



(12) **EUROPEAN PATENT APPLICATION**
published in accordance with Art. 153(4) EPC

(43) Date of publication:
25.08.2010 Bulletin 2010/34

(51) Int Cl.:
C22C 9/06 (2006.01) C22F 1/08 (2006.01)
C22F 1/00 (2006.01)

(21) Application number: **08843774.4**

(86) International application number:
PCT/JP2008/069977

(22) Date of filing: **31.10.2008**

(87) International publication number:
WO 2009/057788 (07.05.2009 Gazette 2009/19)

(84) Designated Contracting States:
AT BE BG CH CY CZ DE DK EE ES FI FR GB GR
HR HU IE IS IT LI LT LU LV MC MT NL NO PL PT
RO SE SI SK TR
Designated Extension States:
AL BA MK RS

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(30) Priority: **01.11.2007 JP 2007285605**

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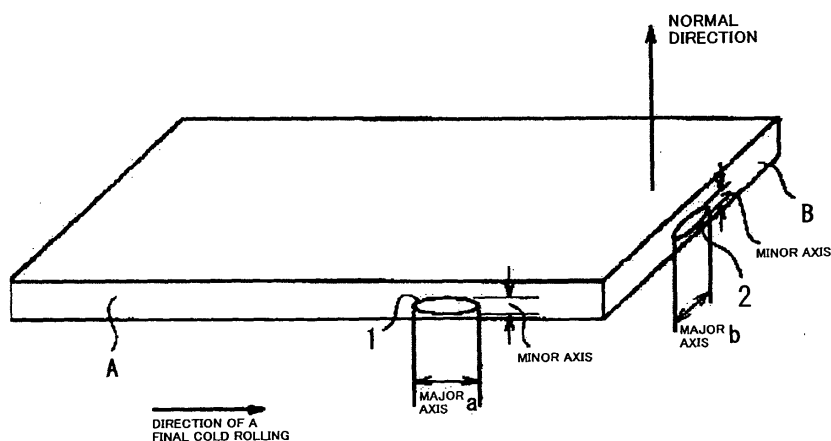
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(54) **COPPER ALLOY MATERIAL EXCELLENT IN STRENGTH, BENDING WORKABILITY AND STRESS RELAXATION RESISTANCE, AND METHOD FOR PRODUCING THE SAME**

(57) A copper alloy material according to the present invention is **characterized in that** the same comprises: Ni between 2.8 mass% and 5.0 mass%; Si between 0.4 mass% and 1.7 mass%; S of which content is limited to

less than 0.005 mass%; and the balance of the copper alloy material is composed of copper and unavoidable impurity, wherein a proof stress is stronger than or equal to 800 MPa, and the same is superior in bending workability and in stress relaxation resistance.

Fig. 1



Description

Technical Field

5 **[0001]** The present invention relates to a copper alloy material and a method for producing the same.

Background Art

10 **[0002]** Conventionally, as a material for a usage of an electrical apparatus and of an electronic equipment in general, not only a material of iron system but also a material of copper system that is superior in electrical conduction property and in thermal conduction property, such as a phosphor bronze, a red brass, a brass, or the like, is made use as widely. In recent years, a demand is increased for a packaging in smaller size of the electrical apparatus and of the electronic equipment, to be lightened, and then to be high density mounted that is accompanied by those. And hence various kinds of properties are required as well for the material of copper system that is to be applied to these. And then as a major
15 property it is able to give an example of such as a mechanical property, an electrical conductivity, a stress relaxation resistance, a bending workability, or the like. Moreover, in order to satisfy the demand of obtaining a smaller in size of a component and part in recent years an improvement of a tensile strength and of the bending workability is required as strongly among the above mentioned properties.

20 **[0003]** Further, a spring property becomes to be important in order to maintain a contact pressure at a contact member of a spring after performing a molding into a shape of a connector. And then therefore not only the tensile strength but also a proof stress that is a limit of an elastic deformation zone is required to be higher for a material which is to be made use.

25 **[0004]** Still further, as a material for a usage of an electronic component and part for which a demand of a higher strength is high in particular, a high strength beryllium copper (an alloy as pursuant to the JIS-C1720) has been made use. And then this alloy has the tensile strength of stronger than or equal to 815 MPa as pursuant to the 1/2HM Temper and of stronger than or equal to 910 MPa as pursuant to the HM Temper for a mill-hardened material for which it is not necessary to perform an aging heat treatment after performing a press molding process, and the same is superior in bending workability as well. In the meantime however, the metal of beryllium is harmful for a human body. And then a material for substituting is desired in accordance with a consideration of a processing of production and thereof for an environment as well.

30 **[0005]** And hence an alloy of Cu-Ni-Si system becomes to be made use as the material for substituting, that is superior in a balance between the strength and the electrical conductivity. Still further, the alloy of Cu-Ni-Si system is an alloy of a precipitation type in which a precipitate is to be formed and then the same is to be hardened, that is comprised of Ni and Si, and then an ability to harden is higher as extremely.

35 **[0006]** In the meantime however, in accordance with the alloy of Cu-Ni-Si system the higher the tensile strength and the proof stress become to be, the more difficult to maintain the bending workability. Still further, there is a problem of which the stress relaxation resistance becomes to be deteriorated in a case where a higher processing rate is introduced for a material in order to obtain the strength. Still further, there are other problems of which such as the grain of matrix becomes to be larger and then the material becomes to have an anisotropy of the strength or the bending workability becomes to be deteriorated or the like in a case where a solution heat treatment is performed at a temperature as higher
40 in order to increase a precipitation amount of Ni₂Si. And then therefore an alloy of Cu-Ni-Si system is required, that is superior in the proof stress, in the bending workability and in the stress relaxation resistance, and that has the anisotropy of the strength to be smaller as well. And then as mentioning with being based on a specific standard for a material to be required as equivalent to the high strength beryllium copper (the alloy as pursuant to the JIS-C1720), a standard is required by which a material has a proof stress of higher than or equal to 800 MPa, and any crack will not be occurred even in a bending test of which a ratio between a bending radius and a plate thickness is lower than or equal to 1.0 in
45 a case where a (W) bending of 90 degrees is performed.

50 **[0007]** In conjunction with such a Corson alloy, a high strength copper alloy of which the strength and the bending workability are improved is proposed in such as the following patent documents from 1 to 3 or the like. However, in accordance with those heretofore known inventions any material has not yet been developed, which is superior in the proof stress, in the bending workability and in the stress relaxation resistance, and which satisfy to have the anisotropy of the strength to be smaller as well at the same time, that are mentioned above.

[Patent Document 1] Japanese Patent No. 3520046

[Patent Document 2] Japanese Patent Application Publication No. 2006-283107

55 [Patent Document 3] Japanese Patent Application Publication No. 2006-219733

Disclosure of the Invention

[0008] With having regard to the problems that are described above, an objective of the present invention is to provide a copper alloy material that has the strength as higher and that is superior in the bending workability and in the stress relaxation resistance, and to provide a method for producing such a copper alloy material.

