4 mass%, the amount ratio of Si/Co: 1/4) (see, for example, Patent Literature 1).

In the production of this copper alloy described in Patent Literature 1, a method is adopted, in which a solution treatment temperature is set high (for example, 950°C in the example of Patent Literature 1), the elements are sufficiently made into a solid solution in copper, and then a precipitation-hardening is conducted by a heat treatment.

40 However, this method causes the coarsening of grains. It is known that, in an alloy structure, if a grain size is coarsened, a bending property is poor. With conventional copper alloys obtained through solution treatment, it is impossible to attain a favorable bending property.

45 {Patent Literature 1} JP-A-63-307232 ("JP-A" means unexamined published Japanese patent application)

DISCLOSURE OF INVENTION

50 TECHNICAL PROBLEM

[0005] The present invention is contemplated for providing a copper alloy material for electric/electronic parts, which can be favorably used in products subjected to severe bending, such as connectors or the like, and which is excellent in mechanical strength, electrical conductivity, and bending property.

55 SOLUTION TO PROBLEM

[0006] According to the present invention, there is provided the following means:

(1) A copper alloy material for an electric/electronic part, comprising Co 0.5 to 2.5 mass% and Si 0.1 to 1.0 mass%, at a ratio of Co/Si of 3 to 5 (mass ratio), with the balance of Cu and inevitable impurities, which is obtained by subjecting to a solution treatment at a temperature T_s (°C) from 800°C to 960°C and lower than $-122.77X^2 + 409.99X + 615.74$, in which X represents the content (mass%) of Co;

(2) A copper alloy material for an electric/electronic part, comprising Co 0.5 to 2.5 mass% and Si 0.1 to 1.0 mass%, at a ratio of Co/Si of 3 to 5 (mass ratio), and comprising 0.01 to 1.0 mass% of one or two or more selected from the group consisting of Cr, Mg, Mn, Sn, V, Al, Fe, Ni, Ti and Zr, with the balance of Cu and inevitable impurities, which is obtained by subjecting to a solution treatment at a temperature T_s (°C) from 800°C to 960°C and lower than $-94.643X^2 + 329.99X + 677.09$, in which X represents the content (mass%) of Co;

(3) The copper alloy material for an electric/electronic part as described in the item (1) or (2), which has a yield stress of not less than 500 MPa but less than 650 MPa, an electrical conductivity of 60 %IACS or more, and a value (R/t) representing a bending property of less than 0.5;

(4) The copper alloy material for an electric/electronic part as described in the item (1) or (2), which has a yield stress of 650 MPa or more, an electrical conductivity of 50 %IACS or more, and a value (R/t) representing a bending property of less than 1.5;

(5) The copper alloy material for an electric/electronic part as described in the item (1) or (2), which has a yield stress of not less than 500 MPa but less than 650 MPa, an electrical conductivity of 60 %IACS or more, and a value (R/t) representing a bending property of 1.2 or less, with respect to each of a sample parallel to a rolling direction and a sample perpendicular to the rolling direction; and

(6) The copper alloy material for an electric/electronic part as described in the item (1) or (2), which has a yield stress of 650 MPa or more, an electrical conductivity of 50 %IACS or more, and a value (R/t) representing a bending property of 1.5 or less, with respect to each of a sample parallel to a rolling direction, and a sample perpendicular to the rolling direction.

Herein, the value (R/t) representing a bending property means a value R/t obtained as follows: cutting out samples with a respective sheet thickness and with a sheet width w of 10 (mm) from a test specimen; rubbing lightly the surface of the sample with metal polishing powders, to remove an oxide layer; subjecting the resultant sample to W-bending, such that the inner angle of bending would be 90°, with respect to two kinds of: [1] bending (GW) of the sample parallel to the rolling direction, and [2] bending (BW) of the sample perpendicular to the rolling direction; and dividing the smallest bending radius R (mm) at which no micro-cracks occur, by a sample's sheet thickness t (mm). In the present invention, the bending property is evaluated with this value R/t.

ADVANTAGEOUS EFFECTS OF INVENTION

[0007] The copper alloy material of the present invention for electric/electronic parts is excellent in all of the mechanical strength, the electrical conductivity, and the bending property. The copper alloy material of the present invention for electric/electronic parts can be favorably used even in the products subjected to severe bending, such as connectors or the like.

