

[Title of Document] Description

[Title of Invention] COPPER ALLOY FINE WIRE FOR BALL BONDING

[Technical Field]

[0001]

The present invention relates to a copper alloy fine wire for ball bonding which is suitable for connecting an IC chip electrode used for a semiconductor device to a board such as an outer lead, and in particular, relates to a copper alloy fine wire whose tail wire does not bend even when the copper alloy fine wire is an extrafine wire having a wire diameter of 15  $\mu\text{m}$  or less.

[Background Art]

[0002]

In general, a method called ball bonding is employed for the first bonding of a copper bonding wire to an electrode, and a method called wedge bonding is employed for the wedge bonding of the copper bonding wire to a wiring on a wiring circuit board for a semiconductor, respectively. In the first bonding, a true sphere called a free air ball (FAB) is formed at the tip of the wire by a system called an electronic-flame-off (EFO) system which supplies the arc input heat to the tip of the wire from a torch electrode. Then, the bonding wire and an aluminum pad are bonded together by pressing the FAB on the aluminum pad which has been heated to a temperature within the temperature range from 150°C to 300°C, by means of a capillary while applying ultrasonic waves on the aluminum pad.

[0003]

Next, the capillary is caused to rise by letting out the bonding wire, and the capillary is moved to the point of wedge

bonding by drawing a loop-shaped track in the direction toward the lead. By describing with reference to the figures, in the case of wedge bonding by using a capillary, as shown in Figure 1, a bonding wire (1) is wedge-bonded to a lead (3) by means of a capillary (2). At this time, an end part of the wedge-bonded bonding wire (1) is crushed by a tip part of a capillary (2). As shown in Figure 2, the area of the end face of the wire at the bonding position becomes thinner than the diameter of the wire. And then, the bonding wire (1) is cut off from this bonding position. The way of cutting off is as follows: after a wire clasper (4) located above the capillary (2) clamps the bonding wire (1) and then pulls the bonding wire (1) up, as shown in Figure 3, the bonding wire (1) becomes easily cut at the tip part of the bonding wire (1) at the bonding position with the lead (3).

[0004]

Next, though being omitted in the figures, the capillary is moved to the point of the first bonding. Then, spark discharge is performed by a discharging torch such that a molten ball (FAB) is formed at the tip of the bonding wire to perform the first bonding of the bonding wire and the aluminum pad. Such a bonding cycle is repeated such that the pad and the lead (3) are connected through the bonding wire (1) sequentially.

[0005]

However, it has been difficult for a copper alloy bonding wire which contains 10 to 500 ppm of phosphorus (P) and the remainder of copper (Cu) of 99.9% or more in purity and the like to achieve uniform mechanical properties (Japanese Patent Application Laid Open No. Hei 7-122564). Accordingly, after

the bonding wire (1) is subjected to the second bonding, when the wire is cut by raising the capillary (2) together with the wire clamber (4), with the wire clamber (4) being closed, there have been some cases where the tip of the bonding wire bends, or even worse, there have been other cases where the bonding wire bends within the capillary in a Z-shape, as shown in Figure 4.

[0006]

Accordingly, so far, problems in mechanical properties of a bonding wire have been solved by an improvement of a bonder which pulls the bonding wire upward (by a little amount) after the second bonding such that a narrow-diameter portion is formed in the bonding wire, opens a wire clamber once, then closes the wire clamber and pulls the wire again (this time, strongly) to cut the bonding wire at the narrow-diameter portion (Japanese Patent Application Laid Open No. 2007-66991 (Patent Literature 1 described below)).

[0007]

Few wires with such J-shaped deformations have been found when the wire is a copper bonding wire having a wire diameter as thick as 25  $\mu\text{m}$ . However, when the wire diameter of a bonding wire is thin, that is, the wire diameter is thinner than 20  $\mu\text{m}$ , as well as when the bonding speed is made to be higher, the above-described improved bonder cannot be adopted, and the wire with J-shaped deformation has become apparent.

