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(54) COPPER ALLOY MATERIAL FOR ELECTRICAL/ELECTRONIC COMPONENT

(57) A copper alloy material for electrical/electronic components containing Co and Si as additional elements, wherein a compound A composed of Co and Si and having an average particle diameter of not less than 5 nm but less than 50 nm is dispersed, and at least one compound selected from the group consisting of a compound B containing one or neither of Co and Si and having an average particle diameter of not less than 50 nm but not more than 500 nm, a compound C containing both of Co and Si and an additional element and having an average particle diameter of not less than 50 nm but not more than 500 nm, and a compound D composed of Co and Si and having an average particle diameter of not less than 50 nm but not more than 500 nm, is also dispersed. The copper alloy material for electrical/electronic components is also **characterized in that** the matrix copper alloy has a crystal grain size of 3-35 [mu]m, and that the copper alloy material has a conductivity of not less than 50% IACS.

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Description

TECHNICAL FIELD

[0001] The present invention relates to a copper alloy material that is applied to an electric/electronic part, such as a connector or terminal material for an electric/electronic equipment, particularly a high-frequency relay or switch where high electrical conductivity is desired, or a connector or terminal material to be mounted on an automotive vehicle, and a lead frame.

BACKGROUND ART

[0002] Hitherto, copper alloys, such as brass (C26000) and phosphor bronze (C51910, C52120, C52100), as well as beryllium copper (C17200, C17530) and Corson-series copper alloy (hereinafter, also simply referred to as Corson copper, for example, C70250), and the like, have been used, for example, for connectors, terminals, relays, and switches for electric/electronic equipments. Herein, the term "Cxxxxx" denotes types of copper alloys specified in CDA (Copper Development Association).

[0003] In recent years, since a frequency of electric current applied to the electric/electronic equipments using those alloys becomes high, materials for those have been required to have a high electrical conductivity. Under the circumstances, although brass and phosphor bronze each originally are low in electrical conductivity while Corson copper shows a medium electrical conductivity (EC nearly equals to 40 %IACS) as a connecter material, a higher electrical conductivity has been required. Further, it is well known that beryllium copper is expensive. On the other hand, pure copper (C11000), 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.

Herein, the CXXXXX denotes types of copper alloys specified in CDA (Copper Development Association). The term "%IACS" is a unit which indicates an electrical conductivity of a material, and "IACS" is an abbreviation of "International Annealed Copper Standard".

[0004] Particularly, among the parts for electronic equipments of recent years, there are many connectors or terminals that have been subjected to complicated and severe bending, concomitantly with the size reduction of electronic equipments. This is because although the size of connectors is also reduced along with the size reduction, it is desired to take a contact length as long as possible in order to maintain the reliability of connection. A connector or terminal having such a design concept is, in many cases, referred to as a bellows-bent (corrugated) connector or terminal. That is, there is a strong demand for the mounting and installation of terminals or connectors that are bent in a complicated manner in small parts. On the other hand, the material of connectors and terminals to be used is becoming thinner concomitantly with the size reduction. This trend is furthered from the viewpoint of weight reduction and resource saving. Thin materials are demanded to have higher mechanical strength as compared with thick materials, in order to maintain the same contact pressure.

[0005] As a method of increasing the mechanical strength of a copper alloy material, there are various strengthening methods, such as solid solution strengthening, work strengthening, and precipitation strengthening. Generally, the electrical conductivity and the mechanical strength are properties in an inconsistent relationship. Among those methods, it is known that precipitation strengthening is promising, as a method of enhancing the mechanical strength without decreasing the electrical conductivity of the copper alloy material. This precipitation strengthening is a technique of: subjecting an alloy to which elements causing precipitation have been added, to a heat treatment at high temperature, to thereby cause solid-solution of these elements into the copper matrix, and then heat treating the alloy at a temperature lower than the temperature used for the solid solution, thereby precipitating the solid-solution elements. For example, beryllium copper, Corson copper, and the like employ that strengthening method.

[0006] Meanwhile, the bending property and the mechanical strength are properties in an inconsistent relationship. In general, a material high in the mechanical strength is poor in the bending property, while a material good in the bending property is, on the contrary, low in the mechanical strength. In order to enhance the mechanical strength, it is considered effective to increase the cold-rolling ratio; however, if the cold rolling ratio is increased, there is a tendency that the bending property is conspicuously deteriorated. It has hitherto been considered that beryllium copper, Corson copper, titanium copper, and the like, as precipitation type copper alloys, have a well balance between bending property and mechanical strength. However, with respect to beryllium copper, beryllium, which is an additive element, is regarded as an environmental burden material, and there is a demand for a substitute material. Further, Corson copper or titanium copper generally does not have an electrical conductivity of 50 %IACS or higher. Examples of the applications where a high electrical conductivity of 50 %IACS or higher is required, include battery terminals and relay contacts to which high current is applied. Furthermore, since materials having high electrical conductivity are generally excellent in the thermal conduction property as well, materials for the sockets or heat sinks of central processing units (CPU; integrated logic elements), which require heat emission properties, are also required to have high electrical conductivity. Particularly, recent hybrid cars or CPUs handling high speed processing are required to use materials having high electrical conductivity and high mechanical strength.

[0007] Under such circumstances, copper alloys which have mechanical strength, bending property, and electrical conductivity (thermal conductivity), and which utilize intermetallic compounds containing Co (cobalt) and Si (silicon), are increasingly attracting attention. Copper alloys containing Co and Si as essential elements, or techniques related to these, are known as shown below.

[0008] First, conventional techniques for copper alloys containing Co and Si as essential elements will be described.

Patent Literature 1 describes an alloy containing Co, Si, Zn (zinc), Mg (magnesium), and S (sulfur) as essential elements. The purpose in Patent Literature 1 is to improve hot workability.

Patent literature 2 describes an alloy containing Mg, Zn, and Sn (tin), in addition to Co and Si. Patent literature 3 describes an alloy essentially containing Sn and Zn, in addition to Co and Si. Further, Patent Literature 2 and Patent Literature 3 describe that the precipitate (compound) of Co and Si is a Co_2Si compound. Patent Literature 4 describes a Cu-Co-Si-based alloy. The alloy of Patent Literature 4 is applied in lead frames, and it is described that the kind of the alloy is a precipitation strengthening type alloy.

Patent Literature 5 describes a Cu-Co-Si-based alloy, in which the size of inclusions precipitated is 2 μm or less.

Patent literature 6 describes a Cu-Co-Si-based alloy, in which a Co_2Si compound is precipitated.

[0009] The techniques described in Patent Literatures 1 to 6 all describe only on one kind (or one size) of intermetallic compound composed of Co and Si. However, in regard to other alloy systems, particularly the so-called Corson copper which contains Ni and Si as essential additive elements, it is known that when two or more kinds of intermetallic compounds are dispersed in the copper alloy, the bending property and the like are improved. This technique is known in Patent Literatures 7 to 11.

[0010]

Patent Literature 1: JP-A-61-87838 ("JP-A" means unexamined published Japanese patent application)
Patent Literature 2: JP-A-63-307232
Patent Literature 3: JP-A-02-129326
Patent Literature 4: JP-A-02-277735
Patent Literature 5: JP-A-2008-88512
Patent Literature 6: JP-A-2008-56977
Patent Literature 7: JP-A-2006-161148
Patent Literature 8: JP-A-2006-265731
Patent Literature 9: JP-A-2007-314847
Patent Literature 10: JP-A-2008-75151
Patent Literature 11: JP-A-2008-75152

DISCLOSURE OF INVENTION

TECHNICAL PROBLEM

[0011] However, all of the techniques described in the patent literatures do not satisfy all of the mechanical strength, bending property, and electrical conductivity (thermal conductivity), each at a high level.