[0009] Here, the present inventors have studied regarding a copper alloy material which is to be suitable for a usage of an electrical apparatus and of an electronic equipment. And then it becomes able to complete the invention of the copper alloy material that has the strength as higher and that is superior in the bending workability and in the stress relaxation resistance, by performing a control of a composition of the copper alloy. Moreover, the present inventors found out as well that it becomes able to obtain a copper alloy material which has an anisotropy to be smaller in addition to the above description, by performing a control of a grain of matrix size and of a shape of a grain of matrix in a structure of the copper alloy, and by performing a control of a hardening amount at a period of a manufacturing process. And then in accordance with the present invention it becomes able to obtain the aspects that will be described in detail below.

1. A copper alloy material, comprising:

Ni between 2.8 mass% and 5.0 mass%;

Si between 0.4 mass% and 1.7 mass%;

S of which content is limited to less than 0.005 mass%; and the balance of the copper alloy material is composed of copper and unavoidable impurity,

wherein a proof stress is stronger than or equal to 800 MPa, and the copper alloy material is superior in bending workability and in stress relaxation resistance.

2. The copper alloy material according to the aspect 1, further comprising at least one nature of Mg between 0.01 mass% and 0.20 mass%, Sn between 0.05 mass% and 1.5 mass% and Zn between 0.2 mass% and 1.5 mass%.

3. The copper alloy material according to the aspect 1 or 2, further comprising at least any one nature or more than or equal to any two natures in the following (I) to (IV) between 0.005 mass% and 2.0 mass% in total:

(I) at least any one nature or more than or equal to any two natures between 0.005 mass% and 0.3 mass% that is selected from a group of Sc, Y, Ti, Zr, Hf, V, Mo and Ag;

(II) Mn between 0.01 mass% and 0.5 mass%;

(III) Co between 0.05 mass% and 2.0 mass%; and

(IV) Cr between 0.005 mass% and 1.0 mass%.

4. The copper alloy material according to any of the aspects 1 to 3, wherein a grain of matrix size is larger than 0.001 mm but smaller than or equal to 0.025 mm, and a ratio (a / b) between a major axis (a) of a grain of matrix on a cross section which is parallel to a direction for a final plastic working and a major axis (b) of the grain of matrix on the cross section which is at right angles to the direction for the final plastic working is higher than or equal to 0.8 but lower than or equal to 1.5.

5. The copper alloy material according to any of the aspects 1 to 4, wherein a maximum value of a difference between a proof stress in a rolling direction (which is equivalent as normally to the direction for the final plastic working) and a proof stress in a direction of which has an angle of 90 degrees against the rolling direction is lower than or equal to 100 MPa.

6. A method for producing the copper alloy material according to any of the aspects 1 to 5, comprising the steps of:

performing a processing in order to obtain a solution heat treated recrystallized structure in a plate of a copper alloy; and

performing thereafter a series of processing of a cold rolling as a first term and then an aging treatment, and then another cold rolling as a second term and then a low temperature annealing,

wherein following formulas (1) to (3) are satisfied, in a case where a variation of a proof stress after the low temperature annealing is defined to be Δ_{total} (MPa) that is based on a proof stress immediately before the cold rolling as the first term, where a variation of a proof stress before and after the cold rolling as the first term is defined to be $\Delta C1$ (MPa), and where a variation of a proof stress before and after the cold rolling as the second term is defined to be $\Delta C2$ (MPa):

$$0.1 \leq \Delta C1 / \Delta t_{total} \leq 0.35 \quad (1);$$

$$0 \leq \Delta C2 / \Delta t_{total} \leq 0.35 \quad (2);$$

$$0.1 \leq (\Delta C1 + \Delta C2) / \Delta t_{total} \leq 0.45 \quad (3);$$

in which the proof stress means a 0.2% proof stress.

[0010] The above and other aspects and advantages according to the present invention will be further clarified by the following description, with reference to the drawings to be attached as properly therefor.

Brief Description of the Drawings

[0011] [FIG. 1] FIG. 1 is an explanatory drawing showing an evaluation method of a grain of matrix size and of a shape of a grain of matrix which is specified in accordance with the present invention.

Best Mode for Carrying Out the Invention

[0012] A desired embodiment regarding a composition and an alloy structure of a copper alloy material in accordance with the present invention will be described in detail below. Moreover, the copper alloy material in accordance with the present invention means a copper alloy which has a specified shape, such as a plate material, a bar material, a wire rod, or the like.

In the first instance, it becomes able to form an Ni_2Si phase as mainly and then it becomes able to perform an improvement of the strength and of the electrical conductivity in a case where an aging treatment is performed for the Ni and the Si in a copper alloy. And then it is desirable for a content of the Ni to be between 2.8 mass% and 5.0 mass%, or it is further preferable for the same to be between 3.0 mass% and 4.8 mass%. Moreover, a ground to be specified in such a manner is because there becomes to be occurred the problems of which it is not able to obtain the strength as equivalent to or stronger than that of the high strength beryllium copper (the alloy as pursuant to the JIS-C1720) in a case where an added amount is less than 2.8 mass%, and in the meantime, in a case where the same is more than 5.0 mass% a formation of a chemical compound that is not to contribute to the improvement of the strength at a period of performing a casting or at a period of performing a hot working, and then not only that it is not able to obtain the strength which corresponds to the added amount, but also that a hot workability becomes to be worsened and then the same becomes to effect as negatively.

[0013] Next, it is desirable for a content of the Si to be between 0.4 mass% and 1.7 mass%, and then it is further preferable for the same to be between 0.6 mass% and 1.3 mass%. Moreover, a ground to be specified in such a manner is because that it is not able to obtain the improvement of the strength as sufficiently by making use of the aging treatment, and then that it is not able to obtain the strength which is equivalent to or more than that of the alloy which is pursuant to the JIS-C1720 in a case where an amount of Si is less than 0.4 mass%, and in the meantime, that in a case where the content of the Si is more than 1.7 mass% it becomes a cause of a decrease in the electrical conductivity in addition to an occurrence of the problems that is similar to the case where the amount of Ni is excessive.

Further, Ni and Si form the Ni_2Si phase as mainly. And then therefore there is an optimal ratio between Ni and Si in order to perform the improvement of the strength. And then a ratio (Ni / Si) between the Ni (mass%) and the Si (mass%) is determined to be 4.2 in a case where the Ni_2Si phase is formed regarding the amount of the Si. Furthermore, it is desirable to perform a control of the (Ni / Si) to be between 3.0 and 6.0 with the above mentioned value to be a central value, and then it is further preferable to perform the control of the (Ni / Si) to be between 3.8 and 4.6.

[0014] And in the meantime, S is contained with a very small amount in a copper alloy in general. And then in a case where the amount is more than or equal to 0.005 mass% the same becomes a cause of worsening the hot workability. And then therefore it is required to specify the content to be less than 0.005 mass%. Or, it is further preferable for the same to be less than 0.002 mass% in particular.