[0008]

When a bonding wire has such a J-shaped deformed tip portion, the loop-shape tends to be distorted when the loop-shaped track is drawn. In addition, a spark current

tends not to hit the tip of the bonding wire correctly, and the center deviation of a molten ball tends to occur, which may cause the generation of a ball with a flat and irregular shape as an FAB. Further, when the J-shaped deformation becomes serious, the deformation may become a Z-shaped deformation which has been found so far and has been a cause of the clogging of a capillary.

[0009]

On the other hand, it is known that a clean true sphere shape can be achieved when phosphorus (P) is added to high purity oxygen-free copper of  $\geq 99.99$  wt.% purity, because phosphorus (P) acts for deoxidizing copper (Cu) by forming an oxide at 350°C and prevents the surface oxidation during the formation of an FAB in the first bonding (Japanese Patent Application Laid Open No. Sho 62-80241). In addition, it is also known that phosphorus (P) rapidly diffuses in polycrystalline high purity copper (Cu) (P. SPINDLER et al., METALLURGICAL TRANSACTIONS A, June 1978, Vol. 9A, page 763), and that phosphorus (P) tends to segregate on the surface of the high purity copper (Cu) (I. N. SERGEEV et al., Bulletin of the Russian Academy of Sciences: Physics, October 2008, Vol. 72, No. 10, page 1388).

[0010]

Meanwhile, high purity copper of  $\geq 99.99$  wt.% (4N) purity means copper whose purity, which is expressed in terms of weight percent relative to the total metal components excluding gaseous components such as H, N, C and O, is that in which the number of "9" is four. Normally, high purity copper does not contain expensive noble metal components, and

therefore, high purity copper of  $\geq 99.99$  wt.% purity means copper which contains less than 100 mass ppm in total of base metal elements other than copper (Cu). In addition, normally, gaseous components are excluded from the definition of high purity copper (Shoji Aoki et al., Copper and copper alloy: journal of Japan Research Institute for Advanced Copper-Base Materials and Technologies, January 2003, Vol. 42, No. 1, page 21). On the other hand, it is said that when a gaseous component such as oxygen is present at a high concentration in a bonding wire, the gaseous component exerts bad influences on an FAB of the bonding wire.

[0011]

Accordingly, there are a lot of patent applications relating to the control of gaseous components in high purity copper. For example, the description of Japanese Patent Application Laid Open No. Sho 61-20693 describes "these added elements fix H, O, N and C in an alloy and suppress generation of  $H_2$ ,  $O_2$ ,  $N_2$  and CO gasses" (the publication, page 2, the upper right column, lines 12 to 14). Similarly, Japanese Patent Application Laid Open No. 2003-225705 discloses "a working method of a soft copper material where copper of  $\geq 99.98$  wt.% is used as a raw material, and is subjected to extension working so as to control the cross section to  $\leq 0.01$  mm<sup>2</sup>, and the total content of gas components of oxygen, carbon, nitrogen, and sulfur present in the copper material after temper-annealing is controlled to  $\leq 0.005$  wt.%, wherein as a lubricating solution used in the above extension working stage, an aqueous solution in which the total content of oil contents and a surfactant is  $\leq 0.02$  wt.% is adopted" according

to the fact that the Vickers hardness (Hv) of a copper bonding wire and the amount of gas components of oxygen, carbon, nitrogen, and sulfur present in the copper material have a correlation when the Vickers hardness of an initial ball of a soft copper wire of each wire diameter was measured.

[0012]

In addition, there are patent applications which define chlorine that is not included in a base metal material of high purity copper of  $\geq 4N$  (Japanese Patent Application Laid Open No. 2008-153625, Japanese Patent Application Laid Open No. 2011-3745).

