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(54) **COBALT SILICIDE-CONTAINING COPPER ALLOY**

(57) The present invention discloses copper alloy containing cobalt and silicon, which comprises (in percentage of weight): 69% to 92% of copper; 6.5% to 30.5% of zinc; 0.01% to 3% of cobalt; and 0.01% to 0.5% of silicon; characterized in that, the total content of copper and zinc is greater than 95%, and the content of inevitable impurities is less than 0.2%. Preferably, the copper alloy comprises matrix phases of copper-zinc  $\alpha$  solid solution and  $\text{Co}_x\text{Si}_y$  precipitated phases; the  $\text{Co}_x\text{Si}_y$  precipitated phases are dispersedly distributed on a matrix phase; the percentage of the matrix phases by area is greater than or equal to 95%; and, the percentage of the  $\text{Co}_x\text{Si}_y$  precipitated phases by area is 0.01% to 5%.

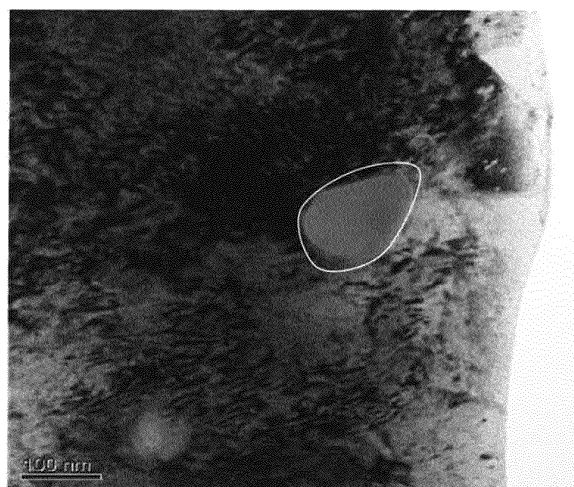


FIG.1

**Description****Technical Field of the Invention**

5     **[0001]** The present invention relates to the technical field of alloys, and in particular to a copper alloy containing cobalt and silicon.

**Background of the Invention**

10    **[0002]** Due to its good conductivity, corrosion resistance, and good hot and cold workability, brass is widely applied in various industries, and becomes indispensable metal material in the current era. However, since the copper resources are limited, the reserve of the resources decreases gradually with continuous exploitation. Copper alloys, with the advantages of high strength, high elasticity, fatigue resistance and corrosion resistance, represented by tin-phosphor bronze, are widely applied to connectors, terminals, relays, springs and switch elements in various fields such as medical, aviation, communication, automobiles, and electronic and electrical fields. However, since the tin-phosphor bronze belongs to bronze alloys having a high content of copper and even contains a high content of more expensive metal Sn, this product holds at a high price due to the cost of raw material. With the increasingly fierce competition, enterprises come into a small-profit situation where they urgently need to reduce the cost of various aspects to improve the profitability. For the enterprises in these industries, there is an urgent need to find low-cost and elastic material satisfying the application requirements to reduce the cost.

20    **[0003]** As a copper alloy containing copper and zinc as main components, the brass can be added with other alloy elements to form complex brass to satisfy different requirements. Due to its good processing property, mechanical property and corrosion performance, the brass alloy becomes one of the most widely used alloys among non-ferrous metals. Since the reserve of zinc is abundant and the cost of raw material is thus far lower than that of copper, the cost of raw material of the brass is generally lower than that of the bronze. In terms of both the reserve of resources and the profit of enterprises, it will be a great trend to replace the bronze with the brass by improving some performances of the brass by proper schemes so that the brass meets the requirements in more application fields.

25    **[0004]** In the current market, there have been several kinds of complex elastic brass material for substituting tin-phosphor bronze. However, there are still many problems in practical applications. Although the indexes such as tensile strength and yield strength have reached the application requirements of the elastic substitute material, due to the basic material properties, all the high-temperature resistance, creep resistance, service life and reliability are worse than those of phosphor bronze, and the service environment is limited. In addition, with the weight reduction and miniaturization of the devices used in these industries in recent years, higher requirements and challenges are proposed for the substitute material for the phosphor bronze or even the phosphor bronze itself. For example, for an elastic element, to realize miniaturization while maintaining the clamping force or resilience force meeting the application requirements, the only way is to increase the modulus of elasticity of the material. This index is determined by the basic properties of the material. The modulus of elasticity of the phosphor bronze is about 110 GPa; in contrast, the brass-type substitute material has a reduced modulus of elasticity of about 105 GPa due to the increase of the solid solution strengthening proportion, so that the brass-type substitute material cannot meet the requirements on miniaturization and weight reduction in the application fields of the elastic material. Secondly, to realize miniaturization and wall thinning, the material forming the devices is required to have a higher strength and a tradeoff between strength and ductility. It is well known that the strength and the plasticity are conflicted with each other. If the strength of the material is increased by cold-deformation work hardening, the ductility will be decreased, and the plastic processing capability of the material is thus reduced. Consequently, its applications will be limited. In addition, in some applications field where a high current and a highest service temperature are required, for example, a power supply connector requiring a higher conductivity, since the conductivity of the existing phosphor bronze is about 16% IACS, a substitute material with a higher conductivity is required objectively. However, for the existing substitute material, for example, tin brass, due to the cost and the mechanical property, the solid solution treatment of more alloy elements in a matrix phase will greatly limit the increase of the conductivity of the material, so that the conductivity can only reach about 20% IACS.

30    **[0005]** For example, at present, a kind of brass material for substituting tin-phosphor bronze, with Chinese Standard HSn70-1 and American Standard C44300, contains the following components: 70% to 73% of Cu, 0.9% to 1.2% of Sn and the remaining of Zn. By work hardening, the mechanical property can meet the application requirements on the material in the above industries, but its stress relaxation rate is less than 80% under an initial stress at a yield strength of 50% at 100°C for 1000 h, so that it is difficult to meet the requirements on durability.

35    **[0006]** For another example, Chinese Patent Application No. CN103088229A has disclosed a substitute material for tin-phosphor bronze, which reduces the cost by reducing the content of Sn. The substitute material for tin-phosphor bronze contains the following main components: 0.01% to 2.5% of Sn, 0.01% to 0.3% of P, 0.01% to 0.5% of Fe, 0.01% to 0.5% of Ni, 0.01% to 0.1% of Mn, and the remaining of Cu. The conductivity of this substitute material is only 10% to

16% IACS, so its application fields are limited. Moreover, the cost is not reduced greatly. Since the content of Cu is increased to above 97% while reducing the content of Sn, the overall cost is reduced by only 5% to 10%.

### Summary of the Invention

**[0007]** A technical problem to be solved by the present invention is to provide a copper alloy containing cobalt and silicon, which can significantly reduce the alloy cost and which has lower stress relaxation rate, higher creep resistance, higher yield-to-strength ratio, higher modulus of elasticity and better conductivity.

**[0008]** To solve the technical problem, the copper alloy containing cobalt and silicon comprises (in percentage of weight):

69% to 92% of copper;

6.5% to 30.5% of zinc;

0.01% to 3% of cobalt; and

0.01% to 0.5% of silicon;

characterized in that, the total content of copper and zinc is greater than 95%, and the content of inevitable impurities is less than 0.2%.

**[0009]** Preferably, the copper alloy comprises matrix phases of copper-zinc  $\alpha$  solid solution and  $\text{Co}_x\text{Si}_y$  precipitated phases; the  $\text{Co}_x\text{Si}_y$  precipitated phases are dispersedly distributed on a matrix phase; the percentage of the matrix phases by area is greater than or equal to 95%; and, the percentage of the  $\text{Co}_x\text{Si}_y$  precipitated phases by area is 0.01% to 5%.

**[0010]** Preferably, the percentage of the  $\text{Co}_x\text{Si}_y$  precipitated phases having a particle size between 10 nm and 200 nm is greater than or equal to 90%, and the percentage of the  $\text{Co}_x\text{Si}_y$  precipitated phases having a particle size above 200 nm is less than or equal to 10%.

**[0011]** Preferably, an atomic ratio of copper to zinc (Cu/Zn) is 2.3 to 15.8, and a mass fraction of copper and zinc satisfies  $0.65 \leq ([\text{Cu}]/3+1)/([\text{Zn}]+5) \leq 3.5$ .

**[0012]** Preferably, a yield strength/tensile strength of the copper alloy is greater than or equal to 85%; and a stress relaxation rate under an initial stress at a yield strength of 50% at 100°C for 1000 H is less than or equal to 15%.

**[0013]** Preferably, the copper alloy further comprises (in percentage of weight) at least one of 0.01% to 3.5% of Sn, 0.01% to 4.0% of Al and 0.01% to 3% of Ni.

**[0014]** Preferably, in the above schemes, the copper alloy further comprises (in percentage of weight) 0.01% to 0.35% of P.

**[0015]** Preferably, the copper alloy further comprises  $\text{Co}_m\text{P}_n$  precipitated phases, and a percentage of the  $\text{Co}_m\text{P}_n$  precipitated phases by area is 0.01% to 5%.

**[0016]** Preferably, in the above schemes, the copper alloy comprises A having a total content of 0.0001% to 2%, and the A is at least one selected from a group comprises (in percentage of weight) 0.01% to 1.5% of Mn, 0.01% to 1.5% of Fe, 0.001% to 0.3% of Cr, 0.001% to 0.2% of Zr, 0.001% to 0.5% of Mg, 0.001% to 0.8% of Ti, 0.0005% to 0.3% of B and 0.0001% to 0.1% of Re.

**[0017]** The copper and zinc have the following functions and proportions: Zn is solved into Cu to form a single-phase  $\alpha$  solid solution which plays a role of solid solution strengthening and forms a matrix for the alloy structure. The  $\alpha$  solid solution can be formed as long as the content of Zn is less than 38%, but the content of copper and the content of zinc need to satisfy a certain relationship. When the atomic ratio of copper to zinc is less than 2.3 and the mass ratio of copper to zinc is less than 0.68, i.e.,  $([\text{Cu}]/3+1)/([\text{Zn}]+5) < 0.68$ , due to excessive zinc solved into copper, the conductivity and the modulus of elasticity of the matrix become low, and the high-temperature resistance is degraded sharply, so that the requirements on current transmission, signal transmission, temperature rise in unit time, clamping force, durability and the like cannot be satisfied. When the atomic ratio Cu/Zn of copper to zinc is greater than 15.8 and the mass ratio of copper to zinc satisfies the condition  $([\text{Cu}]/3+1)/([\text{Zn}]+5) > 2.88$ , there are less lattice distortions caused by the solid solution treatment. Consequently, the solid solution formed by solving a cobalt-silicon compound into lattices by the solid solution treatment is less stable, and a saturated solid solution of the cobalt-silicon compound can be formed only by quick cooling at a high temperature. However, since the brass suffers serious oxidization and thus dezincification at a high temperature, the production requirements cannot be satisfied. In the present invention, by controlling the ratio and range of copper and zinc, the cobalt-silicon compound is allowed to still have a high solid solubility at 600°C. In this case, online water-cooling solid solution treatment can be directly performed to form a saturated solid solution. Thus, the conditions for further aging precipitation are satisfied, and the process interval is expanded. During the solid solution treatment procedure, no secondary solid solution treatment or fast cooling is required. For example, fast cooling with liquid nitrogen after hot rolling is required, as described in CN104232987A. Therefore, the resource consumption and the production cost are greatly reduced. Preferably, the atomic ratio of copper to zinc is 2.4 to 15, and the mass ratio of

copper to zinc satisfies the condition  $0.69 \leq ([Cu]/3+1)/([Zn]+5) \leq 2.76$ . In terms of mass fraction, the mass fraction of Cu is preferably 81% to 92%.