Other and further features and advantages of the invention will appear more fully from the following description.

BEST MODE FOR CARRYING OUT THE INVENTION

[0008] With respect to an alloy composition of the copper alloy material of the present invention, a preferable embodiment is explained in detail below. The copper alloy material of the present invention is a copper alloy material having a specific shape, such as a sheet material, a strip material, a wire material, a rod material, a foil, and the like, and the copper alloy material can be used for any electric/electronic parts. The electric/electronic parts are not specifically limited. The copper alloy material is favorably used, for example, for connectors, terminal materials, and the like; particularly, high-frequency relays and switches, which are desired to be high in electrical conductivity, or connectors, terminal materials, lead frames, and the like, which are mounted in vehicles or the like.

[0009] In the copper alloy composition according to the present invention, Co and Si are essential elements. Co and Si in the copper alloy mainly form a precipitate of a Co_2Si intermetallic compound, thereby to enhance the strength and the electrical conductivity.

The content of Co is 0.2 to 2.5 mass%, preferably 0.3 to 2.0 mass%, more preferably 0.5 to 1.6 mass%. The content of Si is 0.1 to 1.0 mass%, preferably 0.1 to 0.7 mass%, more preferably 0.1 to 0.5 mass%. The reason why their contents are specified is explained as follows. As described above, these mainly form the precipitate of the intermetallic compound of Co_2Si , to contribute to the precipitation strengthening. If the content of Co is less than 0.5 mass%, the precipitation strengthening degree is small, and if the content of Co is more than 2.5 mass%, the effect due to Co is saturated. Further, from a stoichiometric proportion, the optimum addition ratio of the compound is Co/Si nearly equals to 4.2, and the

addition amount of Si is determined to be in this range. It is preferable to control the Co/Si to be within a range of 3.0 to 5.0, more preferably within a range of 3.2 to 4.5, with the above-mentioned value to be the central value. Hereinafter, Si and Co may be referred to as "elements I to be added".

In the case of a copper alloy having the above-mentioned composition, the temperature T_s (°C) for conducting the solution treatment is from 800°C to 960°C, and lower than $-122.77X^2 + 409.99X + 615.74$ (°C), in which the Co content (mass%) is represented by X.

[0010] To the copper alloy of the present invention, it is preferable to add one or two or more kinds of any of Cr, Mg, Mn, Sn, V, Al, Fe, Ni, Ti, and Zr, and the addition amount thereof is 0.01 to 1.0 mass%. Hereinafter, these Cr, Mg, Mn, Sn, V, Al, Fe, Ni, Ti, and Zr may be referred to as "element(s) II to be added".

When the addition amount of the element(s) II to be added is less than 0.01 mass%, the effect due to the addition is small. When the addition amount is more than 1.0 mass%, any of the following occurs: <1> the electrical conductivity conspicuously lowers, by the element(s) making a solid-solution, such as Mg, Mn and Sn; <2> the strength lowers by a precipitation other than the timing of an aging, or a solution temperature raises due to a raise of a solid-solution temperature, by the element(s) which accelerate(s) the precipitation, such as Cr, V, Al, Fe, Ni, Ti, and Zr; and <3> a casting become difficult to be conducted, due to a conspicuous oxidation, by Cr, Mg, Al, Ti, and Zr.

[0011] Among these elements II to be added, Cr, Ni, and Fe have a function of forming a Co-x-Si compound ($x = \text{Cr, Ni or Fe}$), to enhance the strength, by being replaced with a part of Co in a main precipitate phase.

Mg, Mn, and Sn have an action of making a solid solution in the copper matrix, to strengthen the copper alloy. Mg and Mn also exhibit an effect for improving a hot workability.

V, Al, Ni, Ti, and Zr have an action of forming a compound together with Co and Si, to strengthen and suppress coarsening of the grains.

[0012] A preferable method of producing the copper alloy material according to the present invention includes the following steps. That is, such steps are: meltcasting → re-heat-treatment → hot rolling → cold rolling → solution treatment → aging heat-treatment → final cold-rolling → stress-relief annealing. The order of the aging heat-treatment and the final cold-rolling may be reversed. The stress-relief (low-temperature) annealing to be finally conducted may be omitted.

[0013] In the present invention, the solution treatment before subjecting to the final rolling is conducted at a temperature from 800°C to 960°C.