The purpose in Patent Literature 1 is to improve hot workability, but the Patent Literature 1 has no description on the precipitate (compound) of Co and Si and has no description on mechanical strength or electrical conductivity.

Patent Literature 2 has no description on performing a recrystallization treatment, and it is thought that the resultant alloy is poor in bending property.

Patent Literature 3 shows, in the example section, that the electrical conductivity is a relatively low value of 30 %IACS or less.

Patent Literature 4 describes a precipitation strengthening type alloy, but has no description on the specific compound or its size. Further, there is no description on performing a recrystallization treatment, and it is thought that the resultant alloy is poor in bending property.

In Patent Literature 5 and Patent Literature 6, examples are described in which bending property is evaluated under the conditions of R/t = 1, in which an inner bending radius of the material is represented by R, and a sheet thickness is represented by t. However, it is thought that with the mechanical strength level of this extent, definitely there will be instances where the resulting alloys are not capable of coping with the bending property demanded in the future.

[0012] Furthermore, the techniques described in Patent Literatures 7 to 11 each are related to the so-called Corson copper containing Ni and Si as main additive elements. Corson copper and Cu-Co-Si-based alloys differ from each other in the alloying elements, and have differences, for example, in different temperature of carrying out a solution heat treatment. For example, in the case of Corson copper, when the amount of Ni is 3 mass% or more, a solution heat treatment temperature of about 900°C is required; while, in the case of a Cu-Co-Si alloy, it has been known that at a solution heat treatment temperature of about 900°C, alloys having an amount of Co of about 1.0 to 1.2 mass% only can be sufficiently treated by a solution heat treatment. Furthermore, in the case of a Corson copper having an amount of Ni of 3 mass% or more, when it is tried to enhance the mechanical strength and improve the bending property, it is practically difficult to obtain an electrical conductivity of 20 %IACS or more, and a copper alloy having high electrical conductivity cannot be obtained. That is, the Corson copper and the Cu-Co-Si alloys have significant differences in the solution heat treatment temperature or the properties of alloy, so there is a demand for a new technique which is not an extension of the conventional techniques.

SOLUTION TO PROBLEM

[0013] In view of the above, in order to simultaneously satisfy high electrical conductivity, high mechanical strength, and satisfactory bending property in copper alloy materials, the inventors of the present invention found a specifically preferable relationship of those properties with the grain size, by dispersing a precipitate (compound) of two or more kinds in a Cu-Co-Si-based copper alloy, and controlling the size of such a precipitate (if necessary, including its density). By conducting further investigations, the inventors attained the present invention.
According to the present invention, there is provided the following means:

(1) A copper alloy material for electric/electronic parts, comprising Co and Si as additive elements,
wherein, in the copper alloy material, a compound A is dispersed, which is composed of Co and Si and which has an average particle diameter of 5 nm or more but less than 50 nm, and at least one compound is dispersed, in which said at least one compound is selected from the group consisting of a compound B which does not contain one of Co and Si or any of those and which has an average particle diameter from 50 nm to 500 nm, a compound C which contains both of Co and Si and another element and which has an average particle diameter from 50 nm to 500 nm, and a compound D which is composed of Co and Si and which has an average particle diameter from 50 nm to 500 nm,
wherein a grain size of the copper alloy of the matrix is 3 to 35 μm, and
wherein an electrical conductivity is 50 %IACS or more.
(2) A copper alloy material for electric/electronic parts, comprising Co and Si as additive elements,
wherein, a compound A which is composed of Co and Si and which has an average particle diameter of 5 nm or more but less than 50 nm, a compound B which does not contain one of Co and Si or any of those and which has an average particle diameter from 50 nm to 500 nm, a compound C which contains both of Co and Si and another element and which has an average particle diameter from 50 nm to 500 nm, and a compound D which is composed of Co and Si and which has an average particle diameter from 50 nm to 500 nm, are dispersed in the copper alloy material,
wherein the ratio of dispersion densities of the compounds A, B, C, and D satisfies the relationship: $0.0001 \leq \{(\text{dispersion density of the compound B} + \text{dispersion density of the compound C} + \text{dispersion density of the compound D})/\text{dispersion density of the compound A}\} \leq 0.1$,
wherein a grain size of the copper alloy of the matrix is 3 to 35 μm, and wherein an electrical conductivity is 50 %IACS or more.
(3) The copper alloy material for electric/electronic parts as described in item (1) or (2), further comprising at least one selected from Al, Ag, Sn, Zn, Mg, Mn, and In in an amount of 0.05 to 1.0 mass% in total, with the balance being Cu and unavoidable impurities.
(4) The copper alloy material for electric/electronic parts as described in any one of items (1) to (3), further comprising at least one selected from Fe, Cr, Ni, Zr, and Ti in an amount of 0.05 to 1.0 mass% in total, with the balance being Cu and unavoidable impurities.
(5) The copper alloy material for electric/electronic parts as described in item (1) or (2), comprising Co and Si as additive elements, with the balance being Cu and unavoidable impurities.
(6) The copper alloy material for electric/electronic parts as described in any one of items (1) to (5), wherein the content of Co is 0.4 to 2.0 mass%, and the content of Si is 0.1 to 0.5 mass%.
(7) The copper alloy material for electric/electronic parts as described in any one of items (1) to (6), wherein, in the production of an ingot, an average cooling speed from the solid state temperature to 500°C is 5 to 100°C/second.

Herein, the term "average particle diameter (size) of a precipitate (compound)" is the average particle size of a precipitate in interest determined by the method described below. The term "grain size" means a value measured according to JIS-H0501 (cutting method) described below.

ADVANTAGEOUS EFFECTS OF INVENTION

[0014] According to the present invention, a copper alloy material can be provided, which has an optimized grain size, which is high in electrical conductivity, high in mechanical strength, and excellent in bending property, and which is favorable for the use in electric/electronic parts, by controlling two or more kinds of precipitates (compounds) in a Cu-Co-Si alloy which exhibits a high electrical conductivity.

[0015] Other and further features and advantages of the invention will appear more fully from the following description.

BEST MODE FOR CARRYING OUT THE INVENTION

[0016] Preferable embodiments of the copper alloy material of the present invention will be described in detail. Herein, the term "copper alloy material" means a product obtained after a copper alloy base material (herein, the "copper alloy base material" means a mixture of component elements of a copper alloy not having the concept of shape) is worked into a predetermined shape (for example, sheet, strip, foil, rod, or wire). Further, the term "copper alloy of matrix" means a copper alloy not having the concept of shape.

Although explanation will be given on a sheet material and a strip material as preferable specific examples of the copper alloy material, but the shape of the copper alloy material is not limited to the sheet material or the strip material.

[0017] First, the technical idea of the present invention will be described. The inventors of the present invention found, by studying keenly, that, in order to obtain a copper alloy material high in mechanical strength, high in electrical conductivity, and favorable in bending property, two or more kinds of precipitates (compounds) having different sizes are needed in a Cu-Co-Si-based alloy, and that it is important to control the grain size of the copper alloy of the matrix to 3 to 35 μm. Further, the inventors found that it is preferable to control the density of the precipitates (compounds) so as to control the grain size of the copper alloy of the matrix to 3 to 35 μm. Furthermore, the inventors found that, between two kinds of precipitates having different sizes, a giant (coarse) compound having an average particle diameter from 50 nm to 500 nm can be obtained preferably by appropriately setting the cooling speed in the production of an ingot.

[0018] Furthermore, for a copper alloy material appropriate favorable for the use in electric/electronic parts, the electrical conductivity is 50 %IACS or more, and, with regard to the relationship between tensile strength and bending property, it is preferable that when the tensile strength is 550 MPa or more but less than 650 MPa, $R/t \leq 0.5$, in which R/t serves as an index for bending property; when the tensile strength is 650 MPa or more but less than 700 MPa, $R/t \leq 1$; when the tensile strength is 700 MPa or more but less than 750 MPa, $R/t \leq 2$; and when the tensile strength is 750 MPa or more but less than 800 MPa, $R/t \leq 3$.