**[0018]** The cobalt and silicon have the following functions and proportions: when only Co is added, Co is solved into the matrix, so that the strength of the material is improved by the solid solution strengthening effect. The zinc equivalent coefficient of Si is 10, and the addition of a unit of Si is equivalent to the addition of 10 units of zinc. The  $\alpha$ -phase region is reduced while the  $\beta$  region is expanded. The solid solution strengthening will facilitate the formation of the harder  $\beta$  phase, so that the strength of the material is improved. The individual addition of the both will reduce the conductivity and modulus of elasticity of the material, and thus cannot improve the elasticity and durability of the material. By adding both Co and Si, a cobalt-silicon intermetallic compound can be formed. By a solid solution aging process, the compound is precipitated and dispersedly distributed on the matrix. As a result, Co and Si to be solved into the matrix phase to reduce the conductivity are left out of the matrix, and the conductivity of the material is thus improved. When a plastic deformation occurs at a temperature lower than the recrystallization temperature, the fine precipitated phases dispersedly distributed on the matrix phase can hinder the slippage of lattices and the movement of dislocations to thus form more dislocations and dislocation pileups, i.e., to form Cottrell air masses, so that the material has a higher strength and a larger ratio of the yield strength to the tensile strength than the addition of only Co. Due to the hindering to lattice distortion and the pinning effect on dislocations, the fine precipitated phases dispersedly distributed on the matrix phase makes the material require a higher stress during elastic deformation, that is, the modulus of elasticity of the material is improved. Similarly, the difficulty of having plastic deformation within the elastic deformation range of the material and at a relatively high temperature is increased, that is, the resistance to stress relaxation of the material is improved. If the content of Co exceeds 3 wt%, the hot workability of the material will be degraded; and, if the content of Co is less than 0.01 wt%, it is unable to form sufficient precipitated phases to improve the material performance. If the content of Si exceeds 0.5%, hot shortness of the material will be caused, and the conductivity will be reduced greatly; and, if the content of Si is less than 0.01 wt%, it is unable to form sufficient precipitated phases to improve the material performance.

**[0019]** The microstructure of the copper alloy has the following characteristics: the  $\alpha$ -phase formed by the copper-zinc solid solution is the matrix phase and has a percentage by area greater than or equal to 95%; and the  $Co_xSi_y$  intermetallic compound formed by cobalt and silicon is dispersedly distributed on the matrix and has a percentage of 0.01% to 5% by area. Since the cobalt-silicon intermetallic compound has a nanometer-level particle size, pictures of the microstructure need to be taken by a scanning electron microscope or a transmission electron microscope, and its percentage by area is then calculated. The type of the  $Co_xSi_y$  intermetallic compound is identified by EDS energy spectrum analysis mated with the scanning electron microscope or transmission electron microscope, and then described by a value of  $x/y$ , where  $x/y$  is between 0.2 and 3. When the value of  $x/y$  is greater than 3 or less than 0.2, the precipitated phase has limited effects on the improvement of the material performance. Preferably, for the compound, the  $x/y$  is between 0.5 and 2. If the percentage of the precipitated phases by area is less than 0.01%, the improvement on various performances of the material is limited; and, if the percentage of the precipitated phases by area is greater than 5%, various performances begin to be degraded, and the precipitated phase tends to grow by aggregation so that the improvement on metal performances is weakened. Preferably, the percentage of the precipitated phases is 0.05% to 4%, and the percentage of the  $\alpha$ -phase is greater than or equal to 96%. More preferably, the percentage of the precipitated phases is 0.1% to 3.5%, and the percentage of the  $\alpha$ -phases is greater than or equal to 96.5%.

**[0020]** In the structure of the copper alloy, the percentage of the  $Co_xSi_y$  precipitated phases having a particle size between 10 nm and 200 nm is greater than 90%, and the remaining has a particle size above 200 nm. If the particle size is smaller, the effects of hindering the slippage of lattices and pinning dislocations are stronger during the plastic deformation of the metal at a temperature lower than the recrystallization temperature, so that more dislocations and dislocation pileups are formed, and the material is thus allowed to have a higher strength and a larger yield-to-strength ratio. Similarly, during the elastic deformation, if the stress resulting in the elastic deformation of the material is larger, the material is allowed to have a higher modulus of elasticity and better high-temperature durability. Meanwhile, if the particle size of the precipitated phases is smaller, the obstruction to electron transmission is lower, and the material is allowed to have higher conductivity. Preferably, the percentage of the precipitated phases having a particle size between 10 nm and 200 nm is greater than 92%. More preferably, the percentage of the precipitated phases having a particle size between 10 nm and 200 nm is greater than 95%.

**[0021]** In the applications of the elastic material, the most concerned points are the elasticity and the endurance of elasticity. The elasticity is mainly related to the yield strength/tensile strength ratio and the modulus of elasticity of the material. The yield strength of the material is absolutely lower than the tensile strength. If the applied stress exceeds the yield strength, plastic deformation occurs. If the tensile strength is higher, the amount of plastic deformation endurable for the material before fracture failure is larger; if the yield strength is higher, the maximum endurable elastic deformation is larger; and, if the modulus of elasticity is larger, a larger resilience force can be obtained under a same elastic displacement. Therefore, for a same kind of material, to allow the material to have better elasticity, it is required to obtain a yield strength/tensile strength and a modulus of elasticity as high as possible.

**[0022]** In the copper alloy containing cobalt and silicon of the present invention, since the fine precipitated phases of

$\text{Co}_x\text{Si}_y$  intermetallic compound are dispersedly distributed on the copper-zinc matrix phase, firstly, the matrix is strengthened, and the tensile strength and yield strength of the material are improved; and secondly, during the plastic deformation of the material, the slippage of lattices and the movement of dislocations can be hindered so that more dislocations and dislocation pileups are generated, and these dislocations and dislocation pileups allow the material to have a higher yield strength, i.e., to have a higher yield strength/tensile strength ratio. In addition, due to the hindering to lattice distortion and the pinning effect on dislocations, the fine precipitated phases of  $\text{Co}_x\text{Si}_y$  intermetallic compound dispersedly distributed on the matrix phase makes the material require a higher stress during elastic deformation, so that the modulus of elasticity of the material is improved. In the copper alloy containing cobalt and silicon of the present invention, the yield strength/tensile strength ratio is greater than 85%, preferably greater than 88%, and more preferably greater than 92%.

**[0023]** The endurance of elasticity refers to the capability of keeping sufficient clamping force when a lasting external stress is applied to the material, particularly at a high temperature ( $>80^\circ\text{C}$ ). In the materialogy, the endurance of elasticity is described by the stress relaxation rate. To describe this characteristic, the following three conditions need to be determined: the initially applied stress value which is commonly described by the percentage of the yield strength, the test temperature, and the test duration. The stress relaxation performance of the material is essentially an integral of creep deformation lower than the yield strength. When tests are performed under the three specific conditions, the reduction rate of the yield strength is the stress relaxation rate. A lower stress relaxation rate indicates better endurance of elasticity of the material.

**[0024]** In the copper alloy containing cobalt and silicon of the present invention, since the fine precipitated phases of  $\text{Co}_x\text{Si}_y$  intermetallic compound are dispersedly distributed on the copper-zinc matrix phase, during the continuous plastic deformation of the material, the creep deformation and dislocation of crystal boundaries and lattices and the spread of dislocation pileups are hindered and relieved, and dislocations in different directions are merged and then disappear. Accordingly, the stress relaxation rate of the material is reduced, and the endurance of elasticity of the material is improved. Endurance tests are performed on the alloy under an initial stress at a yield strength of 50% at  $100^\circ\text{C}$  for 1000 h, and the stress relaxation rate is less than or equal to 15%, preferably less than or equal to 12%, and more preferably less than or equal to 10%.

**[0025]** The tin has the following functions and proportion. The copper alloy can further comprise Sn having a percentage of 0.01% to 3.5% by mass. The Sn can further stabilize the solid solution state of the cobalt-silicon intermetallic compound, inhibit the rapid precipitation of the precipitated phases at a high temperature, and thus reduce the percentage of the precipitated phases having a particle size above 200 nm. In addition, the Sn can further improve the strength and hardness of the material through the solid solution strengthening effect. The tin can further inhibit the dezincification, and thus improve the corrosion resistance of the material. The tin can further improve the hot dipping and electroplating performance and the brazing performance of the material. If the content of Sn is less than 0.01%, the above functions cannot be realized. However, if the content of Sn is higher than 3.5%, segregation of Sn will be caused. As a result, the compositions of the material are not uniform and the performance is thus not uniform. Moreover, the cracking risk during hot working is increased. The content of Sn (in percentage of weight) is preferably 0.05% to 3.0%, and more preferably 0.1% to 2.5%.

**[0026]** The aluminum and nickel have the following functions and proportions: the copper alloy can further comprise at least one of Al and Ni, characterized in that, the percentage of Al is 0.01% to 4.0% by mass, and the percentage of Ni is 0.01 wt% to 3 wt% by mass. Both Ni and Al can improve the heat resistance and hot workability of the material, and also have the solid solution strengthening effect and improve the corrosion resistance of the material. In addition, Ni and Al can inhibit the growth of the cobalt-silicon intermetallic compound during the aging process, so that the percentage of the cobalt-silicon intermetallic compound having a particle size between 10 nm and 150 nm is increased. In addition, Ni can form Ni-Si precipitated phases together with Si. As a result, the matrix is further strengthened, the conductivity is improved, the modulus of elasticity is increased, and the endurance of elasticity and the clamping force of the material are improved. If the content of Ni and of Al is less than 0.01%, the above functions cannot be realized. However, if the content of Ni is greater than 3% and the content of Al is greater than 4%, the conductivity will be reduced greatly, and the modulus of elasticity will be decreased. Preferably, the percentage of Ni is 0.01% to 2.5% by mass, and the percentage of Al is 0.05% to 3.5% by mass. More preferably, the percentage of Ni is 0.02% to 2.0% by mass, and the percentage of Al is 0.1% to 3.0% by mass.

**[0027]** The phosphorus has the following functions and proportion: the copper alloy can further comprise P having a percentage of 0.01% to 0.35% by mass. The P, together with Co, can also form an intermetallic compound  $\text{Co}_m\text{P}_n$ , which can be precipitated. In this case, the microstructure has the following characteristics: the copper-zinc  $\alpha$ -phase forms the matrix, and the  $\text{Co}_x\text{Si}_y$  precipitated phases and the  $\text{Co}_m\text{P}_n$  precipitated phases coexist and are dispersedly distributed on the matrix phase, characterized in that, the percentage of the  $\alpha$ -phases by area is greater than or equal to 90%, the percentage of the  $\text{Co}_x\text{Si}_y$  precipitated phases by area is 0.01% to 5%, and the percentage of the  $\text{Co}_m\text{P}_n$  precipitated phases by area is 0.01% to 5%. Since the cobalt-phosphorus intermetallic compound is distributed on the matrix, the growth rate of the cobalt-silicon intermetallic compound during the aging process can be effectively relieved, and the

particles become smaller. Consequently, the dispersion uniformity of the cobalt-silicon intermetallic compound on the matrix is improved, and the effects of improving the mechanical property, conductivity and high-temperature durability of the material are enhanced. If the content of P is greater than 0.35%, hot shortness of the material will be caused, and the conductivity will be reduced greatly; and, if the content of P is less than 0.01 wt%, it is unable to form sufficient precipitated phases to improve the material performance. The content of P is preferably 0.01% to 0.30%, and more preferably 0.01% to 0.25%.

**[0028]** The copper alloy can further comprise at least one of A, and the A is selected from a group comprises (in percentage of weight): 0.01% to 1.5% of Mn, 0.01% to 1.5% of Fe, 0.001% to 0.3 of Cr, 0.001% to 0.2% of Zr, 0.001% to 0.5% of Mg, 0.001% to 0.8% of Ti, 0.0005% to 0.3% of B, and 0.0001% to 0.1% of Re.

**[0029]** The manganese and iron have the following proportions and functions. Mn and Fe can effectively improve the distribution of the  $\text{Co}_x\text{Si}_y$  precipitated phases, so that the distribution thereof is more uniform and the dispersity is better. Consequently, the effects of the precipitated phases are enhanced. Mn can further realize deoxidization during the smelting process so as to improve the purity of the metal, and can further improve the hot workability of the material. Both Mn and Fe have the solid solution strengthening effect, and can improve the basic mechanical property of the material and decrease the modulus of elasticity of the material. If the content of Mn and of Fe is less than 0.01%, the above functions cannot be realized. However, if the content of Mn is greater than 1.5% and the content of Fe is greater than 1.5%, the conductivity will be reduced greatly, and the modulus of elasticity will be decreased, so that the application requirements of this material cannot be satisfied. Meanwhile, if the content of Fe is greater than 1.5%, the corrosion resistance of the material will be reduced greatly. Preferably, the content of Mn is 0.05% to 1.3%, and the content of Fe is 0.02% to 1.2%. More preferably, the content of Mn is 0.08% to 1.0%, and the content of Fe is 0.05% to 1.0%.