[0015] Moreover, it is desirable to perform an addition of Mg into the copper alloy. And then it is desirable for the amount to be between 0.01 mass% and 0.20 mass%. Further, due to Mg it becomes able to perform an improvement of a stress relaxation property as extremely, in the meantime however, the same effects as negatively to the bending

workability. Furthermore, it is necessary for an amount of the Mg to be more than or equal to 0.01 mass% in order to perform the improvement of the stress relaxation property, and then the more the amount is, the better the improvement becomes to be. And in the meantime however, in a case where the amount is more than 0.20 mass% it becomes unable to satisfy a required property of the bending workability. And hence it is further preferable for the amount to be between

0.05 mass% and 0.15 mass%.
[0016] Moreover, it is desirable to perform an addition of Sn into the copper alloy. And then it is desirable for the amount to be between 0.05 mass% and 1.5 mass%. Further, due to the Sn with relating to Mg together it becomes able to perform the further improvement of the stress relaxation property, however, the advantage is not so large with comparing to that according to the Mg. And then in a case where the Sn is less than 0.05 mass% it is not able to obtain the advantage as sufficiently. In the meantime however, in a case where the amount is more than 1.5 mass% the electrical conductivity becomes to be decreased as excessively. And hence it is further preferable for the amount to be between 0.1 mass% and 0.7 mass%.

[0017] Moreover, it is desirable to perform an addition of Zn into the copper alloy. And then it is desirable for the amount to be between 0.2 mass% and 1.5 mass%. Further, due to the Zn it becomes able to perform an improvement of the bending workability with a little amount of degrees. And then by specifying the amount of the Zn to be between 0.2 mass% and 1.5 mass% it becomes able to obtain the bending workability that corresponds the standard of which there is no problem for a practical use even in a case where it is to be performed an addition of Mg with 0.20 mass% at the maximum. Furthermore, due to the Zn it becomes able to perform an improvement of such as a property of adherence or a property of migration or the like regarding such as a plating of Sn or a plating of solder or the like. In the meantime however, in a case where the amount of the Zn is less than 0.2 mass% it is not able to obtain the advantage as sufficiently, and in the meantime, in a case where the amount is more than 1.5 mass% the electrical conductivity becomes to be decreased. And hence it is further preferable for the amount to be between 0.3 mass% and 1.0 mass%.

[0018] Moreover, it is able to perform an addition of any one nature or more than or equal to any two natures into the copper alloy, that is selected from a group of Sc, Y, Ti, Zr, Hf, V, Mo and Ag with an amount between 0.005 mass% and 0.3 mass% in total. Further, any of Sc, Y, Ti, Zr, Hf, V and Mo forms a chemical compound with Si. And then it is able to obtain an advantage by which it becomes able to prevent a grain of matrix size from becoming coarse. Still further, it is possible to perform the addition with the amount of the addition to be within the above mentioned range by which the property of such as the strength or of the electrical conductivity or the like will not be worsened.

And in the meantime, due to the Ag it becomes able to perform the improvement of a heat resistance and of the strength. Still further, it becomes able to prevent the grain of matrix from becoming coarse, and it becomes able to perform the improvement of the bending workability at the same time. In the meantime however, in a case where the amount of the Ag is less than 0.005 mass% it is not able to obtain the advantage as sufficiently. And in the meantime, in a case of performing the addition of more than 0.3 mass% it becomes a cause of a high cost of production, though there is no effect as negatively to be given to the properties. And then therefore it is desirable for the content of the Ag to be within the above mentioned range from a point of view of those.

[0019] Still further, due to the Mn it becomes able to obtain an advantage to perform an improvement of a hot workability. And then therefore it is effective to perform the addition of the amount between 0.01 mass% and 0.5 mass% that is a degree so as not to deteriorate the electrical conductivity.

Still further, due to the Co that forms a chemical compound with the Si which is similar to that according to Ni it becomes able to obtain a function to perform an improvement of the strength. And then therefore it is desirable to contain Co with the amount between 0.05 mass% and 2.0 mass%. In the meantime however, in a case where the content is less than 0.05 mass% it is not able to obtain the advantage as sufficiently. And in the meantime, in a case where the amount is more than 2.0 mass% a body to be crystallized separately and a precipitate become to exist even after performing the solution heat treatment that will not individually correspond to the strength. And hence the bending workability becomes to be deteriorated.

Still further, the Cr becomes to be precipitated as finely into the copper and then the same becomes to contribute to the improvement of the strength. Still further, the same becomes to form a chemical compound with the Si or with the Ni and the Si together, and then it becomes able to obtain an advantage to prevent the grain of matrix size from becoming coarse, that is similar to the above mentioned group of Sc, Y, Ti, Zr, Hf, V and Mo. In the meantime however, in a case where the amount is less than 0.05 mass% it is not able to obtain the advantage as sufficiently. And in the meantime, in a case where the amount is more than 1.0 mass% the bending workability becomes to be deteriorated.

[0020] Furthermore, in a case of performing an addition of more than or equal to any two natures that are selected from the above mentioned group of Sc, Y, Ti, Zr, Hf, V, Mo, Ag, Mn, Co and Cr the amount is to be specified within a range between 0.005 mass% and 2.0 mass% in total with corresponding to a required property.

[0021] In accordance with the present invention it is desirable to specify a grain of matrix size and a shape of a grain of matrix in order to realize the properties of the copper alloy material which has the above mentioned composition. And then in accordance with the present invention it is desirable for the above mentioned grain of matrix size to be larger than 0.001 mm, but to be smaller than or equal to 0.025 mm. Or, it is further preferable for the same to be larger than

0.001 mm, but to be smaller than or equal to 0.015 mm. In the meantime however, in a case where the grain of matrix size is smaller as excessively it becomes easier for a recrystallized structure to be a mixed grain (a structure in which grains of matrix exist together that have a different size from each other), and hence the bending workability and also the stress relaxation property become to be worsened. And in the meantime, in a case where the grain of matrix size is larger as excessively the bending workability becomes to be effected as negatively. Moreover, in the case where the grain of matrix size is larger the matter becomes a cause of increasing a difference of the strength between a vertical direction of rolling and a parallel direction thereof. Further, the above mentioned grain of matrix size is determined to be a value which is measured with being pursuant to the JIS-H0501 (the method of cutting).

[0022] Still further, the shape of the grain of matrix in accordance with the present invention indicates a ratio (a / b) between a major axis (a) of the grain of matrix on a cross section which is parallel to a direction for a final plastic working and a major axis (b) of the grain of matrix on the cross section which is at right angles to the direction for the final plastic working. And then in accordance with the present invention it is desirable for the ratio (a / b) to be higher than or equal to 0.8 but lower than or equal to 1.5. Or, it is further preferable for the same to be between 1.0 and 1.3. In the meantime however, in a case where the above mentioned ratio (a / b) is higher as excessively the stress relaxation property becomes to be worsened. Still further, in a case where the above mentioned ratio (a / b) is lower as excessively the stress relaxation property becomes to be worsened either. And hence it is desirable for the same to be higher than or equal to 0.8.