[0013]

On the other hand, there are a lot of patent applications relating to addition of nickel (Ni) as an additive element to a high purity copper-phosphorus alloy. For example, Japanese Patent Application Laid Open No. Sho 61-20693, in Claims (1), discloses "a bonding wire, comprising 0.001 to 2 wt.% of one or more kinds of elements selected from " 24 elements including Ni and P (which also includes a rare earth element as one of 24 elements) "and the remainder substantially of copper". In addition, Japanese Patent Application Laid Open No. Sho 61-52333, in Claims (1), also discloses, "a bonding wire, comprising 0.001 wt.% or more and less than 0.1 wt.% of one or more kinds of elements selected from (the 1st group of additive elements)" which includes 7 elements such as silver (Ag) "as well as 0.001 to 2 wt.% of one or more kinds of elements selected from (the 2nd group of additive elements)" which includes 22 elements such as Ni, Pd, Pt, Au and P "and the remainder substantially of copper".

[0014]

In addition, Japanese Patent Application Laid Open No. 2010-171235 (Patent Literature 2 described below), in Claim 2 and Claim 5, discloses "a copper alloy wire for high purity ball bonding, wherein the initial ball hardness at room temperature of the bonding wire is lowered by adding phosphorus (P) such that the hardness becomes lower than that of a copper alloy of which purity excluding phosphorus (P) is equal to or greater than the copper alloy wire, and wherein the total content of metallic elements other than phosphorus (P) is equal to or smaller than the content of phosphorus (P)" and "wherein metallic elements other than phosphorus (P) in copper (Cu) are any one or more kinds selected from Pt, Au, Ag, Pd, Ca, Fe, Mn, Mg, Ni, Al, Pb and Si".

[0015]

Further, Japanese Patent Application Laid Open No. Hei 01-290231 (Patent Literature 3 described below), in Claims (2), discloses "a copper alloy extra fine wire for a semiconductor device obtained by adding Si of at least 1.0 ppm to high purity oxygen-free copper containing S, Se and Te in total of 1.0 ppm or less and further adding Si and one or more kinds" of 8 elements including Ni and P "in the total amount of the 8 elements and Si of 1.0 to 500 ppm". Furthermore, Example 17 of the invention shows that a copper alloy fine wire having a diameter of 25  $\mu\text{m}$  was manufactured by adding "alloying elements whose contents (ppm) are as follows: Si : 132; Ni : 28; P : 76".

[0016]

The object of these prior art documents relating to high

purity copper having controlled gaseous components and relating to a high purity copper-phosphorus alloy is to provide a copper based bonding wire for a semiconductor device, which has a reduced material cost, is excellent in a ball bonding shape, wire bonding properties and the like, and has a good loop formability, and a superior mass productivity. However, only by providing a dense layer of phosphorus (P) on the surface of the bonding wire or the like, mechanical properties of the wire itself tend to be unstable when the bonding wire is thin, and the problems that the above-described tail wire tends to bend and that the wire tip tends to bend still remain unsolved.

[Citation List]

[Patent Literature]

[0017]

[PTL 1] Japanese Patent Application Laid Open No.2007-66991

[PTL 2] Japanese Patent Application Laid Open No.2010-171235

[PTL 3] Japanese Patent Application Laid Open No. Hei 01-290231

[Summary of Invention]

[Technical problem]

[0018]

The present invention is made in order to solve the problems of bending of a tail wire within a capillary and bending of a wire tip when a wire is pulled upwards as it is after the second bonding and is cut, and an object of the present invention is to provide a copper alloy bonding wire which is free from J-shaped bending of a tail wire by adding nickel (Ni) to a

copper-phosphorus alloy.

[Solution to Problem]

[0019]

One invention of the copper alloy fine wire for ball bonding which solves the problems of the present invention is a copper alloy fine wire for ball bonding, comprising: 0.02 mass% or more and 2 mass% or less of nickel (Ni), 5 mass ppm or more and 800 mass ppm or less of phosphorus (P), less than 100 mass ppm in total of other base metal elements and the remainder of copper (Cu).