**[0030]** The chromium, zirconium and titanium have the following proportions and functions: in the hot working and solid solution treatment procedures, the copper alloy in the schemes will generate a small amount of strip-shaped cobalt-silicon compound precipitates, and the strip-shaped compound phase will degrade the performance of the metal. The addition of Cr, Zr and Ti can inhibit the formation of this morphological compound. In addition, both Cr and Zr can increase the softening temperature and high-temperature strength of the material, improve the high-temperature stability of the material, and reduce the stress relaxation rate of the material. By adding both Cr and Zr, a  $\text{Cr}_2\text{Zr}$  compound can be formed. Accordingly, the improvement effect is better than that in a case where only one of them is added, and the resistance to bonding and the welding performance of the material can also be improved. Ti can also improve the corrosion performance of the material. If the content of Cr is less than 0.001%, the content of Zr is less than 0.001% and the content of Ti (in percentage of weight) is less than 0.001%, the corresponding functions cannot be realized. However, if the content of Ti is greater than 0.8%, the conductivity of the material will be greatly reduced; meanwhile, if the content of Ti is greater than 0.8%, the content of Cr is greater than 0.3% and the content of Zr is greater than 0.2%, the production cost of the material and the cost of raw material will be increased greatly. Preferably, the content of Cr (in percentage of weight) is 0.005% to 0.25%, the content of Zr is 0.005% to 0.15%, and the content of Ti is 0.005% to 0.6%. More preferably, the content of Cr (in percentage of weight) is 0.008% to 0.20%, the content of Zr (in percentage of weight) is 0.008% to 0.10%, and the content of Ti is (in percentage of weight) 0.008% to 0.5%.

**[0031]** The boron, magnesium and rare earth have the following proportions and functions: all B, Mg and Re can inhibit crystal boundary reactions, decrease the number of the  $\text{Co}_x\text{Si}_y$  precipitated phases on the crystal boundary, reduce the hardness of the copper alloy after the solid solution treatment, and improve the subsequent cold workability. B can further improve the anti-dezincification capability of the brass and thus improve the corrosion resistance. B and Mg can further increase the resistance to stress relaxation of the material, and improve the cold and hot workability of the material. Re can realize the removal of impurities and deoxygenation during the smelting, so that the purity of metal is improved. Due to its high melting point, the rare earth can be used as a core of crystalline during the smelting. As a result, the content of columnar crystals in the cast ingot is decreased, the content of isometric crystals is increased, and the hot workability of the material is improved. If the content of the rare earth is less than (in percentage of weight) 0.0002%, the above functions cannot be realized. If the content of the rare earth exceeds (in percentage of weight) 0.1 t%, high-temperature oxide impurities will be formed, and the performance of metal will be degraded. Preferably, the content of B (in percentage of weight) is 0.001% to 0.2%, the content of Mg (in percentage of weight) is 0.005% to 0.3%, and the content of RE (in percentage of weight) is 0.0008% to 0.08%. More preferably, the content of B (in percentage of weight) is 0.002% to 0.15%, the content of Mg (in percentage of weight) is 0.01% to 0.2%, and the content of RE (in percentage of weight) is 0.001% to 0.05%.

**[0032]** According to different application requirements, the copper alloy can be processed into plates and strips, bars or wire rods.

**[0033]** Preparation methods for plates and strips successively include the following steps.

Method 1: Preparing material→smelting→vertical semi-continuous ingot casting→heating and rolling→solid solution treatment→milling→primary cold rolling→first-stage aging heat treatment→cleaning→secondary cold rolling→second-stage aging heat treatment→cleaning→cold rolling before formation→stress-relief aging heat treatment on

finished products→cleaning→striping→packaging.

Characterized in that, the temperature for smelting is 1080°C to 1280°C, the temperature for vertical semi-continuous casting is 1060°C to 1260°C, the initial rolling temperature at the beginning of heating and rolling is 700°C to 900°C, the final rolling temperature is not lower than 600°C, and the working rate of hot rolling is 60% to 95%. The solid solution treatment is online cooling after the hot rolling, where the cooling medium is air or water and the cooling rate is 10°C/min to 150°C/S.

Or, method 2: preparing materials→smelting→horizontal continuous casting→solid solution treatment→milling→primary cold rolling→first-stage aging heat treatment→cleaning→secondary cold rolling→second-stage aging heat treatment→cleaning→cold rolling before formation→stress-relief aging heat treatment on finished products→cleaning→striping→packaging.

The temperature for horizontal continuous casting and smelting is 1080°C to 1280°C, and the temperature for horizontal continuous casting is 1050°C to 1250°C. The solid solution treatment is online cooling after the casting, where the cooling medium is air or water and the cooling rate is 10°C/min to 150°C/S.

In the methods 1 and 2, in the production method of strips, the working rate of the primary cold rolling, the secondary cold rolling and the cold rolling before formation is 5% to 95%; the temperature for the first-stage aging heat treatment is 350°C to 650°C, the temperature holding time is 10 min to 10 h, the heating rate is 2°C/min to 50°C/min, and the cooling rate is 5°C/min to 50°C/min; the temperature for the second-stage aging heat treatment is 300°C to 600°C, the temperature holding time is 10 min to 10 h, the heating rate is 2°C/min to 50°C/min, and the cooling rate is 5°C/min to 50°C/min; and, the temperature for the stress-relief aging heat treatment on finished products is 100°C to 300°C, the temperature holding time is 10 min to 10 h, the heating rate is 2°C/min to 50°C/min, and the cooling rate is 5°C/min to 50°C/min. The number of the combined processes of the cold rolling and the aging heat treatment can be increased or decreased according to different product specifications and performances, but is at least ensured to be more than two. In the production method of strips, the aging heat treatment can be performed online at a temperature of 200°C to 750°C and a speed of 20 m/min to 250 m/min.

Method 3: Preparing materials→smelting→vertical semi-continuous casting or horizontal continuous casting→heating and extruding→solid solution treatment→primary drawing→first-stage aging heat treatment→secondary drawing→second-stage aging heat treatment→drawing before formation→stress-relief aging heat treatment on finished products→straightening→sizing→packaging.

Characterized in that, the temperature for smelting is 1080°C to 1280°C, the temperature for vertical semi-continuous casting is 1060°C to 1260°C, the temperature for horizontal continuous casting is 1050°C to 1250°C, and the temperature for extruding is 650°C to 900°C. The solid solution treatment is online cooling after extrusion, where the cooling medium is air or water and the cooling rate is 10°C/min to 150°C/S. The working rate of the primary drawing, the secondary drawing and the drawing before formation is 3% to 80%. The temperature for the first-stage aging heat treatment is 350°C to 650°C, the temperature holding time is 10 min to 10 h, the heating rate is 2°C/min to 50°C/min, and the cooling rate is 5°C/min to 50°C/min. The temperature for the second-stage aging heat treatment is 300°C to 600°C, the temperature holding time is 10 min to 10 h, the heating rate is 2°C/min to 50°C/min, and the cooling rate is 5°C/min to 50°C/min. The temperature for the stress-relief aging heat treatment on finished products is 100°C to 300°C, the temperature holding time is 10 min to 10 h, the heating rate is 2°C/min to 50°C/min, and the cooling rate is 5°C/min to 50°C/min. The number of the combined processes of the cold drawing and the aging heat treatment can be increased or decreased according to different product specifications and performances, but is at least ensured to be more than two.

Method 4: Preparing materials→smelting→vertical semi-continuous casting/ horizontal continuous casting→heating and extruding→solid solution treatment→primary inverse drawing→first-stage aging heat treatment→secondary inverse drawing→second-stage aging heat treatment→continuous drawing and aging heat treatment→packaging.

Characterized in that, the temperature for smelting is 1080°C to 1280°C, the temperature for vertical semi-continuous casting is 1060°C to 1260°C, the temperature for horizontal continuous casting is 1050°C to 1250°C, and the temperature for extruding is 650°C to 900°C. The solid solution treatment is cooling after extrusion, where the cooling medium is air or water and the cooling rate is 10°C/min to 150°C/S.

Method 5: Preparing materials→smelting→horizontal continuous casting/ continuous up casting→solid solution treatment→primary inverse drawing→first-stage aging heat treatment→secondary inverse drawing→second-stage aging heat treatment→continuous drawing and aging heat treatment→packaging.

**[0034]** Characterized in that, the temperature for smelting is 1080°C to 1280°C, the temperature for horizontal continuous casting is 1050°C to 1250°C, and the temperature for continuous up casting is 1060°C to 1260°C. The solid solution treatment is cooling after casting, where the cooling medium is air or water and the cooling rate is 10°C/min to 150°C/S.

**[0035]** In the methods 4 and 5, in the production method of wire rods, the working rate of the primary inverse drawing and the secondary inverse drawing is 5% to 60%, and one shaving process at a working rate of 1% to 3% can be added

to remove surface defects. The temperature for the first-stage aging heat treatment is 350°C to 650°C, the temperature holding time is 10 min to 10 h, the heating rate is 2°C/min to 50°C/min, and the cooling rate is 5°C/min to 50°C/min. The temperature for the second-stage aging heat treatment is 300°C to 600°C, the temperature holding time is 10 min to 10 h, the heating rate is 2°C/min to 50°C/min, and the cooling rate is 5°C/min to 50°C/min. The continuous drawing and aging heat treatment is successively performed by a large-sized continuous drawing and aging heat treatment machine, a middle-sized continuous drawing and aging heat treatment machine and a small-sized continuous drawing and aging heat treatment machine according to specifications for different stages of corridor billet. The finished products are processed by a small-sized continuous drawing and aging heat treatment machine.

**[0036]** In the preparation methods 1 to 5, the two-stage aging heat treatment processes play a key role in the performance of the finished products. The first-stage aging temperature is 350°C to 650°C, and the second-stage aging temperature is 300°C to 600°C. After primary cold working, the precipitation proportion and granularity of the precipitated phases are controlled by the first-stage aging heat treatment. After secondary cold working, the distribution pattern of the precipitated phases is controlled by the second-stage aging heat treatment. If the precipitated phase is precipitated more completely and has a smaller granularity and a more uniform distribution, various performances of the material are better. When the aging heat treatment is performed beyond the temperature range, it is unable to achieve the expected effects.

**[0037]** In conclusion, the copper alloy of the present invention has a larger value of yield strength/tensile strength and a larger modulus of elasticity, and thus has better elasticity and higher resilience clamping force. Furthermore, the copper alloy has a low stress relaxation rate, better resistance to stress relaxation and better endurance of elasticity. Moreover, the copper alloy has higher conductivity, good conduction performance when in use, large clamping force, less heat, good material formability and long service life.

### Brief Description of the Drawings

**[0038]**

Fig. 1 is a transmission electron microscope graph of a finished product according to Embodiment 74, with a magnification of 29000, where the phase within the white block is a  $\text{Co}_x\text{Si}_y$  precipitated phase;

Fig. 2 is a transmission electron microscope graph of a finished product according to Embodiment 82, with a magnification of 43000, where the phase within the white block is a  $\text{Co}_x\text{Si}_y$  precipitated phase;

Fig. 3 is a transmission electron microscope graph of a finished product according to Embodiment 80, with a magnification of 71000, where the phase within the white block is a  $\text{Co}_x\text{Si}_y$  precipitated phase;

Fig. 4 is a transmission electron microscope graph of a finished product according to Embodiment 81, with a magnification of 43000, where the phase within the white block is a  $\text{Co}_x\text{Si}_y$  precipitated phase; and

Fig. 5 is a scanning electron microscope graph of a finished product according to Embodiment 52, with a magnification of 10000, where a small area, which is whitened relative to the light color, shows a  $\text{Co}_x\text{Si}_y$  precipitated phase.