[0023] Still further, in accordance with the present invention it is desirable to specify a maximum value of a difference between a proof stress in a rolling direction (which is equivalent as normally to the above mentioned direction for the final plastic working) and a proof stress in a direction of which has an angle of 90 degrees against the rolling direction to be lower than or equal to 100 MPa. The ground is because there becomes to be occurred a problem of such as that in a case where the value is higher than 100 MPa it becomes difficult to perform a designing of a connector or to perform a setting of a metallic mold at a time of performing the bend working, or a contact pressure strength of the connector is not to satisfy the property due to a difference from a designed value, or the like. Furthermore, it is further preferable for the maximum value of the difference between the above mentioned each of the values to be lower than or equal to 50 MPa. And in the meantime, there is no limitation in particular regarding a lower limit of this difference, however, it is regarded that there is almost no difference of the proof stresses that individually correspond to each of the directions if the same is equivalent to approximately 5 MPa as normally.

[0024] Next, a desired method for producing the copper alloy material in accordance with the present invention is embodied by such as the follows or the like. And then a schematic manufacturing process as desired for the copper alloy material in accordance with the present invention comprises the following steps of:

- performing a processing of casting;
- performing a processing of hot rolling;
- performing a processing of dough rolling (a cold rolling as normally);
- performing a processing of a solution heat treatment;
- performing a processing of a cold rolling as a first term (rolling (1));
- performing a processing of an;
- performing a processing of another cold rolling as a second term (rolling (2)); and
- performing a processing of a low temperature annealing.

[0025] And then in accordance with the present invention a method for producing the same is desired, that satisfy the following formulas from (1) to (3), in a case where a variation of a proof stress after the low temperature annealing is defined to be Δ_{total} (MPa) that is varied from a proof stress immediately before the rolling (1) that is after obtaining the recrystallized structure by performing the solution heat treatment, where a variation of a proof stress before and after the rolling (1) is defined to be $\Delta C1$ (MPa), and where a variation of a proof stress before and after the rolling (2) is defined to be $\Delta C2$ (MPa), for the material that is to be produced by the above mentioned steps of the casting → the hot rolling → the dough rolling → the solution heat treatment → the rolling (1) → the aging treatment → the rolling (2) → the low temperature annealing:

$$0.1 \leq \Delta C1 / \Delta_{total} \leq 0.35 \quad (1);$$

$$0 \leq \Delta C2 / \Delta_{total} \leq 0.35 \quad (2);$$

$$0.1 \leq (\Delta C1 + \Delta C2) / \Delta t_{total} \leq 0.45 \quad (3);$$

in which each of these variations of the proof stress is calculated with making use of a proof stress in an LD direction (a direction that is parallel to the rolling direction) which is evaluated with being pursuant to the JIS that will be described later.

[0026] And then the ground that it is desirable to perform the control of the variation of the proof stress at each of the processes is because the variation of the proof stress, and more specifically the variation of the proof stress at the cold rolling has a correlation with an amount of strain which is introduced into the material. Moreover, such as the proof stress of a material, the bending workability, the stress relaxation resistance, and the like depend on the amount of strain which is introduced into the material. And then in a case where the amount of strain is larger the bending workability and the stress relaxation resistance become to be deteriorated. In the meantime however, the amount of strain which is to be introduced into a material depends on a state of solution and precipitation of a mother phase of copper. And then therefore there is not performed a unified interpretation regarding an evaluation by making use of such as a conventional rate of rolling or the like in a case where a composition and a state of precipitation are different.

[0027] Here, the present inventors perform a standardization of the variation of the proof stress at the period of performing the cold rolling by making use of a total variation of the proof stress after performing the low temperature annealing varied from that immediately after performing the solution heat treatment. And then by performing a control of this standardized value to be within a range of the specification, it is found out that it becomes able to produce a copper alloy material that has the strength as higher, and that is superior in the bending workability and in the stress relaxation resistance with comparing to the conventional materials.

[0028] Further, in accordance with the present invention the casting is designed to be performed by making use of such as a general DC method or the like. Still further, it is desirable for the hot rolling to perform the rolling at a temperature between 700°C and 1000 °C immediately after performing a homogenization treatment of an ingot at a temperature between 850°C and 1000 °C with an amount of time between 0.5 hour and six hours, and then thereafter it is desirable to perform a water cooling in order to prevent from a precipitation at a period of performing the cooling. Still further, after performing the hot rolling and then after performing a facing of an oxide film layer the dough rolling is designed to be performed. And then the rolling is designed to be performed regarding this dough rolling in order to obtain a plate thickness by which it becomes able to obtain a predetermined processing rate at the rolling (1) and at the rolling (2). Furthermore, it becomes able to obtain a sample material which has a plate shape by making use of the above mentioned hot rolling and the dough rolling.

[0029] Next, it is desirable for the solution heat treatment to be performed at a substantial temperature of a material between 800°C and 1000°C, to be maintained thereafter with an amount of time approximately between three seconds and sixty seconds, and to be cooled down thereafter with a cooling rate of faster than or equal to 15°C per second in order to prevent from the precipitation. (Or, it is further preferable for the same to be faster than or equal to 30°C per second. And in the meantime, there is no limitation in particular regarding an upper limit, however, it is desirable for the same to be slower than or equal to 150°C per second.) In the meantime however, in a case where the temperature of the solution heat treatment is lower as excessively it is not able to obtain a sound recrystallized structure. And hence there become to have the problems of such as that the same becomes a cause to effect as negatively to the bending workability, and that each of the amount of the solution of the Ni and the Si becomes to be insufficient, and then that the amount of the precipitation of the Ni₂Si becomes to be insufficient at the period of performing the aging treatment, and hence that it is not able to obtain the proof stress as sufficiently, or the like. And in the meantime, in a case where the temperature of the solution heat treatment is higher as excessively the recrystallized grain size becomes to be coarse. And hence the same becomes a cause of the decrease in the strength, of a coming out of the anisotropy, and of the deterioration of the bending workability.

[0030] Next, the rolling (1) is designed to be performed in order to perform an improvement of the tensile strength and of the proof stress at the period of performing the aging treatment. And then a dislocation is to be introduced into the mother phase of the copper alloy at the period of performing the rolling (1). Moreover, a part of those dislocations becomes to function as a site for generating a heterogeneous core of the Ni₂Si at the period of performing the aging treatment which is the next process. And then the same becomes an assistant for the Ni₂Si to be formed as densely and as finely. Further, the higher the increased amount of the proof stress ($\Delta C1$) is enhanced due to performing the rolling (1), the further the strength of the aging becomes to be improved as well. And then therefore it is desirable for the same to be introduced. In the meantime however, in a case where the $\Delta C1$ is higher as excessively the effect due to the improvement of the strength of the aging cannot help but become to be saturated. Furthermore, the same becomes to be a cause of a deterioration of the bending workability. And then therefore ($\Delta C1 / \Delta t_{total}$) is designed to be specified as more than or equal to 0.1 but less than or equal to 0.35.

[0031] Next, due to the aging treatment it becomes able to disperse and then to precipitate the chemical compound

of the Ni_2Si as uniformly into the mother phase of copper, and then it becomes able to perform the improvement of the strength and of the electrical conductivity. Moreover, it is desirable to perform the same with making use of a furnace of a batch type, and then it is desirable to maintain a material at a substantial temperature between 350°C and 600°C with an amount of time between 0.5 hour and twelve hours. In the meantime however, in a case where the aging temperature is lower as excessively it becomes to be required a longer period of time in order to obtain an amount of the precipitation of the Ni_2Si . And hence it becomes a cause of a higher cost of production. Otherwise, each of the proof stress and the electrical conductivity is not to be sufficient. And in the meantime, in a case where the aging temperature is higher as excessively an Ni_2Si becomes to be formed as coarsely. And hence it is not able to obtain the proof stress as sufficiently.