Herein, the term "R/t" means a result obtained by conducting a W bending test at a bending angle of 90° according to the "Standard test method of bend formability for sheets and strips of copper and copper alloys (JBMA T307)" of the Japan Copper and Brass Association Technical Standards, and is a value obtained by subjecting a sheet material cut out in a direction perpendicular to rolling, to a bending test under the condition of a predetermined bending radius (R), determining the R value of the limit at which any crack (breakage) does not occur at the top, and normalizing the value by the sheet thickness (t). In general, a smaller value of R/t gives more satisfactory bending property.

In the copper alloy material of the present invention for electric/electronic parts, the electrical conductivity of the copper alloy material is set at 50 %IACS or higher. The electrical conductivity is more preferably 55 %IACS or more, and further preferably 60 %IACS or more, and it is preferable that the electrical conductivity is as high as possible, but the upper limit is generally approximately 75 %IACS. In the copper alloy material for electric/electronic parts of the present invention, it is preferable that the tensile strength and the bending property (R/t) have the relationship described above. Further, the lower limit of the bending property (R/t) is 0.

[0019] In order to obtain a material high in electrical conductivity, high in mechanical strength, and excellent in bending property as a copper alloy material favorable for the use in electric/electronic parts, it is useful to utilize a technique of dispersing two or more kinds of intermetallic compounds having different sizes in a Cu-Co-Si-based alloy.

[0020] First, the background of this technique will be described, and the copper alloy as mentioned herein is an example of the case where the intermetallic compound is one kind of compound containing Co and Si. When Co and Si are added to copper, followed by subjecting to an adequate heat treatment, to give a so-called precipitation type copper alloy in which an intermetallic compound composed of Co and Si precipitates.

A heat treatment method of developing the function of a precipitation type copper alloy is generally carried out by essentially performing the following two kinds of heat treatments. The first heat treatment is referred to as heat solution (or recrystallization) treatment or homogenization treatment, and this heat treatment is carried out at a relatively high temperature for a shorter time period. The second heat treatment is referred to as aging heat treatment or precipitation treatment, and this heat treatment is carried out at a temperature lower than the solution heat treatment temperature for a longer time period.

[0021] First, the first heat treatment is carried out, by using a continuous annealing furnace which threads a rolled sheet of a copper alloy inside the heating furnace. This is because, when a sheet is heat treated at a high temperature in a state of being wound in a coil form, adhesion occurs, and because, when the cooling speed thereafter is slow, the elements made into a solid solution uncontrollably precipitate, to form a precipitate that does not contribute to mechanical strength. Further, since there is a concern about sheet breakage caused by threading inside the furnace at high temperature, a heat treatment in a short time period is carried out.

On the other hand, in regard to the second heat treatment, since it is intended to finely disperse the precipitate (compound) that contributes to mechanical strength in the copper alloy, the sheet of the copper alloy wound into a coil form is subjected to a heat treatment for a relatively long time period (specifically, several minutes to several ten hours) in a heating furnace that has been kept under temperature control, and thus the precipitate (compound) which is optimal for a solid phase diffusion treatment is sufficiently dispersed.

[0022] Thus, in a precipitation type copper alloy, the temperature for the solution heat treatment (the first heat treatment) is raised as high as possible, and thereby the amount of solute elements that are made into a solid solution in the copper matrix is increased. Then, a precipitate (compound) is precipitated, by utilizing the difference in temperature from the aging heat treatment (the second heat treatment) performed thereafter, and thus the copper alloy is strengthened. As the temperature of this solution heat treatment (the first heat treatment) is raised higher, the solid solution amount of the solute elements is increased (thereby, the amount of precipitate that precipitates upon the later second heat treatment is increased). Thus, it is advantageous to perform a high temperature heat treatment for the first heat treatment. However, on the contrary, coarsening of the texture of the recrystallization, which occurs simultaneously, has adverse influence on the bending property. If the grain size is coarse in a copper alloy high in mechanical strength, when the copper alloy is subjected to bending, cracks (fissure) occurs at that bent portion, or the surface unevenness of wrinkles (orange peel surfaces, chalk marks) becomes large. Each of those result in that necessary contact pressure may not be obtained, or the contact point becomes unstable, thus the resultant copper alloy material does not serve favorably for applications, such as connectors and terminals. Further, the particle diameter becomes larger upon recrystallization as the temperature is raised higher; and, when the high temperature heat treatment is carried out as the first heat treatment so as to increase the amount of the solute elements as described above, bending property is deteriorated on the contrary. As such, for a copper alloy material in which the intermetallic compound is one kind of compound containing Co and Si, it can be said that it is extremely difficult to satisfy all of high electrical conductivity, high mechanical strength, and satisfactory bending property.

[0023] Thus, according to the present invention, the inventors developed a technique of dispersing two or more kinds of intermetallic compounds having different sizes in a Cu-Co-Si-based alloy, to satisfy all of high electrical conductivity, high mechanical strength, and satisfactory bending property. A fine compound composed of Co and Si and having a size of 5 nm or more but less than 50 nm is a compound that contributes to precipitation strengthening. On the other hand, a coarse compound having a size from 50 nm to 500 nm is a compound that does not contribute to precipitation strengthening but exhibits effects at the time of high temperature solution heat treatment as described in the above. This coarse compound cannot be made into a solid solution in the copper matrix even in the high temperature solution heat treatment, and exists in the copper matrix. Therefore, even if grain growth occurs, the coarse compound becomes a barrier and causes a state in which grain boundary movement is difficult to occur. As a result, coarsening of the grain size is suppressed.

[0024] In the case of a copper alloy, an ingot obtained by melting (making into molten) raw materials followed by solidifying, is used as a starting material, which is subjected to hot rolling and cold rolling, and various heat treatments, thereby a copper alloy material exhibiting desired properties is completed. In the course of the solidification of the ingot, the hot rolling, the cooling thereafter, the various heat treatments, or the cooling thereafter, intermetallic compounds of various sizes are formed, and a solution heat treatment is a treatment to make those intermetallic compounds into solid solution, again, in the copper matrix. The solution heat treatment is a treatment carried out prior to an aging heat treatment, but upon the solution heat treatment, only coarse compounds remain behind, while others are made into a solid solution in the copper matrix. That is, what remain behind in the copper matrix after the solution heat treatment are coarse compounds only.

The aging heat treatment of the subsequent step allows precipitation of fine precipitates (compounds), but at this temperature, the size and density of the coarse compounds that have been exposed to a high temperature in the preceding heat treatment, do not change. There are a cases where the solution heat treatment and the aging heat treatment are carried out in this successive order, and another case where a cold rolling step is conducted between these heat treatments; however, in any of those cases, there is no change in the size and density of the coarse compounds upon the heat treatment steps.

[0025] The compound A having an average particle diameter of 5 nm or more but less than 50 nm, which is a compound that contributes to precipitation strengthening, is a compound that precipitates upon the aging heat treatment, to enhance mechanical strength. The compound A is preferably Co_2Si, but may also contain a compound that does not fulfill the composition ratio of Co_2Si (for example, CoSi, or $CoSi_2$). When the average particle diameter of the compound A is 5 nm or more, the amount of precipitation hardening is sufficient, and when the average particle diameter is less than 50 nm, the mechanical strength is sufficient, without a loss of coherent strain. Therefore, the size of the compound A is defined to be 5 nm or more but less than 50 nm, and a preferred size is from 10 nm to 30 nm. However, since this compound A varies with the observation method, the details of the observation method will be described in the section "Examples" shown below.