[0020]

In addition, one invention of the copper alloy fine wire for ball bonding which solves the problems of the present invention is a copper alloy fine wire for ball bonding, comprising: a core material made of a copper alloy which comprises 0.02 mass% or more and 2 mass% or less of nickel (Ni), 5 mass ppm or more and 800 mass ppm or less of phosphorus (P), less than 100 mass ppm in total of other base metal elements and the remainder of copper (Cu), wherein the core material made of the copper alloy is covered with a stretched layer made of palladium (Pd).

[0021]

Further, one invention of the copper alloy fine wire for ball bonding which solves the problems of the present invention is a copper alloy fine wire for ball bonding, comprising: a core material made of a copper alloy which comprises 0.02 mass% or more and 2 mass% or less of nickel (Ni), 5 mass ppm or more and 800 mass ppm or less of phosphorus (P), less than 100 mass ppm in total of other base metal elements and the remainder

of copper (Cu), wherein the core material made of the copper alloy is covered with a stretched layer made of palladium (Pd) and a stretched thin layer made of gold (Au).

[0022]

In one embodiment of the present invention, the upper limit of the nickel (Ni) is 1 mass% or less.

[0023]

In addition, in one embodiment of the present invention, the upper limit of the phosphorus (P) is 200 mass ppm or less.

[0024]

Further, one embodiment of the present invention is the copper alloy fine wire for ball bonding according to any one of the above-described 3 inventions of the copper alloy fine wire for ball bonding, wherein up to 30 mass% of nickel (Ni) taking the content of the nickel (Ni) as 100 mass% is replaced with palladium (Pd) or platinum (Pt).

[0025]

Furthermore, another embodiment of the present invention is the copper alloy fine wire for ball bonding according to any one of the above-described 3 inventions of the copper alloy fine wire for ball bonding, wherein up to 30 mass% of nickel (Ni) taking the content of the nickel (Ni) as 100 mass% is replaced with gold (Au) or silver (Ag).

[0026]

In the present invention, both "a stretched layer" and "a stretched thin layer" means a theoretical layer calculated by taking a section of a bonding wire and a core material made of a copper alloy as being perfect circle shapes and assuming that the outer ring of a core material made of a copper alloy

is uniformly covered with a layer made of palladium (Pd) or a layer made of palladium (Pd) and a layer made of gold (Au) and its diameter is reduced, in general. Accordingly, the expressions "a stretched layer" and "a stretched thin layer" are used to describe each of these layers as "a layer" by assuming that the layer has a thickness for the sake of convenience in a depth direction from the surface of a bonding wire to the range where fine particles of each of palladium (Pd) and gold (Au) are detected, by means of Auger analysis and the like, though these expressions do not necessarily describe the actual surface properties accurately. In the bonding wire according to the present invention, it is considered that both "a stretched layer" and "a stretched thin layer" are present when the fine particles of each of palladium (Pd) and gold (Au) are detected from the surface of the bonding wire by a high-frequency inductively coupled plasma emission spectrometric analysis method (ICP-AES), since the thickness of each of these layers is very thin.

[0027]

In the copper alloy fine wire for ball bonding according to the present invention, a high purity copper alloy base metal material of 6N to 4N purity normally contains 0.2 mass ppm or more and 50 mass ppm or less of oxygen. The content of oxygen in the copper alloy having the composition according to the present invention hardly changes even when the copper alloy base metal material is subjected to remelting/casting, primary wire drawing, intermediate heat treatment, secondary wire drawing, final heat treatment, storage and the like. It is preferable that the content of oxygen is as small as possible because a

base metal element tends to form an oxide when oxygen is contained in the copper (Cu) matrix. The content of oxygen is preferably 10 mass ppm or less and is more preferably 5 mass ppm or less.

[0028]

In the copper alloy fine wire for ball bonding according to the present invention, the reason why the content of nickel (Ni) is defined to be 0.02 mass% or more and 2 mass% or less is that nickel (Ni) is capable of fixing oxygen contained in a copper alloy base metal material as well as of preventing the surface segregation of phosphorus (P). A certain amount of nickel (Ni) in a copper alloy matrix is dispersed finely and fixes oxygen in the matrix. Oxygen which is fixed by nickel (Ni) is not affected by the deoxidizing action of phosphorus (P), and therefore, the presence of a certain amount of nickel enhances the rigidity of a wire itself. Accordingly, the presence of a certain amount of nickel (Ni) enhances the Young's modulus of a copper alloy.