[0032] Next, the rolling (2) is designed to be performed in order to obtain an improvement of the proof stress. And then in a case where the proof stress after performing the aging is sufficient it may be not necessary to introduce the rolling (2). In the meantime however, in a case where the increased amount of the proof stress (ΔC2) due to performing the rolling (2) is higher as excessively the bending workability becomes to be deteriorated. And hence the same becomes to be a cause of a deterioration of the stress relaxation resistance. And then therefore ($\Delta\text{C2} / \Delta\text{total}$) is designed to be specified as more than or equal to zero but less than or equal to 0.35.

[0033] And in the meantime, in a case where a total amount of the amounts of strain that are to be introduced into the material is higher as excessively the bending workability becomes to be deteriorated, and the stress relaxation resistance becomes to be deteriorated as well. And then therefore a standardized value of a total amount of strain ($(\Delta\text{C1} + \Delta\text{C2}) / \Delta\text{total}$) is designed to be specified as more than or equal to 0.1 but less than or equal to 0.45.

[0034] Next, the low temperature annealing is designed to be performed in order to recover an extensibility, the bending workability and a threshold limit value of a spring with maintaining the strength as a certain amount of degrees. In the meantime however, in a case where the substantial temperature is higher as excessively a recrystallization becomes to be occurred. And hence the same becomes to be a cause of the decrease in the proof stress. And then therefore it is desirable to perform the annealing at the substantial temperature between 300°C and 600°C with an amount of time between five seconds and sixty seconds as a shorter period of time. In the meantime however, in a case where the temperature of the low temperature annealing is lower as excessively the recovery of the extensibility, of the bending workability and of the threshold limit value of the spring is not to be sufficient. And in the meantime, in a case where the temperature of the low temperature annealing is higher as excessively the same becomes to be a cause of the decrease in the strength.

[0035] And thus the copper alloy material of the Cu-Ni-Si system in accordance with the present invention becomes to be a copper alloy material, that has the strength as higher, and that is superior in the bending workability and in the stress relaxation resistance at the same time. And hence the same becomes to be suitable for such as a lead frame, a connector, a terminal material, a relay, a switch, or the like for a usage of an electrical apparatus and of an electronic equipment.

Examples

[0036] The present invention will be described in detailed below, with being based on Examples and Comparative examples. However, the present invention will not be limited to any one of these.

[0037] Here, each of the copper alloy materials which is made use for the corresponding Examples and for the Comparative examples in accordance with the present invention is formed of a copper alloy (No. 1 to 30) which has a chemical composition (the balance is Cu) that is shown in the following Table 1, respectively. Moreover, each of those copper alloys is dissolved by making use of a high frequency melting furnace, and then the same is casted into an ingot thereafter to have a dimension of a thickness of 30 mm and a width of 120 mm and a length of 150 mm by making use of the DC method. Next, each of those ingots are heated up to approximately 950°C , and then the same is maintained at this temperature with an amount of time for one hour approximately, and then the hot rolling is performed thereafter for the same to have the thickness to be 12 mm, and then thereafter the cooling is performed for the same as promptly. And then at this time, regarding the Comparative example No. 24 because the amount of the Ni is more than the specified amount, regarding the Comparative example No. 25 because the amount of the S is more than the specified amount, regarding the Comparative example No. 26 because the amount of the Si is more than the specified amount, regarding the Comparative example No. 28 because the amount of the Cr is more than the specified amount, regarding the Comparative examples No. 29 and 30 because the amount of the Zr, of the Ti, of the Hf, of the V, of the Mo and of the Y is more than the corresponding specified amount respectively, a crack is occurred at the period of performing the hot rolling, and then the following processes are stopped, respectively.

[0038] Next, the oxide film layer is removed by cutting both faces with 1.5 mm for each. And then thereafter the same is processed to have a thickness to be between 0.16 mm and 0.50 mm by performing the cold rolling (dough rolling). And then at this time, regarding the Comparative example No. 27 because the amount of the Sn is more than the corresponding specified amount, a copper crack is occurred at the period of performing the cold rolling, and then the following processes are stopped. And then thereafter the solution heat treatment is performed for the same at a tem-

perature between 800°C and 950°C with an amount of time for approximately thirty seconds. And then immediately thereafter the cooling is performed for the same with the cooling rate of faster than or equal to 15°C per second.

Next, the rolling (1) is performed for each of the samples with various value of rolling rates (a draft: percent) that are individually lower than or equal to fifty percent. And then thereafter the aging treatment is performed in an ambient atmosphere of an inert gas at a temperature of approximately 500°C with an amount of time for approximately two hours. And then thereafter the rolling (2) which is a final plastic working is performed for the same with various value of rolling rates (the draft: percent), and hence each of the final plate thicknesses is adjusted to be 0.15 mm. And then each of the copper alloy plates are obtained which corresponds to each of the numbers, for which the low temperature annealing treatment is performed at a temperature between 400°C and 600°C with an amount of time for approximately thirty seconds after performing the rolling (2), wherein regarding each of the No. 1-1 to 1-11 and each of the No. 2-1 to No. 2-3 a different heat treatment is performed under a different rolling condition within the range that is described above for the corresponding alloy which has the composition in accordance with the above mentioned Example No. 1 or with the Example No. 2 respectively. And then with making use of each of these copper alloy plate materials various kinds of characteristic evaluations are performed.

[0039] Regarding each No. of the copper alloy plates which is produced in accordance with the corresponding Examples and the Comparative examples there are examined the following: (a) the grain of matrix size, (b) the shape of the grain of matrix, (c) the proof stress in a parallel direction to the rolling and in a vertical direction, (d) the electrical conductivity, (e) the W-bendability of 90 degrees, and (f) the stress relaxation property.

[0040] Regarding (a) the grain of matrix size, and (b) the shape of the grain of matrix the grain of matrix size is measured by making use of the method of cutting which is specified in accordance with JIS (the JIS-H0501). And then with being based on this value a calculation is performed.

And then measured cross sections regarding the above mentioned grain of matrix size are individually defined here to be a cross section (A) which is parallel to the direction for the final cold rolling that is shown in FIG. 1 (the direction for the final plastic working), and to be a cross section (B) which is at right angles to the direction for the final cold rolling.

Moreover, in accordance with the above mentioned cross section (A) a diameter of a grain of matrix (1) is measured in the two directions of the direction as parallel to the direction for the final cold rolling and of the direction at right angles thereto. And then a measured value as larger is defined here to be a major axis (a), and in the meantime, the other value as smaller is defined here to be a minor axis. Further, in accordance with the above mentioned cross section (B) a diameter of a grain of matrix (2) is measured in the two directions of the direction as parallel to a normal direction for a rolled surface and of a direction is at right angles to the normal line for the rolled surface. And then a measured value as larger is defined here to be a major axis (b), and in the meantime the other value as smaller is defined here to be another minor axis.