[0026] Next, the compound B is a compound that does not contain one of Co and Si or any of them, and the contribution of this compound to mechanical strength is small. Examples of the composition of the compound B include Co-x, Si-x, and x-y, in which x and y each represent an element other than Co and other than Si. When this compound B is made into a solid solution in the copper matrix at the solution heat treatment temperature to disappear, the compound B cannot be utilized in the control of the grain size of the copper alloy of the matrix. Therefore, this compound B is one having a melting point higher than the solid solution temperature (that is, the melting point) of Co_2Si, which is a main component of the compound A.

When the average particle diameter of the compound B is from 50 nm to 500 nm, the compound B exhibits an effect of suppressing (pinning) the grain boundary movement at high temperature. The compound B is an incoherent compound since it has an average particle diameter of 50 nm or more, and in order to suppress the grain boundary movement of the copper alloy of the matrix, the average particle diameter of the compound B is preferably from 50 nm to 500 nm. The average particle diameter of the compound B is more preferably from 100 nm to 300 nm. The inventors confirmed by an observation of the texture after a solution heat treatment, that the grain growth is suppressed most effectively when the compound B is dispersed.

[0027] Next, the compound C is a compound that contains both of Co and Si and another element, and this compound also is small in contribution to mechanical strength. The difference between the compounds C and B is that the compound C has a composition, for example, Co-Si-x, or Co-Si-x-y, in which x and y each represent an element other than Co and other than Si. Since it is also preferable, as in the case of the compound B, for the compound C not to be made into a solid solution in the copper matrix upon the high temperature solution heat treatment to disappear, the compound C is one having a melting point higher than the solid solution temperature (that is, the melting point) of Co_2Si. The average particle diameter of the compound C is preferably from 50 nm to 500 nm, to exhibit the same effect as the compound B. The average particle diameter of the compound C is more preferably from 100 nm to 300 nm.

[0028] There are the cases where the compound B or C is present in a size of an average particle diameter of 5 nm or more but less than 50 nm, which is the same as the average particle diameter of the compound A. In the case of a compound which has an average particle diameter of 5 nm or more but less than 50 nm and which has a composition similar to that of the compound B or C, when the elements, which have been once made into solid solution by a solution heat treatment, undergo precipitation, the elements substitute Co, which is a main element, and form compounds with Si, thereby contributing to enhancement of mechanical strength. For example, Fe, Ni, and Cr among the additive elements each have a function of substituting a part of Co in the main precipitate phase and forming $(Co, x)_2Si$ compounds (x = Fe, Ni, or Cr), thereby enhancing mechanical strength.

[0029] Finally, the compound D is a compound composed only of Co and Si, and has the same components as those of the compound A. However, the compound D has a different size, and it also includes compounds that do not have the composition ratio of Co_2Si (for example, CoSi, and $CoSi_2$). The compound D is different from the compound A in the following point. Since the size of the compound D is coarse, the time period is not sufficient for the compound D to be made into a solid solution in the matrix in the high temperature solution heat treatment of a short time period, and as a result, the compound D remains in the copper matrix and exhibits the function of suppressing grain growth. Although this compound D has an angular shape in many cases, but its particle size is defined as the average particle diameter. Therefore, since the compound D is utilized to exhibit the same effect as the compound B or C, the average particle diameter of the compound D is also preferably from 50 nm to 500 nm. The average particle diameter of the compound D is more preferably from 100 nm to 300 nm.

The compound B, the compound C, and the compound D are subjected to a component analysis with an EDS (energy dispersive spectrometer) attached to a transmission electron microscope (SEM), and thereby it is determined which compound (precipitate) is which. Thus, the size of each of the compounds can be measured.

[0030] Further, in the present invention, the grain size of the copper alloy of the matrix is set within the range of 3 to 35 μm. This is because, when the grain size is 3 μm or more, recrystallization is sufficient, there is no risk that there could be mixed grains including unrecrystallization where insufficiently recrystallized portions are observed, and the bending property is favorable. Furthermore, when the grain size is 35 μm or less, the grain boundary density is high, the bending stress (applied strain) can be sufficiently absorbed, and the bending property is favorable. The grain size of the copper alloy is preferably from 10 to 30 μm.

Further, in the present invention, the electrical conductivity of the material is set to be 50 %IACS or more. This property is obtained, by precipitating an intermetallic compound of Co_2Si by, for example, adjusting preferably the content of Co to 0.4 to 2.0 mass% and the content of Si to 0.1 to 0.5 mass%.

[0031] The reason is described why adjusting the ratio of the dispersion densities of the compounds preferably to: 0.0001 ≤ {(the dispersion density of the compound B + the dispersion density of the compound C + the dispersion density of the compound D)/the dispersion density of the compound A} ≤ 0.1. First, the coarse compounds B, C, and D that suppress the grain boundary movement of the copper alloy of the matrix, may be exist in two or more kinds of those together with the compound A, but the ratio of their dispersion densities is preferably 0.0001 ≤ {(the dispersion density of the compound B + the dispersion density of the compound C + the dispersion density of the compound D)/the dispersion density of the compound A} ≤ 0.1. When the ratio of dispersion density is within this range, the effect of suppressing the grain boundary movement is high, and the proportion of the coarse precipitates (compounds) is small, which do not contribute to mechanical strength but which suppress movement. Thus, the purpose of high mechanical strength can be sufficiently achieved. The ratio of the dispersion density of the respective compounds is preferably: 0.0001 ≤ {(the dispersion density of the compound B + the dispersion density of the compound C + the dispersion density of the compound D)/the dispersion density of the compound A} ≤ 0.01, and more preferably: 0.0001 ≤ {(the dispersion density of the compound B + the dispersion density of the compound C + the dispersion density of the compound D)/the dispersion density of the compound A} ≤ 0.001.

If the number of compounds B, C, and D (particularly, the total number of those) is too small, for example, deterioration in bendability of the resultant copper alloy material may occur due to grain coarsening, and the like.

In the copper alloy material of the present invention, as the number of precipitates of the compound A increases, that is, the dispersion density of the compound A in the copper alloy material increases, the mechanical strength is enhanced. Further, as the number of precipitates of the compound B, C, and D (particularly, the total number of these) is larger, that is, the (the dispersion density of the compound B + the dispersion density of the compound C + the dispersion density of the compound D) in the copper alloy material is higher, a copper alloy material can be obtained, which has a favorable bendability, with respect to mechanical strength enhancement. In regard to the number of these compounds (and the dispersion density thereof), it is thought that, generally, the larger the amounts of the additive alloying elements is, the more the number of resultant compounds is, as long as the conditions for the solution heat treatment or aging treatment are appropriately controlled.

[0032] In regard to the amounts of addition of Co and Si in the copper alloy material of the present invention, the amount of addition of Co is set at 0.4 to 2.0 mass%, since, when the amount of addition of Co is 0.4 mass% or more, a desired mechanical strength can be obtained, and, when the amount of addition of Co is 2.0 mass% or less, the solution heat treatment temperature is within an appropriate range and no production technique with an extremely high degree of difficulty is needed. On the other hand, in regard to Si, since the stoichiometric ratio of Co_2Si, which is the precipitation strengthening phase of this Cu-Co-Si alloy, is the ratio Co/Si nearly equals to 4.2, the range of the amount of addition of Si is set according to this ratio. As long as the value of the ratio Co/Si is 3.5 or more but 4.8 or less, no problem arises for practical use. When the respective elements of Fe, Ni and Cr substitute a part of Co in the main precipitate phase to form a $(Co, x)_2Si$ compound (in which x is Fe, Ni, or Cr), the calculation of the ratio is as follows: the ratio (Co + x)/Si nearly equals to 4.2 (in which x is Fe, Ni, or Cr). Even in that case, there is no problem for practical use, as long as the ratio (Co + x)/Si nearly equals to 3.5 to 4.8.