### Detailed Description of the Invention

**[0039]** To enable a further understanding of the present invention content of the invention herein, refer to the detailed description of the invention and the accompanying drawings below:

Scheme 1

**[0040]** This scheme includes comparison examples 1 and 2, and embodiments 3 to 12.

**[0041]** This scheme is applied to component tests for indicating the influence of the content and proportion of Cu and Zn on the performance of the copper alloy. Materials are prepared according to the designed composition. The raw materials comprise electrolytic copper, 0# zinc, metal cobalt, and intermediate copper-silicon alloy. Samples are obtained from the extruded blanks, and back-furnace components thereof are tested. As the test instrument, an Inductive Coupling Plasma spectrograph (ICP) is used. Materials in each group are casted and ingoted in a 10 Kg intermediate frequency furnace, then turned into  $\Phi 50$  extruded ingots, and finally extruded into  $\Phi 15$  blanks. The extruded blanks are cooled with water online. The following processing is successively performed on the extruded blanks: cold drawing at a working rate of 60%→aging heat treatment for 5 h at 550°C→cold drawing at a working rate of 30%→aging heat treatment for 4 h at 450°C→cold drawing at a working rate of 20%→heat treatment on finished products for 3 h at 280°C→cleaning. The finished products are machined into  $\Phi 7$  standard tensile samples. Tensile tests are performed on the samples on a 10-ton hydraulic drawing machine to test the tensile strength, yield strength, ductility and modulus of elasticity of the samples. The finished products are cut into a length of 80 cm, and then the conductivity of the finished products is measured by a bridge tester. The various data is shown in Table 1 and Continued Table 1.

Table 1

| Embodiment           | Element content<br>(wt%) |       |      |      | Mass ratio                          | Atomic ratio |
|----------------------|--------------------------|-------|------|------|-------------------------------------|--------------|
|                      | Cu                       | Zn    | Co   | Si   | $[(\text{Cu})/3+1]/[(\text{Zn})+5]$ | Cu/Zn        |
| Comparison example 1 | 66.28                    | 32.5  | 1.02 | 0.18 | 0.62                                | 2.1          |
| Comparison example 2 | 94.12                    | 4.66  | 0.95 | 0.21 | 3.35                                | 20.78        |
| 3                    | 69.11                    | 29.51 | 1.1  | 0.18 | 0.7                                 | 2.41         |
| 4                    | 72.14                    | 26.6  | 0.99 | 0.15 | 0.79                                | 2.79         |
| 5                    | 75.83                    | 22.99 | 0.98 | 0.16 | 0.94                                | 3.39         |
| 6                    | 78.22                    | 20.35 | 1.12 | 0.21 | 1.07                                | 3.95         |
| 7                    | 81.59                    | 17.11 | 1.04 | 0.16 | 1.28                                | 4.91         |
| 8                    | 84.22                    | 14.28 | 1.21 | 0.22 | 1.51                                | 6.07         |
| 9                    | 86.15                    | 12.44 | 1.17 | 0.16 | 1.7                                 | 7.12         |
| 10                   | 88.29                    | 10.55 | 0.89 | 0.13 | 1.96                                | 8.61         |
| 11                   | 90.15                    | 8.69  | 0.92 | 0.16 | 2.27                                | 10.67        |
| 12                   | 91.92                    | 6.7   | 1.05 | 0.25 | 2.7                                 | 14.11        |

Continued Table 1

| Embodiment           | Performance               |                         |                             |               |                       |
|----------------------|---------------------------|-------------------------|-----------------------------|---------------|-----------------------|
|                      | Tensile strength<br>(MPa) | Yield strength<br>(MPa) | Modulus of Elasticity (Gpa) | Ductility (%) | Conductivity (% IACS) |
| Comparison example 1 | 487                       | 438                     | 104                         | 15            | 15.8                  |
| Comparison example 2 | 492                       | 425                     | 113                         | 17            | 22.4                  |

|    |    |     |     |     |    |      |
|----|----|-----|-----|-----|----|------|
|    | 3  | 552 | 511 | 112 | 18 | 26.5 |
| 5  | 4  | 561 | 506 | 112 | 15 | 26.3 |
|    | 5  | 534 | 499 | 113 | 16 | 27.8 |
| 10 | 6  | 547 | 506 | 113 | 17 | 28.1 |
|    | 7  | 554 | 517 | 115 | 16 | 29.7 |
|    | 8  | 549 | 512 | 115 | 16 | 30.6 |
| 15 | 9  | 551 | 516 | 117 | 17 | 33.3 |
|    | 10 | 546 | 505 | 116 | 16 | 35.1 |
| 20 | 11 | 537 | 515 | 122 | 21 | 36.4 |
|    | 12 | 541 | 519 | 125 | 17 | 36.8 |

**[0042]** The Table 1 and the Continued Table 1 mainly indicate the influence of the mass relation and atomic ratio of Cu and Zn in the matrix on the related performances of the material. For example, in the comparison examples 1 and 2, the atomic ratio and the mass relation of copper and zinc are beyond the scope of the claims. In Embodiment 1, due to excessive Zn solved into the matrix, both the conductivity and the modulus of elasticity of the matrix are low, and the mechanical property is improved limitedly, so that the application requirements cannot be satisfied. In Embodiment 2, due to too little Zn solved into the matrix, there are less lattice distortions. As a result, the solid solution formed by solving the cobalt-silicon compound into lattices is less stable, and it is difficult to form a supersaturated solid solution under the online solid solution conditions. Accordingly, the conditions for dispersed precipitation of the cobalt-silicon phase cannot be satisfied, the conductivity of the material is low, and the modulus of elasticity and the mechanical property are improved limitedly, so that the application requirements cannot be satisfied. In Embodiments 3 to 12, the mass relation and the atomic ratio of Cu and Zn are within the scope of the claims. By comparison, various performances of the material are improved significantly, and both the conductivity and the mechanical property are effectively improved and obviously higher than those in the comparison examples.

#### Scheme 2

**[0043]** This scheme is applied to component tests, and includes Embodiments 13 to 23, as shown in Table 2, among which Embodiments 13 and 14 are comparison examples beyond the component scope claimed by the present patent, for indicating the hazards and results when the alloy element or its proportion are beyond the claimed range. To indicate the influence of the content and proportion of Co and Si on the performances of the copper alloy, materials are prepared according to the designed composition. The raw materials comprise electrolytic copper, 0# zinc, metal cobalt, and intermediate copper-silicon alloy. Samples are obtained from the extruded blanks, and back-furnace components are tested. As the test instrument, an Inductive Coupling Plasma spectrograph (ICP) is used. Materials in each group are casted and ingoted in a 10 Kg intermediate frequency furnace, then turned into  $\Phi 50$  extruded ingots, and finally extruded into  $\Phi 15$  blanks. The extruded blanks are cooled with water online. The following processing is successively performed on the extruded blanks: cold drawing at a working rate of 60%→aging heat treatment for 5 h at 550°C→cold drawing at a working rate of 30%→aging heat treatment for 4 h at 450°C→cold drawing at a working rate of 20%→heat treatment on finished products for 3 h at 280°C→cleaning. The finished products are machined into  $\Phi 7$  standard tensile samples. Tensile tests are performed on the samples on a 10-ton hydraulic drawing machine to test the tensile strength, yield strength, ductility and modulus of elasticity of the samples. The finished products are cut into a length of 80 cm, and then the conductivity of the finished products is measured by a bridge tester. Various data is shown in Table 2.

Table 2

| Embodi<br>ment           | Element content (wt%) |       |      |       | Performance                  |                            |                                      |                  |                          |
|--------------------------|-----------------------|-------|------|-------|------------------------------|----------------------------|--------------------------------------|------------------|--------------------------|
|                          | Cu                    | Zn    | Co   | Si    | Tensile<br>strength<br>(MPa) | Yield<br>strength<br>(MPa) | Modulus<br>of<br>elasticity<br>(Gpa) | Ductility<br>(%) | Conductivity<br>(% IACS) |
| Comparison<br>example 13 | 80.33                 | 15.99 | 3.05 | 0.55  | 609                          | 516                        | 109                                  | 15               | 23.4                     |
| Comparison<br>example 14 | 79.91                 | 16.88 | 3.18 | 0.008 | 571                          | 496                        | 105                                  | 14               | 15.7                     |
| 15                       | 80.25                 | 19.65 | 0.01 | 0.01  | 521                          | 482                        | 110                                  | 17               | 30.1                     |
| 16                       | 80.05                 | 19.69 | 0.11 | 0.05  | 529                          | 495                        | 113                                  | 18               | 29.1                     |
| 17                       | 80.06                 | 19.18 | 0.52 | 0.12  | 537                          | 501                        | 115                                  | 16               | 28.5                     |
| 18                       | 80.11                 | 18.57 | 1.04 | 0.22  | 559                          | 518                        | 115                                  | 16               | 28.9                     |
| 19                       | 79.95                 | 18.03 | 1.59 | 0.35  | 577                          | 532                        | 117                                  | 16               | 28.1                     |
| 20                       | 80.26                 | 17.17 | 2.01 | 0.45  | 594                          | 556                        | 117                                  | 15               | 27.5                     |
| 21                       | 80.02                 | 16.92 | 2.55 | 0.47  | 610                          | 572                        | 118                                  | 16               | 27.1                     |
| 22                       | 80.23                 | 16.25 | 2.97 | 0.49  | 623                          | 579                        | 118                                  | 16               | 26.4                     |

**[0044]** The Table 2 mainly indicates the influence of different changes in content of two alloy elements Co and Si on various basic performances of the material. It can be seen from the data in Embodiments 15 to 22 and comparison examples 13 and 14 that, in the present invention, the content of Co needs to be between 0.01% and 3%, and the content of silicon needs to be between 0.01% and 0.5%. If the content of any element is beyond this range, the comprehensive performance of the material cannot satisfy the requirements.

### Scheme 3

**[0045]** This scheme is used for indicating the influence of the proportion of phases in the microstructure of the copper alloy on the material performance, and includes Embodiments 23 to 32, as shown in Fig. 3, among which Embodiments 23 and 24 are comparison examples. The comparison examples are beyond the scope claimed by the present patent, and used for indicating the hazards and results when the microstructure of the copper alloy does not conform to the claimed scope. Materials are prepared according to the designed composition. The raw materials comprise electrolytic copper, 0# zinc, metal cobalt, and intermediate copper-silicon alloy. Samples are obtained from the extruded blanks, and back-furnace components are tested. As the test instrument, an Inductive Coupling Plasma spectrograph (ICP) is used. Materials in each group are casted and ingoted in a 10 Kg intermediate frequency furnace, then turned into  $\Phi 50$  extruded ingots, and finally extruded into  $\Phi 15$  blanks. The extruded blanks are cooled with water online. The following processing is successively performed on the extruded blanks: cold drawing at a working rate of 60%→aging heat treatment for 5 h at 550°C→cold drawing at a working rate of 30%→aging heat treatment for 4 h at 450°C→cold drawing at a working rate of 20%→heat treatment on finished products for 3 h at 280°C→cleaning. The finished products are machined into  $\Phi 7$  standard tensile samples. Tensile tests are performed on the samples on a 10-ton hydraulic drawing machine to test the tensile strength, yield strength, ductility and modulus of elasticity of the samples. The finished products are cut into a length of 80 cm, and then the conductivity of the finished products is measured by a bridge tester. The various data is shown in Table 3 and Continued Table 3.

Table 3

| Embodiment            | Element content (wt%) |       |      |       | Microstructure                    |                                                                |
|-----------------------|-----------------------|-------|------|-------|-----------------------------------|----------------------------------------------------------------|
|                       | Cu                    | Zn    | Co   | Si    | Proportion of $\alpha$ -phase (%) | Proportion of $\text{Co}_x\text{Si}_y$ precipitated phases (%) |
| Comparison example 23 | 85.04                 | 11.80 | 3.11 | 0.008 | 99.992                            | 0.008                                                          |
| Comparison example 24 | 85.09                 | 11.29 | 3.05 | 0.55  | 94.2                              | 5.5                                                            |
| 25                    | 85.11                 | 11.51 | 2.99 | 0.35  | 95.3                              | 4.7                                                            |
| 26                    | 85.06                 | 12.02 | 2.55 | 0.31  | 96                                | 4.0                                                            |
| 27                    | 84.97                 | 12.61 | 2.03 | 0.29  | 96.2                              | 3.8                                                            |
| 28                    | 84.85                 | 13.25 | 1.55 | 0.22  | 97.1                              | 2.9                                                            |
| 29                    | 85.12                 | 13.53 | 1.04 | 0.18  | 98                                | 2                                                              |
| 30                    | 85.15                 | 13.86 | 0.77 | 0.11  | 98.5                              | 1.5                                                            |
| 31                    | 85.01                 | 14.27 | 0.27 | 0.12  | 99.22                             | 0.78                                                           |
| 32                    | 85.06                 | 14.54 | 0.14 | 0.08  | 99.85                             | 0.11                                                           |

Continued Table 3

| Embodiment | Performance            |                      |                             |               |                       |
|------------|------------------------|----------------------|-----------------------------|---------------|-----------------------|
|            | Tensile strength (MPa) | Yield strength (MPa) | Modulus of elasticity (Gpa) | Ductility (%) | Conductivity (% IACS) |

|    |                          |     |     |     |    |      |
|----|--------------------------|-----|-----|-----|----|------|
| 5  | Comparison<br>example 23 | 469 | 352 | 106 | 18 | 16.8 |
| 10 | Comparison<br>example 24 | 471 | 388 | 105 | 11 | 23.1 |
|    | 25                       | 518 | 482 | 112 | 22 | 28.1 |
|    | 26                       | 539 | 505 | 116 | 19 | 30.1 |
| 15 | 27                       | 567 | 511 | 115 | 25 | 30.5 |
|    | 28                       | 579 | 541 | 116 | 23 | 32.2 |
| 20 | 29                       | 584 | 557 | 118 | 16 | 32.8 |
|    | 30                       | 571 | 548 | 119 | 18 | 33.9 |
|    | 31                       | 563 | 544 | 118 | 17 | 34.1 |
| 25 | 32                       | 551 | 529 | 116 | 16 | 34.5 |

30 **[0046]** Since the precipitated phase has a nanometer-level diameter, the proportion of the phase is evaluated on an SEM or TEM graph. The diameter of the precipitated phase is first measured, and the proportion is then determined. For the copper alloy containing cobalt and silicon of the present invention, the area of the precipitated phase is 0.01% to 5%. If the percentage of the precipitated phases by area is less than 0.01%, the improvement to various performances of the material is insufficient; however, if the percentage of the precipitated phases by area is greater than 5%, various performances will be degraded, and the precipitated phases tend to grow by aggregation, so that the effect in improving the metal performance is weakened. This conclusion can be obtained from Table 3.