[0041] Still further, regarding the above mentioned grain of matrix size a photograph of a structure of the above mentioned copper alloy plate is taken by making use of a scanning electron microscope with a magnification of 1000 times. And then a line segment is drawn with a length of 200 mm on the photograph. Still further, the number of the grain of matrix s (n) is counted, that are cut by the above mentioned line segment. And hence the same is evaluated by making use of the formula of $(200 [\text{mm}] / (n) \text{ times } 1000)$. Still further, in a case where the number of the grain of matrix s that are cut by the above mentioned line segment is less than twenty a photograph is taken with a magnification of 500 times. And then the number of the grain of matrix s (n) is counted, that are cut by the a line segment which has a length of 200 mm. And hence the same is evaluated by making use of the formula of $(200 [\text{mm}] / (n) \text{ times } 500)$.

Still further, regarding the grain of matrix size a mean value of each of the major axes and each of the minor axes which is evaluated with making use of the cross section (A) and the (B) is shown with being rounded off to a multiple of 0.005 mm. Furthermore, the shape of the grain of matrix is shown with making use of a value (a / b) of which the major axis (a) of the above mentioned cross section (A) is divided by the major axis (b) of the above mentioned cross section (B).

[0042] Next, regarding (c) the proof stress a test piece of the number fifth which is described in the JIS-Z2201 is made use, and then the value is evaluated with being pursuant to the JIS-Z2241. Moreover, a test is performed in a parallel direction (a longitudinal direction: LD) and in a vertical direction (a transverse direction: TD) to the direction for the rolling (that are individually equivalent to the direction for the above mentioned rolling (1) and for the rolling (2)).

Next, (d) the electrical conductivity is evaluated with being pursuant to the JIS-H0505. Moreover, regarding the electrical conductivity 25% IACS (international annealed copper standard) of an electrical conductivity of a high strength beryllium copper (an alloy as pursuant to the JIS-C1720) is set to be a standard. And then a value which is higher than or equal to 30% IACS is defined here to be EXCELLENT, and in the meantime, a value which is higher than 25% IACS but lower than 30% IACS is defined here to be GOOD, and in the meantime, a value which is lower than or equal to 25% IACS is defined here to be NO GOOD.

Next, regarding (e) the bending workability a treatment device for bending to 90 degrees is made use by which a bended radius at an inner side becomes to be 0.15 mm. And then a (W) bending test of 90 degrees is performed by which a ratio between the bended radius and the plate thickness (R / t) becomes to be 1.0. And hence a judgment is performed, in which for a sample in which no crack becomes to be occurred at all at a bended part is defined here to be GOOD,

and for a sample in which any crack becomes to be occurred is defined here to be NO GOOD.

Next, regarding (f) the stress relaxation resistance the cantilever block method is adopted which is the standard specification in accordance with Electronic Material Association of Japan (EMAS-3003). And then a load stress is set up for a maximum stress on a surface to become eighty percent of the proof stress. Moreover, a sample is maintained in a constant temperature bath at approximately 150°C with an amount of time for 1000 hours approximately. And then a stress relaxation rate (S. R. R. (%)) is evaluated. Further, regarding the stress relaxation resistance a sample of which the stress relaxation rate is lower than or equal to 10 percent is defined here to be EXCELLENT, and in the meantime, a sample of which the same is higher than 10 percent but lower than 15 percent is defined here to be GOOD, and in the meantime, a sample of which the same is higher than or equal to 15 percent is defined here to be NO GOOD.

And thus each of the evaluated results from the No. 1 through 23 will be shown as the Examples and the Comparative examples in the following Table 2, respectively.

[0043] (Table 1)

TABLE 1

	No.	Ni (mass%)	Si (mass%)	Mg (mass%)	Sn (mass%)	Zn (mass%)	S(mass%)	THE OTHERS (mass%)
EXAMPLES	1	3.73	0.89	0.11	0.16	0.48	0.001	Cr:0.19
	2	3.02	0.73	0.09	0.16	0.50	0.001	Cr:0.15
	3	3.26	0.78	0.10	0.15	0.49	0.001	Cr:0.20
	4	4.27	1.01	0.10	0.15	0.50	0.001	Cr:0.19
	5	2.83	0.67	0.09	0.15	0.49	0.001	Cr:0.20
	6	4.96	1.19	0.10	0.14	0.50	0.001	Cr:0.21
	7	3.04	0.52	0.10	0.15	0.49	0.001	Cr:0.17
	8	4.95	1.68	0.11	0.15	0.50	0.001	Cr:0.20
	9	3.15	0.75	0.14	-----	-----	0.001	-----
	10	3.77	0.88	0.11	-----	-----	0.001	Mn:0.12
	11	3.27	0.78	0.10	-----	-----	0.001	Co:0.12
	12	3.26	0.77	0.10	0.14	0.49	0.001	Ag:0.05
	13	3.26	0.77	0.09	0.15	0.45	0.001	Co:0.19
	14	3.75	0.91	0.10	0.14	0.51	0.001	Cr:0.87
	15	3.25	0.77	0.15	0.14	0.47	0.001	Zr:0.006, Ti:0.005,
	16	3.25	0.77	0.15	0.15	0.49	0.001	Sc:0.005, Y:0.01
	17	3.24	0.76	0.13	0.15	0.50	0.001	V:0.007, Mo:0.005

EP 2 221 390 A1

(continued)

	No.	Ni (mass%)	Si (mass%)	Mg (mass%)	Sn (mass%)	Zn (mass%)	S(mass%)	THE OTHERS (mass%)
COMPARATIVE EXAMPLES	18	2.31	0.56	0.10	0.14	0.48	0.001	
	19	3.01	0.32	0.15	0.13	0.52	0.001	
	20	3.26	0.77	0.23	0.15	0.49	0.001	
	21	3.25	0.76	0.11	0.14	0.53	0.001	Mn:0.7
	22	3.26	0.77	0.10	0.16	1.86	0.001	
	23	3.25	0.77	-----	-----	-----	0.001	Co:2.1
	24	5.52	1.68	0.10	0.15	0.52	0.001	
	25	3.26	0.77	0.10	0.16	0.50	0.007	
	26	3.27	2.02	0.11	0.15	0.48	0.001	
	27	3.25	0.77	0.10	1.90	0.40	0.001	
	28	3.25	0.76	0.12	-----	-----	0.001	Cr:1.5
	29	3.23	0.76	0.09	0.14	0.50	0.001	Zr:0.20, Ti: 0.10, Hf: 0.10
	30	3.24	0.77	0.09	0.15	0.50	0.001	V:0.20, Mo:0.10, Y:0.20