[0033] The copper alloy material of the present invention may contain elements other than Co and other than Si.

Al, Ag, Sn, Zn, Mg, Mn, and In have a feature of being made into a solid solution in the copper matrix to strengthen the resultant alloy. When the amount of addition of the elements is 0.05 mass% or more in total, the effect is obtained, and when the amount of addition is 1.0 mass% or less in total, the electrical conductivity is not inhibited. A preferred amount of addition is at least one of these elements in an amount of 0.2 to 0.4 mass% in total.

[0034] In addition to the above, Zn has an effect of improving solder adhesiveness, and Mn has an effect of improving hot workability. Further, the addition of Sn and Mg has an effect of improving the stress relaxation resistance. Individual addition of Sn or Mg also provides the effect, but when those two elements are added, the elements exhibit the effect synergistically. When the amount of addition is 0.1 mass% or more in total, the effect is provided, and when the amount of addition is 1.0 mass% or less, the electrical conductivity is not inhibited, and an electrical conductivity of 50 %IACS or more is secured. On the other hand, there is also a finding on the ratio of addition of Sn and Mg. When Sn/Mg ≥ 1, excellent results on the stress relaxation resistance are obtained in many cases. Further, since the respective elements of Zn, Mn, Sn, and Mg also have the function of serving as x and y of the compounds B and C, the effect of suppressing grain boundary movement as the compounds B and C is exhibited.

[0035] Fe, Cr, Ni, Zr, and Ti are elements that substitute Co to form compounds with Si, to contribute to enhancement of mechanical strength. That is, the respective elements of Fe, Ni, Cr, Zr, and Ti have a function of substituting a part of Co in the main precipitate phase to form a $(Co, z)_2Si$ compound (in which z is Fe, Ni, Cr, Zr, or Ti), thereby enhancing mechanical strength. With respect to the amount of addition, when at least one of these elements is added in an amount of 0.05 mass% or more in total, the effect is exhibited, and when added in an amount of 1.0 mass% or less, the elements do not cause crystallization upon casting, or do not form intermetallic compounds that do not contribute to the mechanical strength. Since the respective elements of Fe, Cr, Ni, Zr, and Ti also have a function of serving as x and y of the compounds B and C, the elements exhibit the effect of suppressing the grain boundary movement as the compounds

B and C. These elements exhibit almost the same effects when added in combination with two or more of those, or added singly. A preferred amount of addition is 0.5 to 0.8 mass% in total for at least one of these elements.
Furthermore, even if at least one of the elements of the group consisting of Al, Ag, Sn, Zn, Mg, Mn, and In and at least one of the elements of the group consisting of Fe, Cr, Ni, Zr, and Ti are added in combination, as long as the respective amounts of addition are within the ranges described above, the properties of the individual elements will not be inhibited.
Examples of the unavoidable impurities in the copper alloy material for electric/electronic parts of the present invention include H, C, O, S, and the like.

[0036] Next, the copper alloy material of the present invention will be described from the viewpoint of the production method.
The copper alloy material of the present invention can be produced by, for example, the following steps. An outline of the main production steps for the copper alloy material of the present invention includes: melting → casting → homogenization treatment → hot rolling → face milling → cold rolling → solution heat treatment → aging heat treatment → final cold-rolling → low-temperature annealing. The aging heat treatment and the final cold-rolling may be in a reversed order. Further, the low-temperature annealing (stress relief annealing) of the final step may be omitted. In regard to the conditions of the respective steps, the steps can be carried out in a usual manner, except for the steps especially mentioned herein.
In the present invention, the fact that the average cooling speed from the solid state temperature to 500°C, in the production of the copper alloy ingot, is 5 to 100°C/sec, also contributes to the precipitation of the compound B, C, and D in appropriate sizes and amounts. When this average cooling speed is from 5 to 100°C/sec, the compounds B, C, and D are appropriately formed, and as a result, the grain size of the copper alloy of the matrix can be adjusted to an adequate range. Herein, the solid state temperature is the temperature at which solidification is initiated, and since a temperature lower than 500°C falls in a temperature zone in which the compound A is precipitated, the lower limit of the temperature range is determined 500°C.
If the cooling speed after the casting is too slow, the mechanical strength may be lowered, owing to an increase of coarse precipitates.

[0037] The solution heat treatment temperature is preferably, when the amount of Co is 0.4 to 1.2 mass%, the temperature is 800°C to 950°C; when the amount is 1.0 to 1.5 mass%, the temperature is 900°C to 950°C; and when the amount is 1.3 to 2.0 mass%, the temperature is 900 to 1,000°C. Then, solution and recrystallization can be sufficiently carried out for the respective cases. The grain size of the copper alloy of the matrix is determined by the heat treatment at these temperatures. Further, it is preferable to conduct rapid cooling with the cooling speed of 50°C /sec or more from the solution heat treatment temperature. If the rapid cooling is not conducted, the element solution-heat-treated at the high temperature may precipitate. The particles (compounds) precipitated upon this cooling are incoherent precipitates, which do not contribute to the mechanical strength, and which give an adverse effect to the characteristics, by contributing as nucleus forming sites in forming coherent precipitates in the subsequent aging heat treatment step (or the aging heat treatment step after the cold rolling step subsequent to the solution heat treatment), thereby to accelerate precipitation at the sites. The above-mentioned cooling speed means an average speed from the solution heat treatment temperature at high temperature to 300°C. At a temperature 300°C or lower, a significant change in the texture does not occur, and the cooling speed to this temperature may be set at a predetermined cooling speed.

[0038] According to the present invention, after the solution heat treatment (recrystallization is also carried out, along with the solution, by this heat treatment), an aging heat treatment is carried out, to form compounds of Co and Si in the copper alloy. This heat treatment may also be carried out after the solution heat treatment, and even after a predetermined cold rolling is carried out after the solution heat treatment. The conditions for this aging heat treatment are preferably at a temperature of 500°C to 600°C for 1 to 4 hours, in the case of performing the aging heat treatment after the solution heat treatment but before the final cold-rolling; and preferably at a temperature of 450°C to 550°C for 1 to 4 hours, in the case of performing the aging heat treatment after the final cold-rolling after the solution heat treatment. Further, the cooling speed after this aging heat treatment has a preferred range. When the cooling speed is in the range of 20 to 100°C/hour, increase of the electrical conductivity is sufficiently achieved. If the cooling speed is faster than 100°C/hour, increase of the electrical conductivity is not achieved sufficiently; and if the cooling speed is slower than 20°C/hour, the target changes in the properties do not occur but only the heat treatment time is prolonged, which is not economical. On the other hand, the temperature range associated with the cooling speed is the range of cooling from the respective heat treatment temperature to 300°C. If the lower limit of the temperature range is higher than 300°C, the target high electrical conductivity cannot be obtained; and if the lower limit of the temperature range is set at a much lower value than 300°C, there is no change in the obtained electrical conductivity.
The cooling speed after the aging heat treatment can be adjusted by controlling the temperature at a heating furnace. Further, in the case where it is required to conduct a rapid cooling, the rapid cooling can be conducted by taking out the subject from a heating zone of the heating furnace and subjecting the subject to forced air cooling or water quenching.

EXAMPLES

[0039] The present invention will be described in more detail based on examples given below, but the invention is not meant to be limited by these.