#### Scheme 4

40 **[0047]** This scheme is used for indicating the influence of the size of the  $\text{Co}_x\text{Si}_y$  precipitated phase in the microstructure of the copper alloy on the material performance, and includes Embodiments 33 to 38, among which Embodiments 33 and 34 are comparison examples, and the percentage of the cobalt-silicon compound by size is beyond the scope claimed by the present patent and used for indicating the hazards and results when the microstructure of the copper alloy does not conform to the claimed scope. Materials are prepared according to the designed composition. The raw materials comprise electrolytic copper, 0# zinc, metal cobalt, and intermediate copper-silicon alloy. Samples are obtained from the extruded blanks, and back-furnace components are tested. As the test instrument, an Inductive Coupling Plasma spectrograph (ICP) is used. Materials in each group are casted and ingoted in a 10 Kg intermediate frequency furnace, then turned into  $\Phi 50$  extruded ingots, and finally extruded into  $\Phi 15$  blanks. The extruded blanks are cooled with water online. The following processing is successively performed on the extruded blanks: cold drawing at a working rate of 60%→first-stage aging heat treatment→cold drawing at a working rate of 30%→second-stage aging heat treatment→cold drawing at a working rate of 20%→heat treatment on finished products for 3 h at 280°C→cleaning. The finished products are machined into  $\Phi 7$  standard tensile samples. Tensile tests are performed on the samples on a 10-ton hydraulic drawing machine to test the tensile strength, yield strength, ductility and modulus of elasticity of the samples. The finished products are cut into a length of 80 cm, and then the conductivity of the finished products is measured by a bridge tester. In the processes, by adjusting the two-stage aging heat treatment processes, the particle size of the  $\text{Co}_x\text{Si}_y$  precipitated phase is changed. Various data is shown in Table 4.

Table 4

| Embodiment            | Element content (wt%) |       |      |      | Proportion of the Co <sub>x</sub> Si <sub>y</sub> precipitated phases having a diameter of 10 nm to 200 nm (%) | Performance            |                      |                             |               |                       |
|-----------------------|-----------------------|-------|------|------|----------------------------------------------------------------------------------------------------------------|------------------------|----------------------|-----------------------------|---------------|-----------------------|
|                       | Cu                    | Zn    | Co   | Si   |                                                                                                                | Tensile strength (MPa) | Yield strength (MPa) | Modulus of elasticity (Gpa) | Ductility (%) | Conductivity (% IACS) |
| Comparison example 33 | 70.17                 | 29.39 | 0.25 | 0.12 | 85                                                                                                             | 491                    | 405                  | 110                         | 8             | 19.6                  |
| Comparison example 34 | 90.26                 | 9.11  | 0.43 | 0.15 | 83                                                                                                             | 482                    | 401                  | 115                         | 11            | 24.9                  |
| 35                    | 70.17                 | 29.39 | 0.25 | 0.12 | 92                                                                                                             | 505                    | 488                  | 112                         | 12            | 22.5                  |
| 36                    | 70.17                 | 29.39 | 0.25 | 0.12 | 96                                                                                                             | 516                    | 491                  | 112                         | 15            | 22.9                  |
| 37                    | 90.26                 | 9.11  | 0.43 | 0.15 | 90                                                                                                             | 525                    | 490                  | 120                         | 13            | 31.5                  |
| 38                    | 90.26                 | 9.11  | 0.43 | 0.15 | 95                                                                                                             | 537                    | 512                  | 125                         | 16            | 32.9                  |

**[0048]** It can be seen from Table 4 that the comprehensive performance of the material is better if the proportion of the  $\text{Co}_x\text{Si}_y$  precipitated phases having a diameter of 10 nm to 200 nm is higher. To meet the requirements, the proportion of the  $\text{Co}_x\text{Si}_y$  precipitated phases within this size range needs to be greater than 90%, preferably greater than 92%, and more preferably greater than 95%.

#### Scheme 5

**[0049]** This scheme is used for indicating the influence of Sn on the compound precipitated phases having a diameter of above 200 nm in the microstructure of the copper alloy, and includes Embodiments 39 to 43, among which Embodiment 43 is a comparison example for indicating hazards and results when the content of Sn exceeds the claimed scope. Materials are prepared according to the designed composition. The raw materials comprise electrolytic copper, 0# zinc, metal cobalt, intermediate copper-silicon alloy and metal tin. Samples are obtained from the extruded blanks, and back-furnace components are tested. As the test instrument, an Inductive Coupling Plasma spectrograph (ICP) is used. Materials in each group are casted and ingoted in a 10 Kg intermediate frequency furnace, then turned into  $\Phi 50$  extruded ingots, and finally extruded into  $\Phi 15$  blanks. The extruded blanks are cooled with water online. The following processing is successively performed on the extruded blanks: cold drawing at a working rate of 60%→aging heat treatment for 5 h at 550°C→cold drawing at a working rate of 30%→aging heat treatment for 4 h at 450°C→cold drawing at a working rate of 20%→heat treatment on finished products for 3 h at 280°C→cleaning. The finished products are machined into  $\Phi 7$  standard tensile samples. Tensile tests are performed on the samples on a 10-ton hydraulic drawing machine to test the tensile strength, yield strength, ductility and modulus of elasticity of the samples. The finished products are cut into a length of 80 cm, and then the conductivity of the finished products is measured by a bridge tester. Various data is shown in Table 5.

Table 5

| Embodiment            | Element content (wt%) |       |      |      |      | The number of precipitated phases having a diameter of above 200 nm in a single field of view | Performance            |                      |                             |               |                       |
|-----------------------|-----------------------|-------|------|------|------|-----------------------------------------------------------------------------------------------|------------------------|----------------------|-----------------------------|---------------|-----------------------|
|                       | Cu                    | Zn    | Co   | Si   | Sn   |                                                                                               | Tensile strength (MPa) | Yield strength (MPa) | Modulus of elasticity (Gpa) | Ductility (%) | Conductivity (% IACS) |
| 39                    | 75.08                 | 29.39 | 0.52 | 0.15 | -    | 3                                                                                             | 529                    | 488                  | 113                         | 16            | 24.5                  |
| 40                    | 75.11                 | 9.11  | 0.51 | 0.14 | 0.05 | 2                                                                                             | 531                    | 494                  | 115                         | 15            | 23.5                  |
| 41                    | 75.02                 | 29.39 | 0.49 | 0.15 | 1.05 | 1                                                                                             | 559                    | 512                  | 115                         | 16            | 23.5                  |
| 42                    | 74.88                 | 29.39 | 0.51 | 0.16 | 2.91 | 0                                                                                             | 566                    | 547                  | 113                         | 15            | 16.2                  |
| Comparison example 43 | 74.93                 | 9.11  | 0.53 | 0.13 | 3.13 | 0                                                                                             | 575                    | 553                  | 111                         | 13            | 13.1                  |

**[0050]** It can be seen from Table 5 that the addition of Sn effectively decreases the number of  $\text{Co}_x\text{Si}_y$  precipitated phases having a particle size of above 200 nm within a single field of view; moreover, with the increase in the addition amount of Sn, the mechanical property of the material is improved significantly. It can be seen from the comparison example that a too high content of Sn will greatly reduce the conductivity, so that the application requirements cannot be satisfied.

#### Scheme 6

**[0051]** This scheme is used for indicating the influence of Ni and Al on the proportion of the compound precipitated phases having a diameter between 10 nm and 150 nm in the structure of the copper alloy, and includes Embodiments 44 to 50. Among those embodiments, Embodiments 49 and 50 are comparison examples for indicating hazards and results when the content of Ni and Al exceeds the claimed scope. Materials are prepared according to the designed composition. The raw materials comprise electrolytic copper, 0# zinc, metal cobalt, intermediate copper-silicon alloy, metal nickel, and metal aluminum. Samples are obtained from the extruded blanks, and back-furnace components are tested. As the test instrument, an Inductive Coupling Plasma spectrograph (ICP) is used. Materials in each group are casted and ingoted in a 10 Kg intermediate frequency furnace, then turned into  $\Phi 50$  extruded ingots, and finally extruded into  $\Phi 15$  blanks. The extruded blanks are cooled with water online. The following processing is successively performed on the extruded blanks: cold drawing at a working rate of 60%→aging heat treatment for 5 h at 550°C→cold drawing at a working rate of 30%→aging heat treatment for 4 h at 450°C→cold drawing at a working rate of 20%→heat treatment on finished products for 3 h at 280°C→cleaning. The finished products are machined into  $\Phi 7$  standard tensile samples. Tensile tests are performed on the samples on a 10-ton hydraulic drawing machine to test the tensile strength, yield strength, ductility and modulus of elasticity of the samples. The finished products are cut into a length of 80 cm, and then the conductivity of the finished products is measured by a bridge tester. Various data is shown in Table 6.

Table 6

| Embd iment             | Element content (wt%) |       |      |      |       |       | Proportion of the Co <sub>x</sub> Si <sub>y</sub> precipitated phases having a diameter between 10 nm and 150 nm (%) | Performance             |                      |                               |               |                       |
|------------------------|-----------------------|-------|------|------|-------|-------|----------------------------------------------------------------------------------------------------------------------|-------------------------|----------------------|-------------------------------|---------------|-----------------------|
|                        | Cu                    | Zn    | Co   | Si   | Ni    | Al    |                                                                                                                      | Tensile strength (MPa ) | Yield strength (MPa) | Mod ulus of elasticity (Gpa ) | Ductility (%) | Conductivity (% IACS) |
| 44                     | 79.88                 | 18.85 | 0.91 | 0.21 | 0.01  | 0.01  | 88                                                                                                                   | 558                     | 507                  | 115                           | 19            | 23.1                  |
| 45                     | 80.05                 | 16.91 | 0.91 | 0.19 | 0     | 1.88  | 91                                                                                                                   | 579                     | 524                  | 114                           | 18            | 16.5                  |
| 46                     | 80.11                 | 14.79 | 0.92 | 0.19 | 0.01  | 3.92  | 93                                                                                                                   | 615                     | 536                  | 112                           | 16            | 17.2                  |
| 47                     | 80.02                 | 17.25 | 0.88 | 0.18 | 1.59  | 0     | 90                                                                                                                   | 571                     | 518                  | 115                           | 17            | 20.1                  |
| 48                     | 80.08                 | 15.77 | 0.9  | 0.19 | 2.97  | 0.01  | 93                                                                                                                   | 599                     | 536                  | 113                           | 16            | 18.8                  |
| Comparison examille 49 | 80.04                 | 15.51 | 0.93 | 0.21 | 3.25  | 0.003 | 94                                                                                                                   | 615                     | 522                  | 110                           | 14            | 13.1                  |
| Comparison example 50  | 80.13                 | 14.34 | 0.89 | 0.19 | 0.008 | 4.33  | 95                                                                                                                   | 628                     | 531                  | 106                           | 13            | 12.5                  |