Further, in the case where the copper alloy material does not contain any of the elements II to be added, the solution treatment temperature T_s (°C) is set to a temperature (°C) lower than $-122.77X^2 + 409.99X + 615.74$, in which the Co content (mass%) is represented by X.

On the other hand, in the case where the copper alloy material contains the element(s) II to be added at the content described above, the solution treatment temperature T_s (°C) is set to a temperature (°C) lower than $-94.643X^2 + 329.99X + 677.09$, in which the Co content (mass%) is represented by X.

The heat treatment at this temperature determines the grain size in the copper alloy material.

[0014] Further, in the present invention, it is preferable to conduct a rapid cooling (quenching) at a cooling speed of 50°C/sec or more, from this solution heat-treatment temperature T_s . If the cooling speed in the quenching is too low, the elements made to be a solid solution at the aforementioned high temperature, may precipitate.

Particles (compounds), precipitated upon cooling at such a too low cooling speed (for example, at a cooling speed lower than 50°C/sec), are non-coherent precipitates that do not contribute to the strength. Further, this non-coherent precipitate may contribute as a nucleation site when a coherent precipitate is formed in the subsequent aging heat-treatment step, and may accelerate the precipitation of a part in which the coherent precipitate formed, and resultantly may affect as negatively to the properties.

Thus, the cooling speed is preferably 50°C/sec or more, more preferably 80°C/sec or more, and even more preferably 100°C/sec or more. Unless the cooling speed is not over a practical upper limit, it is preferably as fast as possible. This cooling speed means an average cooling speed from the high temperature of the solution heat-treatment temperature to 300°C. Since the structure is not varied largely at a temperature less than 300°C, it is enough to control appropriately the cooling speed to this temperature.

[0015] In the present invention, in order to attain favorably the properties of the copper alloy material having the aforementioned composition, the solution treatment temperature is defined.

In the present invention, the grain size is preferably 20 μm or less, and more preferably 10 μm or less. The reason as assumed is because, if the grain size is more than 20 μm, due to the coarse grain size, a grain boundary density is low and a bending stress cannot be sufficiently absorbed, to deteriorate the workability. The lower limit of the grain size is not particularly limited, but is generally 3 μm or more. The "grain size" means a value measured according to JIS-H0501 (cutting method) described below.

Herein, the "size of a precipitate" is an average size of the precipitate, as determined by a method described below.

[0016] In one preferable embodiment of the copper alloy material of the present invention for electric/electronic parts, the copper alloy material has properties of:

a yield stress of not less than 500 MPa but less than 650 MPa; an electrical conductivity of 60 %IACS or more; and a bending property (R/t) of less than 0.5. Herein, the "bending property (R/t) of less than 0.5" means that, at least, a R/t value, in the bending of the sample parallel to a rolling direction, is less than 0.5; and it is preferably that R/t values are less than 0.5, in both of the bending of the sample parallel to the rolling direction and the bending of the sample perpendicular to the rolling direction.

In another preferable embodiment of the copper alloy material of the present invention for electric/electronic parts, the copper alloy material has properties of: a yield stress of 650 MPa or more; an electrical conductivity of 50 %IACS or more; and a bending property (R/t) of less than 1.5. Herein, the "bending property (R/t) of less than 1.5" means that, at least, a R/t value, in the bending of the sample parallel to the rolling direction, is less than 1.5; and it is preferably that R/t values are less than 1.5, in both of the bending of the sample parallel to the rolling direction and the bending of the sample perpendicular to the rolling direction.

In still another preferable embodiment of the copper alloy material of the present invention for electric/electronic parts, the copper alloy material has properties of: a yield stress of not less than 500 MPa but less than 650 MPa; an electrical conductivity of 60 %IACS or more; and the value (R/t) representing the bending property of 1.2 or less (more preferably 1.0 or less, and even more preferably 0.6 or less), in both of the bending of the sample parallel to the rolling direction and the bending of the sample perpendicular to the rolling direction.

In further another preferable embodiment of the copper alloy material of the present invention for electric/electronic parts, the copper alloy material has properties of: a yield stress of 650 MPa or more; an electrical conductivity of 50 %IACS or more; and the value (R/t) representing the bending property of 1.5 or less (more preferably 1.2 or less), in both of the bending of the sample parallel to the rolling direction and the bending of the sample perpendicular to the rolling direction. As mentioned above, the copper alloy material of the present invention high in the electrical conductivity and mechanical strength, and excellent in the bending property, can be favorably used in electric/electronic parts, such as connectors, subjected to severe bending.