(Example 1)

[0040] Alloys (Example Nos. 1 to 35, Comparative Example Nos. 101 to 128) containing elements as shown in Tables 1 and 2, with the balance of Cu and unavoidable impurities, were melted with a high-frequency melting furnace, followed by casting at a cooling speed of 5 to 100°C /sec, to obtain ingots, respectively, with thickness 30 mm, width 100 mm, and height 150 mm. At that time, a thermocouple was placed in the vicinity of the mold wall, and casting and melting were carried out to obtain the ingots, while measuring any time.
The thus-obtained ingots were kept at a temperature from 930 to 1,050°C for 0.5 to 1.0 hour, followed by hot rolling to give hot-rolled sheets with sheet thickness t = 12 mm, face-milling each surface in 1 mm in each to thickness t = 10 mm, cold rolling to finish to sheet thickness t = 0.3 mm, and subjecting to a solution heat treatment at a temperature from 700 to 950°C. The thus-prepared materials were subjected to any one of the following two processes, to produce test specimens of the final products.
Process A: (The solution heat treatment) - Aging heat treatment (at a temperature from 500 to 600°C for 2 to 4 hours) - Cold working (working ratio: 5 to 25%)
*Then, according to the necessity, strain-relieving annealing was conducted at a temperature from 300 to 400°C for 1 to 2 hours.
Process B: (The solution heat treatment) - Cold rolling (working ratio: 5 to 25%) - Aging heat treatment (at a temperature from 450 to 550°C for 2 to 4 hours)
[0041] The resultant test specimens were evaluated by the following property testing. The results of Examples are shown in Table 1, and the results of Comparative Examples are shown in Table 2. In Tables 1 and 2, the expression "E+08" and the like in the items of compound density represents the power of 10 (e.g. in the case of "E+08", it means "$\times 10^8$").

a. Tensile Strength [TS]:
Three test pieces were cut out from the respective test specimen (test piece) in the direction parallel to the rolling direction, according to JIS Z2201-13B, followed by measuring, according to JIS Z2241, to obtain the average value as shown.
b. Measurement of Electrical Conductivity [EC]:
With respect to two respective test pieces, the electrical conductivity was measured in a thermostat controlled at 20°C (±1°C) by using the four-terminal method, to obtain the average value (%IACS) as shown in Tables 1 to 2. The distance between the terminals was 100 mm.
c. Bending property:
Respective test pieces were cut out from the test specimens in a direction perpendicular to the rolling direction into a size of width 10 mm and length 35 mm. The resultant test pieces were subjected to W-bending at 90° (Bad-way bending), with a bending radius R of 0 to 0.5 (mm), at six levels with interval 0.1 mm, in which the bending axis was set to be parallel to the rolling direction. Then, the bent portions were observed, to confirm whether cracks were occurred or not at the bent portion, in which the observation was made with the naked eye with an optical microscope with a magnification of 50X, and with a scanning electron microscope (SEM). In "R/t" in Table 1, R represents the bending radius, and t represents the sheet thickness. The smaller the value is, the more favorable the bending property is.
d. Grain size [GS]:
After a cross-section perpendicular to the rolling direction of the respective test specimen (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. Then, photographs of the resultant polished and corroded surface were taken, with a magnification of 200X to 400X with an optical microscope, or with a magnification of 500X to 2,000X with a scanning electron microscope (SEM) using a secondary electronic image by the SEM, to measure a grain size on the cross-section, according to the cutting method of JIS-H-0501. The magnification of the photographs was changed depending upon the size of the grains observed. The term "mixed grain" in the tables means a texture, in which both of a recrystallized region and an unrecrystallized region (the state of the rolling worked structure remained therein) are co-present; and in the case of mixed grain, no particle size was measured. It is known that if an unrecrystallized region exists, the bending property of the resultant alloy is poor. Thus, the mixed grain is an undesirable texture.
e. Cooling speed after aging heat treatment

The cooling speed was adjusted by changing the weight of the material that was subjected to the heat treatment, or adjusted by controlling the temperature with the heating furnace utilized. By using the same heating furnace (batch type), for example, to obtain a faster cooling speed, the amount of simultaneously performing the heat treatment was decreased, while to obtain a slower cooling speed, a dummy test piece was placed to increase the amount that was simultaneously subjected to the heat treatment, and thereby the respective heat treatments were carried out. Further, when performing rapid cooling, the sample was taken out from the heating zone of the heating furnace and was subjected to forced air cooling or water quenching. The adjustment of the cooling speed was also carried out, by controlling the temperature in the heating furnace. In the case where the number of samples was particularly small, or in the case where the cooling speed was very low, the cooling speed was adjusted, by controlling the temperature in the heating furnace.

f. Size, the number, and dispersion density of compound

The size (average particle size) of the precipitate (compound) was measured using a transmission electron microscope (TEM). Since it is difficult to observe the precipitate in the final product under the influence of working strain, observation was made with respect to the texture of the material after the aging heat treatment. A test piece for TEM was cut out from any site of the heat treated material, followed by electro-polishing (by a twin jet-type electropolishing apparatus) at a temperature in the range of -20 to -25°C by using a methanol solution of nitric acid (20%), to obtain a test piece for observation.

Then, the resultant test piece was observed with an accelerating voltage of 300 kV, to adjust the incident direction of an electron beam in the vicinity of (001), and three sheets of photographs were arbitrarily taken with a magnification of 100,000X. Using the photographs, the number of compounds A (about 100 particles) satisfying the defined size was determined.

Further, the compounds B, C, and D were respectively subjected to a component analysis with an EDS (energy dispersive spectrometer) attached to a transmission electron microscope, and then three sheets of photographs were arbitrarily taken with a magnification of 1,000X to 5,000X. Using the photographs, the number of compounds satisfying the defined size was determined. The number of particles was 10 to 100.

From these values, the respective dispersion densities (/mm^2) of the compounds A, B, C, and D were determined. In the following tables, the dispersion density is simply abbreviated as density. Further, the "densities of compounds B, C, and D (/mm^2)" represents the sum of the dispersion densities (/mm^2) of the compounds B, C and D, and it is needless to say that if a certain compound(s) is not present, the term density represents the dispersion density of the remaining compound alone or the sum of the dispersion densities of the remaining two kinds of compounds. The term "(B+C+D)/A" is an abbreviation of "{(the dispersion density of the compound B + the dispersion density of the compound C + the dispersion density of the compound D)/the dispersion density of the compound A}".

(Note) Abbreviations in the following tables not mentioned in the above are: "Ingot cooling speed" is the cooling speed of the ingot; "Sol. temp." is the temperature in the solution heat treatment; "Aging temp." and "Aging time" are the temperature and the time period in the aging heat treatment, respectively; "Density Comp. A" is the dispersion density of the compound A; and "Density, Comp. B, C, D" is the sum total of the dispersion densities of the compounds B, C, and D (/mm^2, i.e. the number of compounds per square millimeter).