## Scheme 7

**[0052]** This scheme is used for indicating the influence of Mn, Fe and P on the dispersity of the  $\text{Co}_x\text{Si}_y$  precipitated phases in the structure of the copper alloy. The dispersity is evaluated by a variance of the distribution of the precipitated phases by the following method: a corresponding scanning electron microscope graph is divided into  $3 \times 3$  checkers, the number of the  $\text{Co}_x\text{Si}_y$  precipitated phases within each checker is counted, and an expectation and a variance are calculated. This scheme includes Embodiments 51 to 61. Among these embodiments, Embodiments 59, 60 and 61 are comparison examples for indicating hazards and results when the content of Mn, Fe and P exceeds the scope of the claims. Materials are prepared according to the designed composition. The raw materials comprise electrolytic copper, 0# zinc, metal cobalt, intermediate copper-silicon alloy, intermediate copper-phosphorus alloy, metal manganese, and metal aluminum. Samples are obtained from the extruded blanks, and back-furnace components are tested. As the test instrument, an Inductive Coupling Plasma spectrograph (ICP) is used. Materials in each group are casted and ingoted in a 10 Kg intermediate frequency furnace, then turned into  $\Phi 50$  extruded ingots, and finally extruded into  $\Phi 15$  blanks. The extruded blanks are cooled with water online. The following processing is successively performed on the extruded blanks: cold drawing at a working rate of 60%→aging heat treatment for 5 h at  $550^\circ\text{C}$ →cold drawing at a working rate of 30%→aging heat treatment for 4 h at  $450^\circ\text{C}$ →cold drawing at a working rate of 20%→heat treatment on finished products for 3 h at  $280^\circ\text{C}$ →cleaning. The finished products are machined into  $\Phi 7$  standard tensile samples. Tensile tests are performed on the samples on a 10-ton hydraulic drawing machine to test the tensile strength, yield strength, ductility and modulus of elasticity of the samples. The finished products are cut into a length of 80 cm, and then the conductivity of the finished products is measured by a bridge tester. The various data is shown in Table 7 and Continued Table 7.

Table 7

| Embodiment | Element content (wt%) |    |    |    |        | Variance of distribution of $\text{Co}_x\text{Si}_y$ |
|------------|-----------------------|----|----|----|--------|------------------------------------------------------|
|            | Cu                    | Zn | Co | Si | Others |                                                      |

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|                          |       |       |      |      |                      | precipitated<br>phases |
|--------------------------|-------|-------|------|------|----------------------|------------------------|
| 51                       | 87.96 | 11.01 | 0.71 | 0.25 | -                    | 2.025                  |
| 52                       | 88.06 | 10.92 | 0.73 | 0.23 | P: 0.02              | 1.982                  |
| 53                       | 88.07 | 10.65 | 0.69 | 0.21 | P: 0.33              | 1.116                  |
| 54                       | 88.02 | 10.99 | 0.70 | 0.23 | Mn: 0.01<br>Fe: 0.01 | 1.969                  |
| 55                       | 87.94 | 10.52 | 0.73 | 0.21 | Mn: 0.55             | 1.548                  |
| 56                       | 88.11 | 10.24 | 0.74 | 0.25 | Fe: 0.58             | 1.623                  |
| 57                       | 89.03 | 8.51  | 0.72 | 0.19 | Mn: 1.48<br>Fe: 0.01 | 0.937                  |
| 58                       | 89.05 | 8.48  | 0.73 | 0.22 | Fe: 1.43<br>Mn: 0.01 | 0.985                  |
| Comparison<br>example 59 | 89.12 | 9.49  | 0.74 | 0.18 | P: 0.42              | 1.029                  |
| Comparison<br>example 60 | 89.03 | 7.99  | 0.68 | 0.18 | Mn: 2.01             | 0.926                  |
| Comparison<br>example 61 | 89.01 | 7.98  | 0.71 | 0.24 | Fe: 1.58             | 0.919                  |

Continued Table 7

| Embodiment | Performance                  |                            |                                   |                  |                          |
|------------|------------------------------|----------------------------|-----------------------------------|------------------|--------------------------|
|            | Tensile<br>strength<br>(MPa) | Yield<br>strength<br>(MPa) | Modulus of<br>elasticity<br>(Gpa) | Ductility<br>(%) | Conductivity<br>(% IACS) |
| 51         | 551                          | 508                        | 119                               | 18               | 29.5                     |
| 52         | 559                          | 520                        | 120                               | 19               | 28.4                     |
| 53         | 575                          | 539                        | 121                               | 17               | 22.8                     |
| 54         | 569                          | 523                        | 122                               | 19               | 29.1                     |
| 55         | 581                          | 542                        | 119                               | 18               | 26.9                     |

|                          |     |     |     |                     |      |
|--------------------------|-----|-----|-----|---------------------|------|
| 56                       | 576 | 531 | 118 | 18                  | 24.7 |
| 57                       | 609 | 558 | 112 | 15                  | 19.5 |
| 58                       | 595 | 542 | 113 | 15                  | 18.3 |
| Comparison<br>example 59 | 533 | 499 | 105 | Brittle<br>fracture | 10.1 |
| Comparison<br>example 60 | 613 | 555 | 108 | 8                   | 13.2 |
| Comparison<br>example 61 | 622 | 561 | 107 | 7                   | 10.8 |

**[0053]** The uniformity of the distribution of the cobalt-silicon phases is described by the variance in Table 7 and the Continued Table 7. A smaller value of the variance indicates more uniform distribution of the cobalt-silicon phases and more improvements to the basic performances of the material by the cobalt-silicon phases. It can be seen from the tables that, with the addition of the several elements, the value of variance becomes smaller and the material performance becomes better. However, in the comparison examples, if the content of the elements exceeds the claimed scope, the conductivity is reduced greatly and the application requirements thus cannot be satisfied.

#### Scheme 8

**[0054]** This scheme is used for indicating the influence of the addition of Cr, Zr and Ti on the formation of strip-shaped cobalt-silicon compounds, by observing the number of the strip-shaped compounds in a corresponding scanning electron microscope graph. This scheme includes Embodiments 62 to 68. Materials are prepared according to the designed composition. The raw materials comprise electrolytic copper, 0# zinc, metal cobalt, intermediate copper-chromium alloy, intermediate copper-zirconium alloy, and intermediate copper-titanium alloy. Samples are obtained from the extruded blanks, and back-furnace components are tested. As the test instrument, an Inductive Coupling Plasma spectrograph (ICP) is used. Materials in each group are casted and ingoted in a 10 Kg intermediate frequency furnace, then turned into  $\Phi 50$  extruded ingots, and finally extruded into  $\Phi 15$  blanks. The extruded blanks are cooled with water online. The following processing is successively performed on the extruded blanks: cold drawing at a working rate of 60%→aging heat treatment for 5 h at 550°C→cold drawing at a working rate of 30%→aging heat treatment for 4 h at 450°C→cold drawing at a working rate of 20%→heat treatment on finished products for 3 h at 280°C→cleaning. The finished products are machined into  $\Phi 7$  standard tensile samples. Tensile tests are performed on the samples on a 10-ton hydraulic drawing machine to test the tensile strength, yield strength, ductility and modulus of elasticity of the samples. The finished products are cut into a length of 80 cm, and then the conductivity of the finished products is measured by a bridge tester. The various data is shown in Table 8 and Continued Table 8.

Table 8

| Embodiment | Element content (wt%) |       |      |      |                       | The number of strip-shaped $\text{Co}_x\text{Si}_y$ precipitated phases |
|------------|-----------------------|-------|------|------|-----------------------|-------------------------------------------------------------------------|
|            | Cu                    | Zn    | Co   | Si   | Others                |                                                                         |
| 62         | 84.93                 | 14.55 | 0.31 | 0.11 | -                     | 3                                                                       |
| 63         | 85.02                 | 14.21 | 0.32 | 0.09 | Cr:0.28               | 1                                                                       |
| 64         | 85.06                 | 14.23 | 0.29 | 0.12 | Zr:0.19               | 1                                                                       |
| 65         | 85.11                 | 13.65 | 0.32 | 0.09 | Ti:0.77               | 1                                                                       |
| 66         | 84.99                 | 14.43 | 0.30 | 0.13 | Cr:0.11<br>Zr:0.0015  | 0                                                                       |
| 67         | 84.56                 | 14.82 | 0.31 | 0.11 | Cr:0.0013<br>Zr :0.13 | 0                                                                       |
| 68         | 84.97                 | 14.59 | 0.28 | 0.12 | Ti:0.0012             | 2                                                                       |

Continued Table 8

| Embodiment | Performance            |                      |                             |               |                       |
|------------|------------------------|----------------------|-----------------------------|---------------|-----------------------|
|            | Tensile strength (MPa) | Yield strength (MPa) | Modulus of elasticity (Gpa) | Ductility (%) | Conductivity (% IACS) |
| 62         | 542                    | 518                  | 118                         | 18            | 27.1                  |

|    |     |     |     |    |      |
|----|-----|-----|-----|----|------|
| 63 | 563 | 544 | 121 | 19 | 26.5 |
| 64 | 566 | 539 | 120 | 19 | 26.9 |
| 65 | 561 | 527 | 115 | 16 | 22.6 |
| 66 | 553 | 543 | 122 | 20 | 26.7 |
| 67 | 560 | 545 | 121 | 21 | 26.8 |
| 68 | 557 | 523 | 118 | 18 | 27.8 |

**[0055]** As shown in Table 8 and the Continued Table 8, the addition of alloy elements Cr, Zr and Ti effectively reduces the number of the strip-shaped  $\text{Co}_x\text{Si}_y$  precipitated phases within a single field of view. Due to the presence of such strip-shaped compounds, the effect of the precipitated phases in improving the performances of the material will be weakened. Therefore, such strip-shaped compounds should be reduced as far as possible.

#### Scheme 9

**[0056]** This scheme is used for indicating the effect of B, Mg and Re in inhibiting the precipitation of the  $\text{Co}_x\text{Si}_y$  precipitated phases on the crystal boundary, by observing the number of the  $\text{Co}_x\text{Si}_y$  precipitated phases distributed on the crystal boundary in a corresponding scanning electron microscope graph. This scheme includes Embodiments 69 to 75. Materials are prepared according to the designed composition. The raw materials comprise electrolytic copper, 0# zinc, metal cobalt, intermediate copper-boron alloy, intermediate copper-magnesium alloy, and mischmetal. Samples are obtained from the extruded blanks, and back-furnace components are tested. As the test instrument, an Inductive Coupling Plasma spectrograph (ICP) is used. Materials in each group are casted and ingoted in a 10 Kg intermediate frequency furnace, then turned into  $\Phi 50$  extruded ingots, and finally extruded into  $\Phi 15$  blanks. The extruded blanks are cooled with water online. The following processing is successively performed on the extruded blanks: cold drawing at a working rate of 60%→aging heat treatment for 5 h at 550°C→cold drawing at a working rate of 30%→aging heat treatment for 4 h at 450°C→cold drawing at a working rate of 20%→heat treatment on finished products for 3 h at 280°C→cleaning. The finished products are machined into  $\Phi 7$  standard tensile samples. Tensile tests are performed on the samples on a 10-ton hydraulic drawing machine to test the tensile strength, yield strength, ductility and modulus of elasticity of the samples. The finished products are cut into a length of 80 cm, and then the conductivity of the finished products is measured by a bridge tester. Various data is shown in Table 9.