EXAMPLES

[0017] Hereinafter, the present invention is explained in more detail based on the following examples, but the invention is not intended to be limited to those.

(Reference example 1)

[0018] Alloys (Nos. 1 to 9) composed of elements as shown in Table 1, with the balance of Cu and inevitable impurities, were melted with a high-frequency melting furnace, followed by casting at a cooling speed of 10 to 30°C /sec, to obtain ingots with length 180 mm, width 30 mm, and height 110 mm, respectively.

The thus-obtained ingots were maintained at 1,000°C for 30 minutes, followed by working to thickness 12 mm by hot rolling. After the hot rolling, the thus-hot-rolled alloys were immediately quenched by water cooling, followed by face-milling to thickness about 10 mm to remove an oxide layer on the surface of the alloy, and then working by cold rolling. Then, for the purposes of conducting solution-treatment and recrystallization, the resultant alloys were heat-treated by maintaining at 950°C for 30 seconds, followed immediately by quenching by water cooling.

In the above, the temperature raising speed to reach the highest temperature from the room temperature was within the range of 10 to 50°C/sec, and the cooling speed was within the range of 30 to 200°C/sec.

Thereafter, the surface oxide layer was removed, and the alloys were subjected to cold rolling, according to necessity. This cold-rolling also functioned to work hardening, and acceleration of precipitation hardening in heat treatment of the subsequent step.

Then, for the purpose of allowing aging precipitation, the alloys were subjected to a heat treatment at 525°C for 120 minutes. In the above, the temperature raising speed to reach the highest temperature from the room temperature was within the range of 3 to 25°C/min, and in the temperature lowering, the cooling was conducted at a speed within the range of 1°C/min to 2°C/min in the furnace, to 300°C which was a temperature sufficiently lower than the temperature range presumed to affect the precipitation.

After the aging heat treatment, the cold rolling was conducted, so as to reduce 20% of the sheet thickness. For each kind of the alloys, test materials were produced with sheet thickness 0.10 mm, 0.15 mm, 0.20 mm, and 0.25 mm, respectively.

Then, the resultant materials were subjected to a heat treatment at 350°C for 30 minutes. In the above, the temperature raising speed to reach the highest temperature from the room temperature was within the range of 3 to 25°C/min, and in the temperature lowering, the cooling was conducted at a speed within the range of 1°C/min to 2°C/min in the furnace, to 300°C which was a temperature sufficiently lower than the temperature range presumed to affect the precipitation.

[0019] Among the thus-produced alloy materials of Alloy Nos. 1 to 8, with respect to the respective alloy material with

sheet thickness 0.20 mm, a yield stress (YS), a tensile strength (TS), and an electrical conductivity (EC) were measured by the methods described below. The results are shown in Table 3. With respect to the alloy material of Alloy No. 9, it was difficult to conduct the hot rolling due to excessive precipitation and crystallization, and no final product was produced, thus no measurements below were conducted.

Methods of measuring the yield stress and the tensile strength: each two test pieces that were cut out from the direction parallel to the rolling direction according to JIS Z2201-5 were measured according to JIS Z2241; and the average value (MPa) thereof was calculated.

The yield stress was measured according to an offset method. That is, a proof stress, in the case where a permanent elongation was 0.2%, was calculated by using an expression: $\sigma_{0.2} = F_{0.2}/A_0$. In the expression, σ represents a proof stress (N/mm²) calculated by the offset method; and F represents a force, which was determined, by obtaining a relationship curve diagram between a force and a ratio of elongation using an elongation meter, drawing a line parallel to the straight line part of the early stage of the test, from the point on the axis of elongation corresponding to the predetermined permanent elongation ($\epsilon\%$), and determining the force shown at the point at which the parallel line intersects the curve diagram.

Method of measuring the electrical conductivity: the electrical conductivity (%IACS) was calculated, by measuring a specific resistance of the material through a four terminal method in a thermostatic bath maintained at 20°C ($\pm 0.5^\circ\text{C}$). The distance between the terminals was set to 100 mm.