[0042] {Table 1}

Table 1

No.	Co	Si	Other elements	Ingot cooling speed	Sol. temp.	Process	Aging temp.	Aging time	GS	Density Comp. A	Density Comp. B, C,D	(B+C+D) /A	TS	EC	Bending property
	mass%			°C/h	°C		°C	h	µm	/mm^2	/mm^2		MPa	%IACS	R/t
1	0.51	0.153	Cr=0.1	28	760	A	530	2	19	3.5E+08	3.2E+05	0.00091	588	69	0
2	0.98	0.266	Sn=0.1, Mg=0.1, Ni=0.2	32	830	A	555	3	18	7.8E+08	2.1 E+05	0.00027	654	70	0.75
3	1.208	0.307	Fe=0.15, Zr=0.1	28	930	B	530	2	20	1.2E+09	2.3E+06	0.00192	701	60	1.5
4	1.887	0.456	Sn=0.1, Mg=0.1, Ni=0.2	42	950	A	540	2	12	6.2E+09	6.4E+06	0.00103	711	55	1.5
5	0.78	0.177	Sn=0.15, Mg=0.2	81	780	A	540	3	10	4.4E+08	4.0E+06	0.00909	590	71	0
6	0.98	0.231	Sn=0.2, Fe=0.3	27	850	A	565	3	19	3.2E+09	2.9E+06	0.00091	643	69	0.5
7						B	530	3		1.9E+09	1.4E+06	0.00074	639	74	0.5
8	1.193	0.279	Mg=0.1, Sn=0.2	26	950	A	560	3	18	2.9E+08	9.0E+06	0.03103	605	65	0
9						B	510	3		3.4E+09	3.0E+06	0.00088	604	66	0
10	1.575	0.386	Mn=0.06, Ti=0.1	42	950	A	580	2	28	7.4E+09	7.0E+06	0.00095	648	64	0.5
11	1.987	0.491	Zn=0.2, Sn=0.05	37	950	B	530	2	14	9.1 E+09	9.2E+06	0.00101	729	53	1
12	0.957	0.229	Fe=0.25	52	750	A	580	4	13	2.4E+09	2.0E+06	0.00083	590	75	0
13	0.955	0.227	Cr=0.25, Mn=0.1	28	900	A	570	2	13	3.5E+09	3.7E+06	0.00106	665	63	0.75
14						B	530	2		4.5E+09	5.0E+06	0.00111	665	61	1
15	1.175	0.279		27	925	A	580	4	10	7.8E+08	8.8E+05	0.00113	649	64	0.5
16						B	530	4		1.2E+09	1.0E+06	0.00083	653	60	0.75

(continued)

No.	Co	Si	Other elements	Ingot cooling speed	Sol. temp.	Process	Aging temp.	Aging time	GS	Density Comp. A	Density Comp. B, C,D	(B+C+D) /A	TS	EC	Bending property
	mass%			°C/h	°C		°C	h	μm	/mm^2	/mm^2		MPa	%IACS	R/t
17	0.92	0.33	Mg=0.1, Ni=0.5	30	880	A	550	2	12	2.2E+09	1.4E+06	0.00064	612	61	0
18	0.95	0.42	Mg=0.15, Ni=0.8	44	870	B	525	2	16	2.4E+08	1.0E+06	0.00417	622	59	0
19	1.4	0.48	Mg=0.1, Ni=0.5	58	945	A	550	2	18	6.2E+09	4.9E+06	0.00079	734	58	1
20	1.38	0.52	Mg=0.2, Ni=0.8	65	950	A	550	2	20	7.9E+09	6.4E+06	0.00081	723	57	1
21						B	525	2		4.9E+08	3.0E+06	0.00612	745	55	1
22	1.432	0.364	Sn=0.1, Mg=0.2	31	950	A	580	2	7	6.7E+09	7.7E+06	0.00115	659	66	0.75
23	1.742	0.444	Cr=0.4, Ni=0.3	63	950	A	530	5	9	7.7E+09	7.8E+06	0.00101	722	53	2
24	0.641	0.152	Zn=0.5, Cr=0.2, Ag=0.1	63	780	A	545	3	9	3.2E+08	3.0E+05	0.00094	565	73	0
25						B	510	3		1.8E+08	2.0E+06	0.01111	572	75	0.5
26	0.902	0.25		72	800	B	485	4	12	5.2E+08	7.0E+06	0.01346	610	64	0
27	0.887	0.2	Mg=0.1, Ni=0.5, Sn=0.2	73	810	A	560	2	12	8.7E+08	6.6E+05	0.00076	612	65	0
28						A		4		6.7E+08	2.8E+06	0.00418	565	73	0
29						B	515	2		3.3E+09	2.9E+06	0.00088	565	63	0
30	1.2	0.35	Sn=0.2, Fe=0.1, Al=0.1	73	830	A	535	2	17	5.4E+08	4.9E+05	0.00091	675	65	0.5
31						A		5		5.3E+08	3.3E+05	0.00062	671	69	1
32						B	485	3		1.8E+09	1.9E+06	0.00106	659	72	1
33	1.45	0.38	Sn=0.1, Zn=0.5, Ni=0.1	63	850	A	570	2	13	2.2E+08	2.0E+05	0.00091	723	73	1.5
34						B	510	3		2.9E+09	2.8E+06	0.00097	731	66	1.75

(continued)

No.	Co	Si	Other elements	Ingot cooling speed	Sol. temp.	Process	Aging temp.	Aging time	GS	Density Comp. A	Density Comp. B, C,D	(B+C+D) /A	TS	EC	Bending property
	mass%			°C/h	°C		°C	h	μm	/mm^2	/mm^2		MPa	%IACS	R/t
35	1.44	0.35	Mg=0.1, Ni=0.5, Cr=0.1	34	850	A	565	2	9	8.2E+08	8.9E+05	0.00109	729	53	1.5

[0043] {Table 2}

Table 2

No.	Co	Si	Other elements	Ingot cooling speed	Sol. temp.	Process	Aging temp.	Aging time	GS	Density Comp. A	Density Comp. B, C, D	(B+C+D) /A	TS	EC	Bending property
	mass%			°C/h	°C		°C	h	µm	/mm^2	/mm^2		MPa	%IACS	R/t
101	*0.38*	*0.08*	Cr=0.1	83	770	A	530	3	28	3.3E+07	2.0E+05	0.00606	*461*	76	0.5
102	*2.2*	*0.52*	Zn=0.5, Sn=0.2, Fe=0.1	44	990	A	540	2	29	4.5E+10	3.3E+09	0.07333	833	*48*	*3.5*
103	0.824	0.238	Ni=0.3	83	*1000*	A	560	2	*55*	2.5E+09	6.8E+07	0.02720	687	61	*2.5*
104	1.02	0.212	Ag=0.3	63	*750*	B	550	4	*Mixed grain*	3.5E+08	2.0E+06	0.00571	687	63	*2.5*
105	0.928	0.267		*128*	900	A	580	3	39	3.7E+08	*3.0E+04*	*0.00008*	*591*	60	*2*
106	1.4	0.3		*152*	910	B	510	2	37	3.9E+09	*3.0E+04*	*0.00001*	*594*	65	*2*
107	0.825	0.233	Fe=0.2	83	900	A	*400*	2	33	8.9E+07	2.0E+05	0.00225	*436*	*41*	0.5
108	0.928	0.211	Mn=0.1, Sn=0.2	32	920	A	*620*	4	29	*4.2E+03*	*4.0E+01*	0.00952	*464*	74	0.5
109	1.127	0.284	Cr=0.1, Mg=0.3	41	900	B	530	*0.5*	33	5.8E+07	5.0E+05	0.00862	*457*	*39*	0.75
110	0.854	0.227	Al=0.2	64	900	A	560	*0.5*	19	6.2E+07	7.0E+05	0.01129	*457*	*47*	0.75
111	0.905	0.205	Ag=0.05, Ni=0.2	53	920	B	530	*6*	23	9.2E+07	9.7E+06	0.10543	*458*	67	0
112	1.5	0.4		43	985	A	560	*5*	34	5.8E+07	1.2E+07	0.20690	*454*	62	0.25
113	0.507	0.127	*Sn=2.5*	73	800	A	560	4	23	3.7E+09	2.5E+06	0.00068	591	36	0.5
114	0.878	0.223	*Sn=1.4, Mg=1*	63	850	A	580	3		6.2E+09	6.9E+06	0.00111	678	*37*	0.5
115						B	530	2	19	5.8E+08	5.2E+07	0.08966	581	*40*	0.75
116	1.62	0.435	*Zn=0.03, Cr=0.03*	53	950	A	580	2	30	2.5E+09	*2.4E+04*	*0.00001*	663	54	2
117	1.905	0.505	*Zn=0.02, Sn=0.01*	43	950	B	530	3	27	6.3E+09	*6.8E+04*	*0.00001*	708	51	2.5

(continued)