Table 9

| Embodiment | Element content (wt%) |      |      |      |            | The number of the Co <sub>x</sub> Si <sub>y</sub> precipitated phases distributed on the crystal boundary | Performance            |                      |                             |               |                       |
|------------|-----------------------|------|------|------|------------|-----------------------------------------------------------------------------------------------------------|------------------------|----------------------|-----------------------------|---------------|-----------------------|
|            | Cu                    | Zn   | Co   | Si   | Others     |                                                                                                           | Tensile strength (MPa) | Yield strength (MPa) | Modulus of elasticity (Gpa) | Ductility (%) | Conductivity (% IACS) |
| 62         | 90.05                 | 9.22 | 0.55 | 0.15 | -          | 4                                                                                                         | 583                    | 572                  | 125                         | 16            | 37.4                  |
| 63         | 89.98                 | 9.28 | 0.55 | 0.14 | B: 0.19    | 1                                                                                                         | 589                    | 578                  | 125                         | 17            | 37.2                  |
| 64         | 90.01                 | 9.25 | 0.53 | 0.15 | Mg: 0.28   | 1                                                                                                         | 592                    | 577                  | 123                         | 18            | 36.8                  |
| 65         | 90.13                 | 9.11 | 0.56 | 0.14 | Re: 0.077  | 0                                                                                                         | 601                    | 583                  | 122                         | 18            | 35.7                  |
| 66         | 90.07                 | 9.21 | 0.55 | 0.13 | B: 0.0011  | 2                                                                                                         | 580                    | 573                  | 125                         | 16            | 37.5                  |
| 67         | 90.12                 | 9.20 | 0.54 | 0.12 | Mg: 0.0052 | 2                                                                                                         | 586                    | 566                  | 121                         | 14            | 36.3                  |
| 68         | 89.86                 | 9.47 | 0.52 | 0.11 | Re: 0.0008 | 2                                                                                                         | 590                    | 575                  | 122                         | 17            | 37.1                  |

**[0057]** As shown in Table 9, the addition of B, Mg and Re effectively reduces the number of the  $\text{Co}_x\text{Si}_y$  precipitated phases distributed on the crystal boundary. The compounds distributed on the crystal boundary have no significant influence on the macro-performances of the material, but are easy to become crack sources during the stamping process, resulting in burrs, so that the use is influenced. Therefore, the compounds should be avoided as far as possible.

#### Scheme 10

**[0058]** This scheme is used for indicating processing methods of different forms of materials, and includes Embodiments 69 to 85, characterized in that, in Embodiments 69 to 70, wire rods having a product specification of  $\Phi 0.5$  mm are produced by the preparation methods 4 and 5; in Embodiments 71 to 72, bars having a product specification of  $\Phi 15$  mm are produced by the preparation method 3; in Embodiments 73 to 75, strips having a product specification of 0.3 mm are produced by the preparation method 2; and Embodiment 73 is accordance with American Standard C51900 as a comparison example. In Embodiments 76 to 85, strips having a product specification of 0.3 mm are produced by the preparation method 1. Characterized in that, Embodiment 76 is accordance with American Standard C42500, Embodiment 77 is accordance with American Standard C26000, and Embodiment 78 is accordance with American Standard C44300. All Embodiments 76, 77 and 78 are comparison examples. The various data is shown in Table 10 and Continued Table 10:

Table 10

| Embodiment            | Element content (wt%) |       |      |      |                  |
|-----------------------|-----------------------|-------|------|------|------------------|
|                       | Cu                    | Zn    | Co   | Si   | Others           |
| 69                    | 70.11                 | 27.65 | 0.92 | 0.21 | Ni: 1.05         |
| 70                    | 70.15                 | 27.58 | 0.90 | 0.19 | Sn: 1.13         |
| 71                    | 80.05                 | 16.88 | 0.91 | 0.19 | Al: 1.88         |
| 72                    | 88.11                 | 10.29 | 0.74 | 0.25 | Fe: 0.58         |
| Comparison example 73 | 93.3                  | -     | -    | -    | Sn: 6.48、P: 0.15 |
| 74                    | 70.11                 | 28.26 | 0.45 | 0.13 | Sn: 0.99         |
| 75                    | 70.08                 | 28.19 | 0.44 | 0.12 | Sn: 0.98、P: 0.12 |
| Comparison example 76 | 87.9                  | 8.90  | -    | -    | Sn: 3.11         |
| Comparison            | 70.1                  | 29.8  | -    | -    | -                |

|                          |      |       |      |      |                                |
|--------------------------|------|-------|------|------|--------------------------------|
| example 77               |      |       |      |      |                                |
| Comparison<br>example 78 | 70.1 | 28.79 | -    | -    | Sn: 1.05                       |
| 79                       | 89.2 | 9.28  | 0.39 | 0.15 | Sn: 0.92                       |
| 80                       | 89.1 | 9.36  | 0.38 | 0.15 | Sn: 0.9、B: 0.01                |
| 81                       | 89.5 | 8.75  | 0.41 | 0.13 | Sn: 1.0、Mg: 0.11               |
| 82                       | 70.1 | 28.01 | 0.77 | 0.18 | Ni: 0.88                       |
| 83                       | 69.8 | 28.29 | 0.75 | 0.18 | Ni: 0.85、Cr: 0.08<br>Zr: 0.005 |
| 84                       | 70.5 | 26.47 | 0.81 | 0.20 | Al: 1.99                       |
| 85                       | 70.3 | 26.61 | 0.82 | 0.19 | Al: 1.95、Zr: 0.05              |

Continued Table 10

| Embodiment               | Performance                  |                            |                                      |                  |                                           |                          |
|--------------------------|------------------------------|----------------------------|--------------------------------------|------------------|-------------------------------------------|--------------------------|
|                          | Tensile<br>strength<br>(MPa) | Yield<br>strength<br>(Mpa) | Modulus<br>of<br>elasticity<br>(Gpa) | Ductility<br>(%) | Yield<br>strength/tensile<br>strength (%) | Conductivity<br>(% IACS) |
| 69                       | 890                          | 885                        | 110                                  | 2                | 99.44                                     | 23.2                     |
| 70                       | 895                          | 889                        | 108                                  | 2                | 99.33                                     | 23.1                     |
| 71                       | 575                          | 511                        | 114                                  | 18               | 88.87                                     | 24.6                     |
| 72                       | 588                          | 520                        | 120                                  | 17               | 88.44                                     | 28.7                     |
| Comparison<br>example 73 | 586                          | 511                        | 113                                  | 17               | 87.20                                     | 16.5                     |
| 74                       | 574                          | 554                        | 110                                  | 16               | 96.52                                     | 24.2                     |
| 75                       | 582                          | 561                        | 109                                  | 16               | 96.39                                     | 23.9                     |
| Comparison<br>example 76 | 520                          | 460                        | 118                                  | 18               | 88.46                                     | 24.1                     |
| Comparison               | 480                          | 380                        | 112                                  | 16               | 79.17                                     | 27.8                     |

|                          |     |     |     |    |        |      |
|--------------------------|-----|-----|-----|----|--------|------|
| example 77               |     |     |     |    |        |      |
| Comparison<br>example 78 | 535 | 458 | 111 | 20 | 85.61  | 24.1 |
| 79                       | 576 | 552 | 122 | 18 | 95.83  | 33.5 |
| 80                       | 581 | 565 | 120 | 19 | 97.25  | 32.8 |
| 81                       | 585 | 567 | 120 | 17 | 96.92% | 33.4 |
| 82                       | 569 | 507 | 110 | 15 | 89.10% | 25.2 |
| 83                       | 577 | 536 | 110 | 15 | 92.89% | 24.7 |
| 84                       | 605 | 582 | 108 | 14 | 96.20% | 21.5 |
| 85                       | 600 | 573 | 111 | 16 | 95.50% | 21.6 |

**[0059]** As shown in Table 10 and the Continued Table 10, finished products are produced from the copper alloy of the present invention by a large-scale production process, and various performances are then tested. It can be seen from the comparison with the comparison examples that, due to the generation of the  $\text{Co}_x\text{Si}_y$  precipitated phases, various performances of the copper alloy of the present invention are improved significantly and effectively.

#### Scheme 11

**[0060]** This scheme is used for making a comparison in terms of the endurance of elasticity of the copper alloy containing cobalt and silicon and the stress relaxation rate of the material. The strips prepared in Embodiments 73 to 85 are tested in terms of the resistance to stress relaxation of the material. The tests are conducted according to the standard ASTM E328-2002(2008). An initial stress at a yield strength of 50% is applied to a cantilever beam formed by a corresponding sample, and the rolling reduction amount is measured and recorded. Then, the temperature is maintained at 100°C for 1000 h, and the amount of resilience is measured. According to the tested data, the stress relaxation rate of the material is calculated by the following calculation formula: the stress relaxation rate = (the rolling reduction amount - the amount of resilience)/ the rolling reduction amount  $\times$  100%. The results are shown in Table 11.

Table 11

| Embodiment                      | 73  | 74  | 75 | 76  | 77  | 78  | 79 | 80 | 81 | 82 | 83 | 84  | 85 |
|---------------------------------|-----|-----|----|-----|-----|-----|----|----|----|----|----|-----|----|
| Stress relaxation rate at 100°C | 10% | 10% | 7% | 13% | 34% | 16% | 8% | 5% | 8% | 6% | 7% | 10% | 8% |

**[0061]** It can be seen from Table 11 that, in the Embodiments 74, 75, and 79 to 85 with the presence of the  $\text{Co}_x\text{Si}_y$  precipitated phases, the stress relaxation rate is significantly improved in comparison with Embodiments 77 and 78, and the poor endurance of elasticity when serving as the brass is improved greatly. Compared with the existing common elastic materials C51900 (i.e., Embodiment 73) and C42500 (i.e., Embodiment 76), in the embodiments with the presence of the  $\text{Co}_x\text{Si}_y$  precipitated phases, the stress relaxation rate reaches or is lower than that of the existing materials. It is indicated that, based on the improvement to the endurance of elasticity by the existing  $\text{Co}_x\text{Si}_y$  precipitated phases, P, B, Mg, Cr and Zr further improve the endurance of elasticity of the material.

## Claims

1. A copper alloy containing cobalt and silicon comprising (in percentage of weight):

69% to 92% of copper;  
6.5% to 30.5% of zinc;  
0.01% to 3% of cobalt; and  
0.01% to 0.5% of silicon;

**characterized in that** the total content of copper and zinc is greater than 95%, and the content of inevitable impurities is less than 0.2%.

2. The copper alloy according to claim 1, **characterized in that** the copper alloy comprises matrix phases of copper-zinc  $\alpha$  solid solution and  $\text{Co}_x\text{Si}_y$  precipitated phases;  
the  $\text{Co}_x\text{Si}_y$  precipitated phases are dispersedly distributed on a matrix phase;  
the percentage of the matrix phases by area is greater than or equal to 95%; and,  
the percentage of the  $\text{Co}_x\text{Si}_y$  precipitated phases by area is 0.01% to 5%.

3. The copper alloy according to claim 2, **characterized in that**, the percentage of the  $\text{Co}_x\text{Si}_y$  precipitated phases having a particle size between 10 nm and 200 nm is greater than or equal to 90%, and the percentage of the  $\text{Co}_x\text{Si}_y$  precipitated phases having a particle size above 200 nm is less than or equal to 10%.

4. The copper alloy according to claim 3, **characterized in that**, an atomic ratio of copper to zinc (Cu/Zn) is 2.3 to 15.8, and a mass fraction of copper and zinc satisfies  $0.65 \leq ([\text{Cu}]/3+1)/([\text{Zn}]+5) \leq 3.5$ .

5. The copper alloy according to claim 4, **characterized in that**, a yield strength/tensile strength of the copper alloy is greater than or equal to 85%; and  
a stress relaxation rate under an initial stress at a yield strength of 50% at 100°C for 1000 H is less than or equal to 15%.

6. The copper alloy of anyone according to claim 1-5, **characterized in that**, the copper alloy further comprises (in percentage of weight) at least one of 0.01% to 3.5% of Sn, 0.01% to 4.0% of Al and 0.01% to 3% of Ni.

7. The copper alloy of anyone according to claim 1-5, **characterized in that**, the copper alloy further comprises (in percentage of weight) 0.01% to 0.35% of P.

8. The copper alloy according to claim 7, **characterized in that**, the copper alloy further comprises  $\text{Co}_m\text{P}_n$  precipitated phases, and a percentage of the  $\text{Co}_m\text{P}_n$  precipitated phases by area is 0.01% to 5%.

9. The copper alloy according to claim 6, **characterized in that**, the copper alloy further comprises (in percentage of weight) 0.01% to 0.35% of P.

10. The copper alloy according to claim 9, **characterized in that**, the copper alloy further comprises  $\text{Co}_m\text{P}_n$  precipitated phases, and a percentage of the  $\text{Co}_m\text{P}_n$  precipitated phases by area is 0.01% to 5%.

11. The copper alloy according to claim 6, **characterized in that**, further comprises A having a total content of 0.0001% to 2%, and the A is at least one selected from a group comprises (in percentage of weight) 0.01% to 1.5% of Mn, 0.01% to 1.5% of Fe, 0.001% to 0.3% of Cr, 0.001% to 0.2% of Zr, 0.001% to 0.5% of Mg, 0.001% to 0.8% of Ti, 0.0005% to 0.3% of B and 0.0001% to 0.1% of Re.