[0020] {Table 1}

Table 1

	Alloy No.	Elements I to be added		
		Co / mass%	Si/mass%	Co/Si
Example according to this invention	1	0.7	0.17	4.12
	2	1.20	0.30	4.00
	3	1.40	0.35	4.00
	4	1.65	0.40	4.13
	5	1.90	0.45	4.22
Comparative example	6	0.30	0.07	4.29
	7	1.40	0.70	2.00
	8	1.40	0.25	5.60
	9	3.00	0.75	4.00

[0021] {Table 2}

Table 2

Process	Solid-solution / °C	Aging annealing / °C	Rolling (red%)	Stress relief annealing / °C
A	825	525	20	350
B	850	525	20	350
C	875	525	20	350
D	900	525	20	350
E	925	525	20	350
F	950	525	20	350
G	750	525	20	350
H	1000	525	20	350

[0022] {Table 3}

Table 3

Alloy No.	Steps	YS / MPa	TS / MPa	EC (%IACS)
1	F	550	620	68
2	F	620	660	65
3	F	660	700	60
4	F	670	710	59
5	F	675	715	58
6	F	300	380	75
7	F	620	670	33
8	F	610	650	44
9	Hot-rolling was difficult, due to excessive precipitation and crystallization			

[0023] In those tests, since only the strength and the electrical conductivity were evaluated, the treatment temperature of 950°C (Process F in Table 2 above) was employed, at which the strength was sufficiently obtained.

In Alloy Nos. 1 to 5 which satisfy the scope of the composition defined in the present invention, the alloy materials were obtained, which were excellent in both of the strength and the electrical conductivity with a favorable balance.

Contrary to the above, with regard to Alloy No. 6 which had too small amounts of Co and Si, the degree of the precipitation hardening was small, and the strength was insufficient.

Further, with regard to Alloy No. 9 which had a too large amount of Co, the production of the alloy material was difficult, since there occurred a deterioration of the product due to an excessive formation of oxides upon the melting and reheat cracks of the ingot due to an excessive precipitation and the like, to make it difficult to conduct the hot rolling. Further, since a large amount of expensive Co was used, the alloy material was inferior in the competitive power in terms of cost. In the comparative examples of Alloy Nos. 7 and 8 having the Co/Si ratios in the range outside of Co/Si = 3 to 5, the resultant alloy materials contained more of solid-solution elements of Co and Si which did not precipitate, to cause a conspicuous deterioration in the electrical conductivity.

Example 1

[0024] Alloy materials of Examples 1 to 3 and 10 to 16 according to the present invention and Comparative examples 1 to 3 and 18 to 22 were obtained in the same manner as in Reference example 1, except that alloys, composed of the components shown in Table 4 with the balance of Cu and inevitable impurities, were used, and that the temperature for the solution treatment was changed to temperatures of Processes A to H shown in Table 2, respectively. Alloys Nos. 1 to 3 shown in Table 4 had the same compositions as those of Alloys Nos. 1 to 3 shown in Table 1, respectively. Alloys Nos. 10 to 12 of Examples shown in Table 4 were those prepared by adding Cr to Alloys Nos. 1 to 3 shown in Table 1 and Table 4, respectively, in the amounts within the defined ranges; and Alloys Nos. 13 to 16 of Examples shown in Table 4 were those prepared by adding Mg (No. 13), Sn (No. 14), Cr and Mg (No. 15), and Cr and Ti (No. 16) to Alloy No. 3 shown in Table 1 and Table 4, respectively, in the amounts within the defined ranges. Alloys Nos. 18 to 22 of Comparative examples shown in Table 4 were those produced by adding Cr (No. 18), Ti (No. 19), Mg (No. 20), Sn (No. 21), and Zr (No. 22) to Alloy No. 3 shown in Table 1 and Table 4, respectively, in the amounts exceeding the defined ranges.

[0025] With respect to the thus-obtained alloy materials of Examples 1 to 3 and 10 to 16 according to the present invention and Comparative examples 1 to 3 and 18 to 22, the yield stress (YS), the tensile strength (TS), and the electrical conductivity (EC) were measured in the same manner as in Reference example 1. Further, a grain size (GS) and a bending property (R/t) were measured, according to the methods described below. The results are shown in Table 5.