	No.	PROOF STRESS (MPa)		GRAIN OF MATRIX SIZE (mm)	a/b	$\Delta C1/\Delta$ total	$\Delta C2/A$ total	$(\Delta C1+\Delta C2)$ / Δ total	ELECTRICAL CONDUCTIVITY (% IACS)	W- BENDABILITY OF 90 DEGREES	STRESS RELAXATION RATE (%)
		LD	TD								
EXAMPLES	1-1	810	805	0.005	1.0	0.13	0.13	0.26	33	GOOD	7
	1-2	882	890	0.005	1.2	0.12	0.23	0.35	33	GOOD	8
	1-3	893	897	0.005	1.3	0.13	0.28	0.41	33	GOOD	8
	1-4	812	810	0.005	1.1	0.34	0.00	0.34	33	GOOD	7
	1-5	830	823	0.005	1.2	0.30	0.06	0.36	33	GOOD	8
	1-6	900	903	0.005	1.3	0.27	0.15	0.42	33	GOOD	9
	2-1	821	826	0.005	1.2	0.15	0.22	0.37	36	GOOD	10
	2-2	833	838	0.005	1.3	0.28	0.16	0.44	36	GOOD	10
	3	812	805	0.005	1.2	0.31	0.11	0.42	34	GOOD	9
	4	873	857	0.005	1.0	0.14	0.13	0.27	30	GOOD	7
	5	811	811	0.005	1.3	0.28	0.15	0.43	38	GOOD	10
	6	906	889	0.005	1.0	0.12	0.14	0.26	28	GOOD	6
	7	804	814	0.005	1.3	0.26	0.14	0.40	38	GOOD	10
	8	902	897	0.005	1.0	0.27	0.14	0.41	26	GOOD	6
	9	811	818	0.010	1.3	0.28	0.13	0.41	44	GOOD	11
	10	814	815	0.010	1.2	0.11	0.22	0.33	34	GOOD	7
	11	822	817	0.005	1.2	0.30	0.11	0.41	33	GOOD	9
	12	814	808	0.005	1.2	0.29	0.12	0.41	34	GOOD	9
	13	836	827	0.005	1.1	0.30	0.13	0.43	32	GOOD	8
	14	828	817	0.005	1.2	0.29	0.13	0.42	31	GOOD	9
	15	816	811	0.005	1.2	0.28	0.11	0.39	32	GOOD	9
	16	819	809	0.005	1.2	0.29	0.12	0.41	32	GOOD	9

(continued)

	No.	PROOF STRESS (MPa)		GRAIN OF MATRIX SIZE (mm)	a/b	$\Delta C1/\Delta$ total	$\Delta C2/A$ total	$(\Delta C1+\Delta C2)$ / Δ total	ELECTRICAL CONDUCTIVITY (% IACS)	W- BENDABILITY OF 90 DEGREES	STRESS RELAXATION RATE (%)
		LD	TD								
	17	814	806	0.005	1.2	0.30	0.13	0.43	32	GOOD	8
COMPARATIVE EXAMPLES	1-7	765	753	0.005	1.0	0	0.18	0.18	33	GOOD	8
	1-8	895	938	0.005	2.1	0	0.38	0.38	33	NO GOOD	15
	1-9	920	948	0.005	1.6	0.10	0.41	0.51	33	NO GOOD	17
	1-10	957	964	0.005	2.2	0.26	0.27	0.53	33	NO GOOD	23
	1-11	803	687	0.030	1.1	0.13	0.15	0.28	32	NO GOOD	8
	2-3	826	836	0.005	2.0	0	0.40	0.40	35	NO GOOD	22
	18	754	752	0.005	1.9	0.27	0.16	0.43	41	GOOD	20
	19	746	738	0.005	1.3	0.26	0.15	0.41	37	GOOD	10
	20	815	803	0.005	1.3	0.30	0.12	0.42	31	NO GOOD	9
	21	817	810	0.005	1.3	0.25	0.14	0.39	25	GOOD	11
	22	819	815	0.005	1.3	0.24	0.16	0.40	24	GOOD	10
	23	789	768	0.005	1.3	0.23	0.18	0.41	31	NO GOOD	9

[0044] (Table 2)

[0045] Regarding the No. 1-1 to 1-6, 2-1, 2-2, and from 3 through 17 that are individually shown in the Examples each of the copper alloys has the strength to be higher, has the bending workability to be good, and the same is superior in the stress relaxation resistance, respectively. Moreover, the anisotropy of the same is smaller, respectively.

[0046] On the contrary however, in accordance with the No. 1-7 as the Comparative example the proof stress becomes to be lower because the value of the $(\Delta C1 / \Delta total)$ is smaller than that in accordance with the specification. And in the meantime, in accordance with the No. 1-8 and the 2-3 as the Comparative examples the bending workability and the stress relaxation resistance become to be deteriorated because the value of the $(\Delta C2 / \Delta total)$ is larger than that in accordance with the specification. And in the meantime, in accordance with the No. 1-9 as the Comparative example the bending workability and the stress relaxation resistance become to be deteriorated because the value of the $(\Delta C2 / \Delta total)$ and of the $((\Delta C1 + \Delta C2) / \Delta total)$ is larger than that in accordance with the specification, respectively. And in the meantime, in accordance with the No. 1-10 as the Comparative example the bending workability and the stress relaxation resistance become to be deteriorated because the value of the (a / b) and of the $((\Delta C1 + \Delta C2) / \Delta total)$ is larger than that in accordance with the specification, respectively. And in the meantime, in accordance with the No. 1-11 as the Comparative example the anisotropy of the proof stress becomes to be appeared and also the bending workability becomes to be deteriorated, because the grain of matrix size is larger than that in accordance with the specification.

[0047] And, in accordance with the No. 18 as the Comparative example the proof stress becomes to be lower because the Ni concentration is lower than that in accordance with the specification. And in the meantime, in accordance with the No. 19 as the Comparative example the proof stress becomes to be lower either because the Si concentration is lower than that in accordance with the specification. Moreover, in accordance with the No. 18 as the Comparative example the stress relaxation resistance becomes to be inferior. And in the meantime, in accordance with the No. 20 as the Comparative example the bending workability becomes to be deteriorated because the Mg concentration is higher than that in accordance with the specification. And in the meantime, in accordance with the No. 21 and the 22 as the Comparative examples the electrical conductivity becomes to be decreased because the concentration of the Mn and of the Zn is higher than that in accordance with the specification, respectively. And in the meantime, in accordance with the No. 23 as the Comparative example the proof stress becomes to be worsened and also the bending workability becomes to be deteriorated, because the Co concentration is higher than that in accordance with the specification.

Industrial Applicability

[0048] The copper alloy material in accordance with the present invention becomes to be desirable for a material of such as a terminal, a connector, a switch, or the like.

Moreover, the method for producing the copper alloy material in accordance with the present invention becomes to be desirable as the method for producing the above mentioned copper alloy material.

[0049] Thus, the present invention is described above with the embodiment, however, the present invention will not be limited to every detail of the description as far as a designation in particular, and then it should be interpreted widely without departing from the spirit and scope of the present invention as disclosed in the attached claims.

[0050] Furthermore, the present invention claims the priority based on Japanese Patent Application Publication No. 2007-285605, that is patent applied in Japan on the first day of November, 2007, and the entire contents of which are expressly incorporated herein by reference as a part of the description of the present specification.

Claims

1. A copper alloy material, comprising:

Ni between 2.8 mass% and 5.0 mass%;

Si between 0.4 mass% and 1.7 mass%;

S of which content is limited to less than 0.005 mass%; and the balance of the copper alloy material is composed

of copper and unavoidable impurity,

wherein a proof stress is stronger than or equal to 800 MPa, and the copper alloy material is superior in bending workability and in stress relaxation resistance.