No.	Co	Si	Other elements	Ingot cooling speed	Sol. temp.	Process	Aging temp.	Aging time	GS	Density Comp. A	Density Comp. B, C, D	(B+C+D) /A	TS	EC	Bending property
	mass%			°C/h	°C		°C	h	μm	$/mm^2$	$/mm^2$		MPa	%IACS	R/t
118	0.526	0.162	*Fe=2.4*	63	750	A	530	3	*Mixed grain*	8.2E+09	8.0E+07	0.00976	614	65	2.5
119	0.928	0.235	*Cr=2.1*	64	900	A	580	3	*Mixed*	2.9E+08	2.3E+06	0.00793	671	49	2.5
120						B	530	1	*grain*	7.2E+08	2.1 E+06	0.00292	591	59	2.5
121	1.206	0.278	*Ni=2.5, Sn=0.3*	63	900	A	580	4	23	6.7E+08	6.9E+07	0.10299	678	*42*	1
122						B	530	3		1.9E+08	9.1 E+05	0.00479	584	*41*	1.25
123	1.527	0.393	*Cr=0.05*	32	950	A	580	2	17	3.9E+08	*9.2E+03*	*0.00002*	649	50	*1.5*
124	1.301	0.321	*Cr=0.03, Ni=0.04*	32	950	A	560	4	38	9.4E+09	*4.4E+04*	*0.00000*	621	59	*1.5*
125	0.902	0.22	Sn=0.1, Mg=0.1	*3*	850	A	555	2	39	7.7E+07	7.9E+07	1.02597	*476*	54	0.5
126			Sn=0.15, Mg=0.2	*3*	880	B	510	2	44	7.8E+07	8.2E+07	1.05128	*488*	52	0.5
127	1.307	0.302	Sn=0.2, Zn=0.3	*232*	*Cracks occurred in the re-heating before hot-rolling, and it was impossible to conduct hot-rolling.*										
128			Mg=0.3	*183*	*Cracks occurred in the re-heating before hot-rolling, and it was impossible to conduct hot-rolling.*										

[0044] As shown in Table 1, each of Examples (inventive examples according to the present invention) satisfied all of mechanical strength, electrical conductivity, and bending property, each at a high level in a well-balanced manner. Specifically, the electrical conductivity (EC) was 50 %IACS or more, and in regard to the relationship between the tensile strength (TS) and the bending property (R/t), when TS was 550 MPa or more but less than 650 MPa, R/t ≤ 0.5; when TS was 650 MPa or more but less than 700 MPa, R/t ≤ 1; and when TS was 700 MPa or more but less than 800 MPa, R/t ≤ 2, thus, a good balance was achieved, with each of the properties being at a high level. On the contrary, in Comparative Examples shown in Table 2, at least any one of the properties of mechanical strength, electrical conductivity, and bending property was not practical. Among those, Sample Nos. 101, 107 to 112, and 125 to 126 of Comparative Examples had the tensile strengths of less than 500 MPa, which did not reach a practical level.

[0045] 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.

This application claims priority on Patent Application No. 2008-202467 filed in Japan on August 5, 2008, which is entirely herein incorporated by reference.

Claims

1. A copper alloy material for electric/electronic parts, comprising Co and Si as additive elements,
   wherein, in the copper alloy material, a compound A is dispersed, which is composed of Co and Si and which has an average particle diameter of 5 nm or more but less than 50 nm, and at least one compound is dispersed, in which said at least one compound is selected from the group consisting of a compound B which does not contain one of Co and Si or any of those and which has an average particle diameter from 50 nm to 500 nm, a compound C which contains both of Co and Si and another element and which has an average particle diameter from 50 nm to 500 nm, and a compound D which is composed of Co and Si and which has an average particle diameter from 50 nm to 500 nm,
   wherein a grain size of the copper alloy of the matrix is 3 to 35 μm, and wherein an electrical conductivity is 50 %IACS or more.

2. A copper alloy material for electric/electronic parts, comprising Co and Si as additive elements,
   wherein, a compound A which is composed of Co and Si and which has an average particle diameter of 5 nm or more but less than 50 nm, a compound B which does not contain one of Co and Si or any of those and which has an average particle diameter from 50 nm to 500 nm, a compound C which contains both of Co and Si and another element and which has an average particle diameter from 50 nm to 500 nm, and a compound D which is composed of Co and Si and which has an average particle diameter from 50 nm to 500 nm, are dispersed in the copper alloy material,
   wherein the ratio of dispersion densities of the compounds A, B, C, and D satisfies the relationship: $0.0001 \leq$ {(dispersion density of the compound B + dispersion density of the compound C + dispersion density of the compound D)/dispersion density of the compound A} ≤ 0.1,
   wherein a grain size of the copper alloy of the matrix is 3 to 35 μm, and wherein an electrical conductivity is 50 %IACS or more.

3. The copper alloy material for electric/electronic parts according to claim 1 or 2, further comprising at least one selected from Al, Ag, Sn, Zn, Mg, Mn, and In in an amount of 0.05 to 1.0 mass% in total, with the balance being Cu and unavoidable impurities.

4. The copper alloy material for electric/electronic parts according to any one of claims 1 to 3, further comprising at least one selected from Fe, Cr, Ni, Zr, and Ti in an amount of 0.05 to 1.0 mass% in total, with the balance being Cu and unavoidable impurities.

5. The copper alloy material for electric/electronic parts according to claim 1 or 2, comprising Co and Si as additive elements, with the balance being Cu and unavoidable impurities.

6. The copper alloy material for electric/electronic parts according to any one of claims 1 to 5, wherein the content of Co is 0.4 to 2.0 mass%, and the content of Si is 0.1 to 0.5 mass%.

7. The copper alloy material for electric/electronic parts according to any one of claims 1 to 6, wherein, in the production of an ingot, an average cooling speed from the solid state temperature to 500°C is 5 to 100°C/second.

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2009/063615

A. CLASSIFICATION OF SUBJECT MATTER
C22C9/06(2006.01)i, C22C9/00(2006.01)i, C22C9/01(2006.01)i, C22C9/02(2006.01)i, C22C9/04(2006.01)i, C22C9/05(2006.01)i, C22C9/10(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, C22F1/00, C22F1/08, H01B1/02

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 2008-88512 A (Nippon Mining & Metals Co., Ltd.), 17 April 2008 (17.04.2008), claims & WO 2008/041696 A1 & KR 10-2009-0050101 A & CN 101522927 A	1-7
A	JP 2008-56977 A (Mitsubishi Electric Corp., Mitsubishi Electric Metecs Co., Ltd.), 13 March 2008 (13.03.2008), claims & US 2008/0056930 A1 & DE 10 2007 040 822 A1	1-7

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

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
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"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search 13 October, 2009 (13.10.09)	Date of mailing of the international search report 20 October, 2009 (20.10.09)
Name and mailing address of the ISA/ Japanese Patent Office Facsimile No.	Authorized officer Telephone No.

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INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2009/063615

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 2006-274445 A (The Furukawa Electric Co., Ltd.), 12 October 2006 (12.10.2006), claims; paragraphs [0011] to [0014] & US 2008/0011396 A1 & EP 1862560 A1 & WO 2006/093233 A1 & CN 101124345 A	1-7
A	JP 2006-161148 A (The Furukawa Electric Co., Ltd.), 22 June 2006 (22.06.2006), claims; paragraphs [0017] to [0019] & US 2005/0236074 A1 & WO 2005/083137 A1 & DE 11 2005 000 312 T5 & KR 10-2006-0130183 A & CN 1926253 A	1-7

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- JP 2008056977 A **[0010]**
- JP 2006161148 A **[0010]**
- JP 2006265731 A **[0010]**
- JP 2007314847 A **[0010]**
- JP 2008075151 A **[0010]**
- JP 2008075152 A **[0010]**
- JP 2008202467 A **[0045]**