Method of measuring the grain size: a cross-section perpendicular to the rolling direction of a test piece was finished into a mirror surface by wet polishing and buff polishing; the thus-polished surface was corroded with a liquid of chromic acid : water = 1 : 1 for several seconds; and then, a photograph of the resultant polished surface was taken using a secondary electronic image of SEM at a magnification ratio of 400 to 1,000 times; to measure an average grain size (μm) on the cross-section, according to the cutting method of JIS-H-0501. The analysis was conducted at the cross section transverse to the rolling direction.

Evaluation of the bending property: the surface of a sample with a respective sheet thickness and with a sheet width w of 10 (mm) from the test specimen, was rubbed lightly with metal polishing powders, to remove an oxide layer, the resultant sample was subjected to W-bending, such that the inner angle of bending would be 90°, with respect to two kinds of: bending ((GOOD WAY: hereinafter, also referred to GW)) of the sample parallel to the rolling direction; and

bending (BAD WAY: hereinafter, also referred to BW) of the sample perpendicular to the rolling direction. The bending was evaluated with R/t , which was a value obtained by dividing the smallest bending radius R at which no micro-cracks occurred, by the sample's sheet thickness t .

[0026] {Table 4}

Table 4

	Alloy No.	Process	Elements I to be added		Element(s) II to be added
			Co/mass%	Si/mass%	
Example according to this invention	1	A	0.7	0.17	None
	2	C	1.2	0.3	None
	3	E	1.4	0.35	None
	10	A	0.7	0.17	Cr: 0.1 mass%
	11	C	1.2	0.3	Cr: 0.1 mass%
	12	E	1.4	0.35	Cr: 0.2 mass%
	10	B	0.7	0.17	Cr: 0.1 mass%
	11	D	1.2	0.3	Cr: 0.1 mass%
	12	F	1.4	0.35	0.2 mass%
	13	F	1.4	0.35	Cr: Mg: 0.2 mass%
	14	F	1.4	0.35	Sn: 0.4 mass%
	15	F	1.4	0.35	Cr: 0.2 mass%, Mg: 0.1 mass%
	16	F	1.4	0.35	Cr: 0.2mass%, Ti: 0.5 mass%
Comparative example	1	B	0.7	0.17	None
	2	F	1.2	0.3	None
	3	F	1.4	0.35	None
	3	G	1.4	0.35	None
	3	H	1.4	0.35	None
	18	-	1.4	0.35	Cr: 1.2 mass%
	19	-	1.4	0.35	Ti: 1.2 mass%
	20	-	1.4	0.35	Mg: 1.2 mass%
	21	F	1.4	0.35	Sn: 1.2 mass%
	22	-	1.4	0.35	Zr: 1.2 mass%

[0027] {Table 5}

Table 5

	Alloy No.	Process	YS/MPa	TS/MPa	EC (%IACS)	GS/ μm	R/t (GW)	R/t (BW)
Example according to this invention	1	A	520	580	70	10	0.4	0.4
	2	C	550	610	68	10	0.5	0.5
	3	E	600	660	65	10	1	1
	10	A	535	595	68	5	0.4	0.4
	11	C	575	615	66	8	0.5	0.5
	12	E	620	672	64	8	1	1.2
	10	B	540	600	68	15	0.4	0.4
	11	D	590	645	66	18	0.4	0.4
	12	F	600	660	65	20	0.6	1
	13	F	675	700	58	20	1.2	1.2
	14	F	670	710	50	20	1.5	1.5
	15	F	677	725	56	15	1.5	1.5
	16	F	650	710	55	20	1.5	1.5
Comparative example	1	B	530	580	66	50	0.6	0.8
	2	F	630	680	60	80	0.8	1
	3	F	682	720	59	35	1	1.6
	3	G	540	580	72	-	1.5	2
	3	H	700	730	55	50	2.5	3
	18	-	Production was impossible					
	19	-	Production was impossible					
	20	-	Production was impossible					
	21	F	578	675	35	20	1.2	1.5
	22	-	Production was impossible					

[0028] In Examples 1 to 3 according to the present invention in Table 5, the solution treatment temperature T_s ($^{\circ}\text{C}$) was set at a temperature ($^{\circ}\text{C}$) of 800°C to 960°C and lower than $-122.77X^2 + 409.99X + 615.74$, in which the Co content (mass%) was represented by X. Thus, the grain size was able to be maintained at less than $20\ \mu\text{m}$, and it was possible to obtain the copper alloy materials, which were excellent in the balance of the mechanical strength, the electrical conductivity, and the bending property.