2. The copper alloy material according to claim 1, further comprising at least one nature of Mg between 0.01 mass% and 0.20 mass%, Sn between 0.05 mass% and 1.5 mass% and Zn between 0.2 mass% and 1.5 mass%.

3. The copper alloy material according to claim 1 or 2, further comprising at least any one nature or more than or equal to any two natures in the following (I) to (IV) between 0.005 mass and 2.0 mass% in total:

(I) at least any one nature or more than or equal to any two natures between 0.005 mass% and 0.3 mass% that is selected from a group of Sc, Y, Ti, Zr, Hf, V, Mo and Ag;
 (II) Mn between 0.01 mass% and 0.5 mass%;
 (III) Co between 0.05 mass% and 2.0 mass%; and
 (IV) Cr between 0.005 mass% and 1.0 mass%.

4. The copper alloy material according to any of claims 1 to 3,

wherein a grain of matrix size is larger than 0.001 mm but smaller than or equal to 0.025 mm, and a ratio (a / b) between a major axis (a) of a grain of matrix on a cross section which is parallel to a direction for a final plastic working and a major axis (b) of said grain of matrix on said cross section which is at right angles to said direction for said final plastic working is higher than or equal to 0.8 but lower than or equal to 1.5.

5. The copper alloy material according to any of claims 1 to 4,

wherein a maximum value of a difference between a proof stress in a rolling direction and a proof stress in a direction of which has an angle of 90 degrees against said rolling direction is lower than or equal to 100 MPa.

6. A method for producing the copper alloy material according to any of claims 1 to 5, comprising the steps of:

performing a processing in order to obtain a solution heat treated recrystallized structure in a plate of a copper alloy; and

performing thereafter a series of processing of a cold rolling as a first term and then an aging treatment, and then another cold rolling as a second term and then a low temperature annealing,

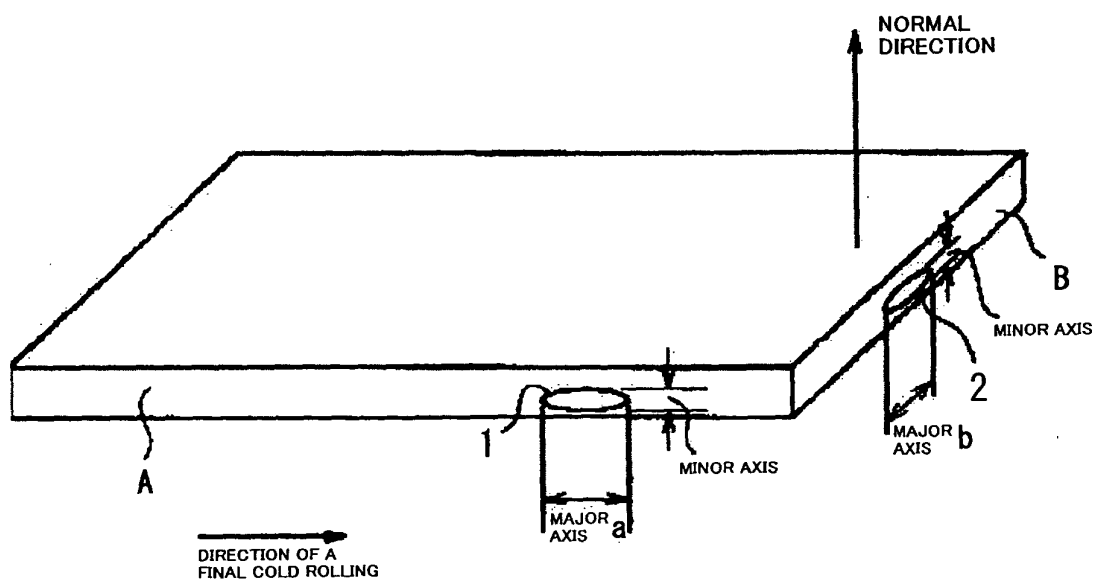
wherein following formulas (1) to (3) are satisfied, in a case where a variation of a proof stress after said low temperature annealing is defined to be Δ_{total} (MPa) that is based on a proof stress immediately before said cold rolling as said first term, where a variation of a proof stress before and after said cold rolling as said first term is defined to be $\Delta C1$ (MPa), and where a variation of a proof stress before and after said cold rolling as said second term is defined to be $\Delta C2$ (MPa):

$$0.1 \leq \Delta C1 / \Delta_{total} \leq 0.35 \quad (1);$$

$$0 \leq \Delta C2 / \Delta_{total} \leq 0.35 \quad (2);$$

$$0.1 \leq (\Delta C1 + \Delta C2) / \Delta_{total} \leq 0.45 \quad (3).$$

Fig. 1



INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2008/069977

A. CLASSIFICATION OF SUBJECT MATTER

C22C9/06(2006.01) i, C22F1/08(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)

C22C9/06, C22F1/08, 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	1996-2009
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.
X A	JP 2006-219733 A (Kobe Steel, Ltd.), 24 August, 2006 (24.08.06), Claims 1 to 9; Par. Nos. [0011], [0017] to [0023] (Family: none)	1-3, 5 6
X A	JP 2002-180161 A (The Furukawa Electric Co., Ltd.), 26 June, 2002 (26.06.02), Claims 1, 2; Par. No. [0023] & US 2002/0119071 A1 & US 2004/0045640 A1 & DE 10147968 A1 & TW 0255860 B & KR 10-2002-0053702 A & CN 1358875 A	2-5 1, 6

☒ Further documents are listed in the continuation of Box C.☐ See patent family annex.

* Special categories of cited documents:

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"&" document member of the same patent family

Date of the actual completion of the international search
16 January, 2009 (16.01.09)Date of mailing of the international search report
27 January, 2009 (27.01.09)Name and mailing address of the ISA/
Japanese Patent Office

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INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2008/069977

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	JP 2007-39789 A (Nippon Mining & Metals Co., Ltd.), 15 February, 2007 (15.02.07), Claims 1 to 4; Par. Nos. [0037] to [0039] & KR 10-2006-0105509 A & CN 1841570 A	2, 3
A	JP 2007-107062 A (Nippon Mining & Metals Co., Ltd.), 26 April, 2007 (26.04.07), Claims 1 to 5; Par. Nos. [0035], [0037] to [0048] (Family: none)	1, 3
A	JP 2006-283107 A (Nippon Mining & Metals Co., Ltd.), 19 October, 2006 (19.10.06), Claims 1 to 4; Par. Nos. [0028] to [0037] (Family: none)	2, 3
A	JP 2006-283059 A (Kobe Steel, Ltd.), 19 October, 2006 (19.10.06), Claims 1 to 5 (Family: none)	2, 3
A	JP 2007-270171 A (Dowa Holdings Co., Ltd.), 18 October, 2007 (18.10.07), Claims 1 to 7 (Family: none)	1-6

Form PCT/ISA/210 (continuation of second sheet) (April 2007)

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- JP 3520046 B [0007]
- JP 2006283107 A [0007]
- JP 2006219733 A [0007]
- JP 2007285605 A [0050]