12. The copper alloy according to claim 7, **characterized in that**, the copper alloy further comprises A having a total content of 0.0001% to 2%, and the A is at least one selected from a group comprises (in percentage of weight) 0.01% to 1.5% of Mn, 0.01% to 1.5% of Fe, 0.001% to 0.3 of Cr, 0.001% to 0.2% of Zr, 0.001% to 0.5% of Mg, 0.001% to 0.8% of Ti, 0.0005% to 0.3% of B, and 0.0001% to 0.1% of Re.

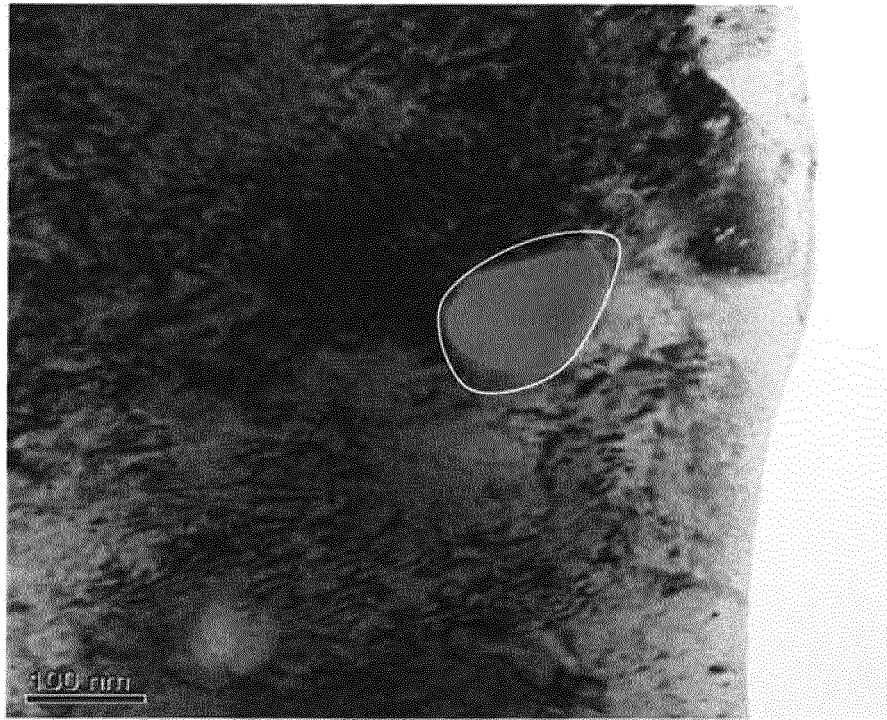


FIG.1

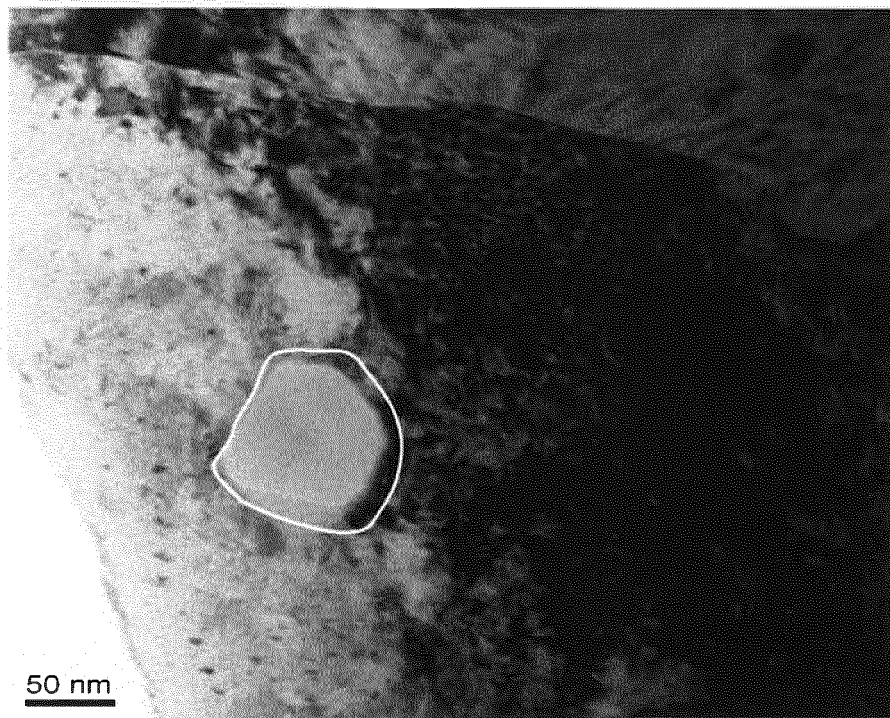


FIG.2

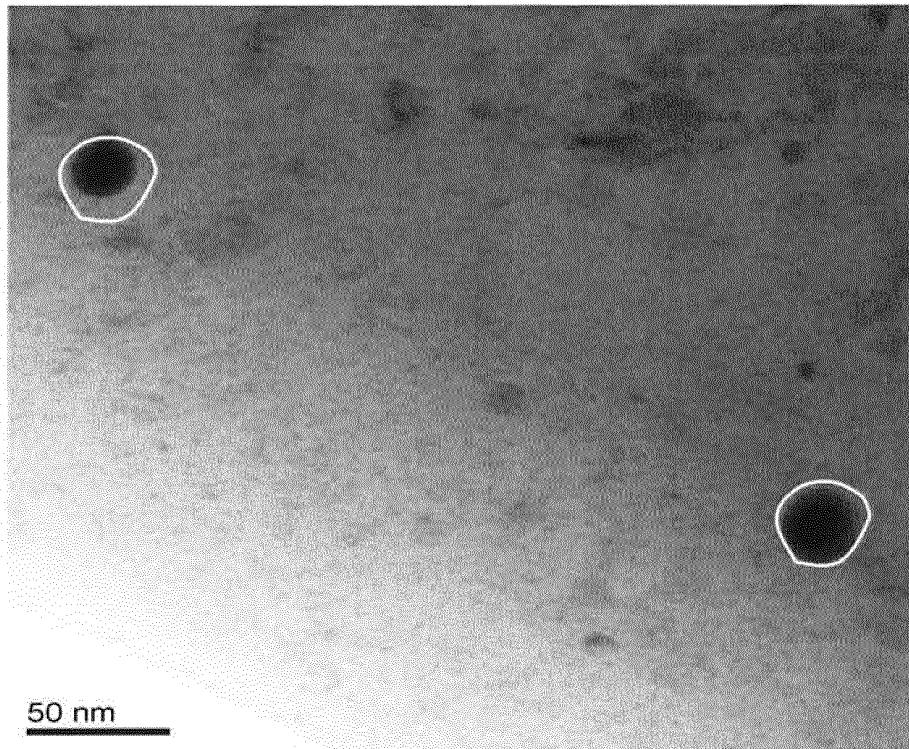


FIG.3

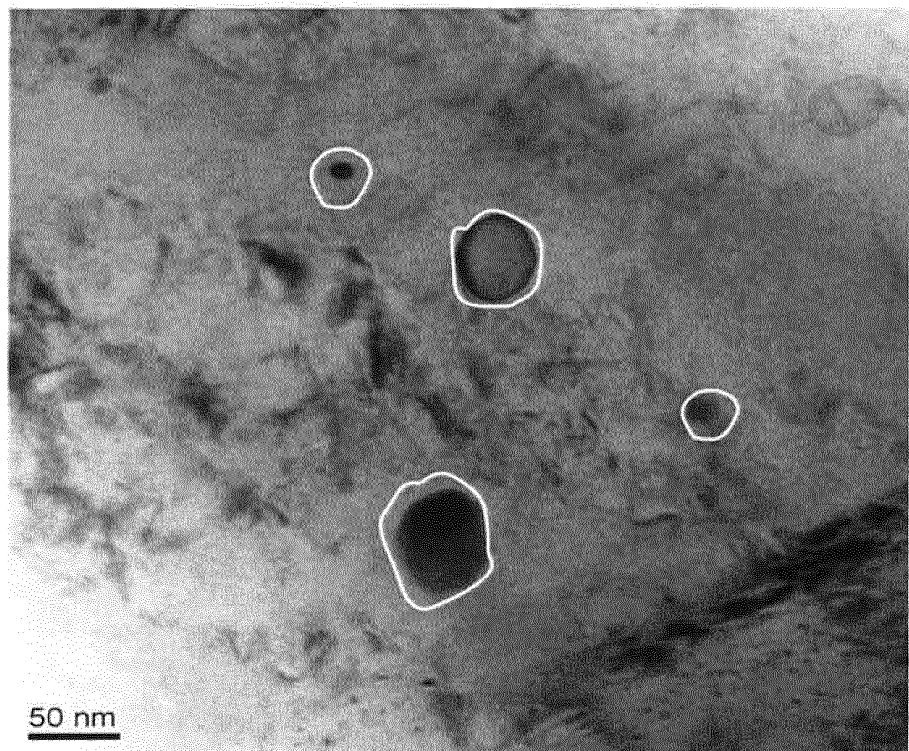


FIG.4

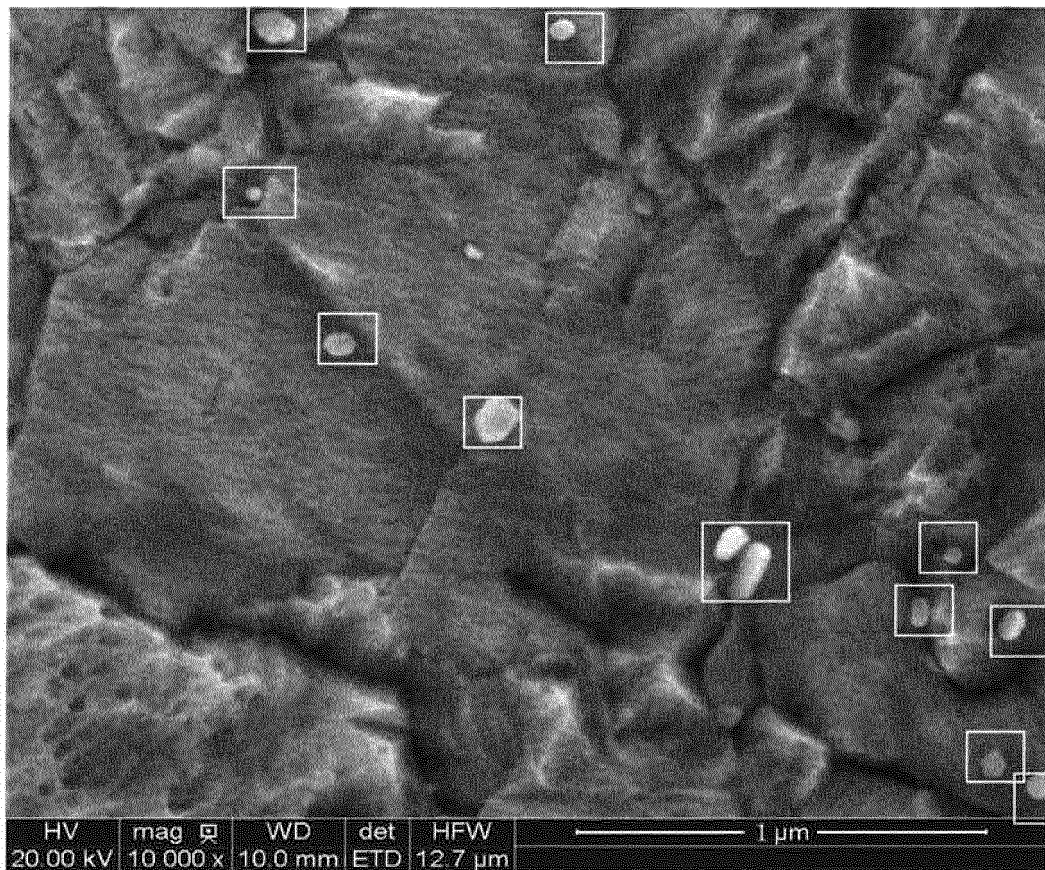


FIG.5

**REFERENCES CITED IN THE DESCRIPTION**

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**Patent documents cited in the description**

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