Specifically, the yield stress was not less than 500 MPa but less than 650 MPa, the electrical conductivity was 60 %IACS or more, and the values (R/t) representing the bending property were 1.0 or less in both of GW and BW. Further, some of the Examples according to the present invention had the values (R/t) representing the bending property of 0.6 or less, or even less than 0.5, in both of GW and BW. Thus, it is found that the copper alloy materials were obtained, which were excellent in the balance of the mechanical strength, the electrical conductivity, and the bending property.

Contrary to the above, even in the same compositions, when the samples were subjected to the heat treatments at the temperatures shown in Comparative examples 1 to 3, the strengths were equal to or higher than those of Examples 1 to 3 according to the present invention, but the grain sizes were coarse and they were poor in the bending property, as compared to Examples 1 to 3 according to the present invention. Further, the value (R/t) representing the bending property showed a tendency to be poor in BW, as compared with that in GW.

As shown in Table 5, in Comparative example 3, the treatment, which was conducted at a solution temperature lower than the predetermined temperature, resulted in the remaining of structures that did not recrystallize (which is shown in Table 5 as no value (-) of grain size), while the treatment, which was conducted at a solution temperature higher than the predetermined temperature, resulted in the coarsening of the grains. Thus, those cases each failed to attain or maintain the target favorable bending property.

[0029] In Examples 10 to 16 according to the present invention in Table 5, one or more of Cr, Mg, Mn, Sn, V, Zn, Al,

Fe, Nb, Ni, Ti, and Zr was added (that is, the element(s) II to be added was added in the total amount of 0.01 to 1 mass%), and the solution treatment temperature T_s (°C) was set at a temperature (°C) of 800°C to 960°C and lower than $-94.643X^2 + 329.99X + 677.09$, in which the Co content (mass%) was represented by X. Thus, it was possible to control the grain size to 20 μm or less, by the heat treatment at a temperature as high as that in Reference example 1, and the copper alloy materials had the same level of mechanical strength as that in Reference example 1 and were excellent in the bending property.

Specifically, with respect to the samples which had the yield stress of not less than 500 MPa but less than 650 MPa and the electrical conductivity of 60 %IACS or more, the values (R/t) representing the bending property were 1.2 or less in both of GW and BW. Some of Examples had the values (R/t) representing the bending property of 1.0 or less, even 0.6 or less, or further even less than 0.5, in both of GW and BW. Further, with respect to the samples which had the yield stress of 650 MPa or more and the electrical conductivity of 50 %IACS or more, the values (R/t) representing the bending property were 1.5 or less, or 1.2 or less, in both of GW and BW. Thus, it is found that it was possible to obtain the copper alloy materials, which were excellent in the balance of the mechanical strength, the electrical conductivity, and the bending property.

Further, even in the case where it was possible to control the grain size to 20 μm or less by adding only Co and Si in the means of Reference example 1, it was able to accelerate a further size reduction of the grains by adding any of the above-mentioned metals, to obtain the excellent bending property.

Contrary to the above, in Comparative examples 18 to 22 in which the addition amount of the element I I to be added exceeded 1%, due to the formation of oxides upon the casting and excessive precipitation in the high-temperature heat-treatment, the productivity was conspicuously deteriorated to make it difficult to obtain products. Further, in Comparative example 21 in which the addition amount of the element II to be added exceeded 1%, the electrical conductivity was conspicuously lowered when the solid-solution-type elements were added, the yield stress was less than 650 MPa, but the value of R/t exceeded 1.2 in BW, which means that the bending property was poor. Further the value (R/t) representing the bending property showed a tendency to be poor in BW, as compared to that in GW.

INDUSTRIAL APPLICABILITY

[0030] The copper alloy material for electric/electronic parts of the present invention can be favorably used in electric/electronic parts, such as connectors, terminal materials, and the like, for electric/electronic equipments, and particularly in high-frequency relays or switches that are required to have a high electrical conductivity, or connectors, terminal materials, and lead frames, to be mounted on vehicles or the like.

[0031] Having described our invention as related to the present embodiments, it is our intention that the invention not be limited by any of the details of the description, unless otherwise specified, but rather be construed broadly within its spirit and scope as set out in the accompanying claims.

[0032] This application claims priority on Patent Application No. 2008-074650 filed in Japan on March 21, 2008, of which is entirely herein incorporated by reference.

Claims

1. A copper alloy material for an electric/electronic part, comprising Co 0.5 to 2.5 mass% and Si 0.1 to 1.0 mass%, at a ratio of Co/Si of 3 to 5 in terms of mass ratio, with the balance of Cu and inevitable impurities, which is obtained by subjecting to a solution treatment at a temperature T_s °C from 800°C to 960°C and lower than $-122.77X^2 + 409.99X + 615.74$, in which X represents the Co content in mass%.
2. A copper alloy material for an electric/electronic part, comprising Co 0.5 to 2.5 mass% and Si 0.1 to 1.0 mass%, at a ratio of Co/Si of 3 to 5 in terms of mass ratio, and comprising 0.01 to 1.0 mass% of one or two or more selected from the group consisting of Cr, Mg, Mn, Sn, V, Al, Fe, Ni, Ti and Zr, with the balance of Cu and inevitable impurities, which is obtained by subjecting to a solution treatment at a temperature T_s °C from 800°C to 960°C and lower than $-94.643X^2 + 329.99X + 677.09$, in which X represents the Co content in mass%.
3. The copper alloy material for an electric/electronic part according to claim 1 or 2, which has a yield stress of not less than 500 MPa but less than 650 MPa, an electrical conductivity of 60 %IACS or more, and a value R/t representing a bending property of less than 0.5.
4. The copper alloy material for an electric/electronic part according to claim 1 or 2, which has a yield stress of 650 MPa or more, an electrical conductivity of 50 %IACS or more, and a value R/t representing a bending property of less than 1.5.

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- 5
6. The copper alloy material for an electric/electronic part according to claim 1 or 2, which has a yield stress of not less than 500 MPa but less than 650 MPa, an electrical conductivity of 60 %IACS or more, and a value R/t representing a bending property of 1.2 or less, with respect to each of a sample parallel to a rolling direction and a sample perpendicular to the rolling direction.
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- 40
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- 55
6. The copper alloy material for an electric/electronic part according to claim 1 or 2, which has a yield stress of 650 MPa or more, an electrical conductivity of 50 %IACS or more, and a value R/t representing a bending property of 1.5 or less, with respect to each of a sample parallel to a rolling direction, and a sample perpendicular to the rolling direction.

INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2009/055531

A. CLASSIFICATION OF SUBJECT MATTER

C22C9/06(2006.01)i, C22F1/08(2006.01)i, H01B1/02(2006.01)i, C22F1/00(2006.01)n

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)

C22C9/00-9/10, C22F1/08, H01B1/02, 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	1996-2009
Kokai Jitsuyo Shinan Koho	1971-2009	Toroku Jitsuyo Shinan Koho	1994-2009

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.
A	JP 2007-169765 A (The Furukawa Electric Co., Ltd.), 05 July, 2007 (05.07.07), Par. Nos. [0011], [0012], [0032]; table 1 (Family: none)	1-6
A	JP 136198 C2 (Kinzoku Zairyo Kenkyushocho), 30 April, 1940 (30.04.40), Full text (Family: none)	1-6
A	JP 02-277735 A (Sumitomo Metal Mining Co., Ltd.), 14 November, 1990 (14.11.90), Claims (Family: none)	2-6



Further documents are listed in the continuation of Box C.



See patent family annex.

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"&"

document member of the same patent family

Date of the actual completion of the international search
09 June, 2009 (09.06.09)

Date of mailing of the international search report
23 June, 2009 (23.06.09)

Name and mailing address of the ISA/
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INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2009/055531

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP 63-307232 A (Sumitomo Metal Mining Co., Ltd.), 14 December, 1988 (14.12.88), Claims (Family: none)	2-6
A	JP 2006-283120 A (Nikko Metal Manufacturing Co., Ltd.), 19 October, 2006 (19.10.06), Par. Nos. [0028], [0032]; table 1 & WO 2006/106939 A1 & EP 1876250 A1 & US 2009/0025840 A1 & KR 10-2007-0112868 A & CA 002602529 A & CN 101151385 A	2-6
P,X	JP 2008-088512 A (Nippon Mining & Metals Co., Ltd.), 17 April, 2008 (17.04.08), Claims 1 to 5; tables 1 to 3 & WO 2008/041696 A1	1-6

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REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- JP 63307232 A [0004]
- JP 2008074650 A [0032]