[0029]

The present inventors have found that a copper alloy fine wire exhibiting a high Young's modulus has a small cross-sectional area of a tip portion of a tail wire, which can give a tail wire of which the second back tends not to bend during the second bonding. In other words, it was found that bending of a tail wire, which is a dynamic characteristic of a bonding wire, is caused by the Young's modulus, which is a static characteristic of a copper alloy fine wire.

[0030]

In the copper alloy fine wire for ball bonding according

to the present invention, nickel (Ni) combines with an oxygen atom and prevents a copper matrix from oxidizing. Nickel (Ni) which is combined with oxygen is fixed in the copper alloy matrix. In this case, when oxygen is continuously supplied in excess, nickel is observed as particles of nickel oxide which are dispersed in the copper alloy matrix. In addition, nickel (Ni) also tends to be combined with phosphorus (P), and prevents phosphorus (P) in the copper matrix from transferring. Accordingly, an appropriate amount of nickel (Ni) acts to enhance the Young's modulus of copper (Cu).

[0031]

When the lower limit of the amount of nickel (Ni) is less than 0.02 mass%, there may be some cases where the surface segregation of phosphorus (P) cannot be prevented, and the way of cutting of the tip part of a tail wire tends to be unstabilized, and therefore, the lower limit of the amount of nickel (Ni) is defined to be 0.02 mass% or more. The lower limit of the amount of nickel (Ni) is preferably 0.04 mass% or more, and is more preferably 0.06 mass% or more.

[0032]

In addition, when the upper limit of the amount of nickel (Ni) exceeds 2 mass%, oxidization beginning from the surface of a bonding wire tends to be accelerated, and therefore, the upper limit of the amount of nickel (Ni) is defined to be 2 mass% or less. The upper limit of the amount of nickel (Ni) is preferably 1 mass% or less. The upper limit of the amount of nickel (Ni) is more preferably 0.5 mass% or less, and is even more preferably 0.3 mass% or less.

[0033]

In the copper alloy fine wire for ball bonding according to the present invention, the content of the phosphorus (P) is defined to be 5 mass ppm or more and 800 mass ppm or less. Phosphorus (P) is an element which tends to act on copper (Cu) and oxygen and tends to segregate on the surface. In addition, it is well known that phosphorus (P) exhibits a flux effect against copper (Cu) and palladium (Pd) as a solder, when phosphorus (P) is present on a scale of a percentage order. Accordingly, it is thought that phosphorus (P) acts to enhance the bonding strength with an aluminum pad by precipitating on the surface of a molten ball even when phosphorus (P) is present in the above-described range. In addition, since phosphorus (P) forms a volatile phosphate ion ( $\text{PO}_4^{2-}$ ) with oxygen, phosphorus (P) acts to release oxygen present in a copper alloy matrix during the formation of a FAB from a molten ball into the atmosphere. However, it has been found that nickel (Ni) acts on oxygen in the copper alloy matrix more preferentially than phosphorus (P).

[0034]

The reason why the upper limit of phosphorus (P) is defined to be 800 mass ppm or less is that a tail wire tends to be unstable when the content of phosphorus (P) exceeds 800 mass ppm. The content of phosphorus (P) is preferably 500 mass ppm or less, and is more preferably 200 mass ppm or less and is even more preferably less than 100 mass ppm. The reason why the lower limit of phosphorus (P) is defined to be 5 mass ppm or more is that the flux effect cannot be exhibited when the content of phosphorus (P) is below 5 mass ppm.

[0035]

In the copper alloy fine wire for ball bonding according to the present invention, the reason why up to 30 mass% of nickel (Ni) taking the content of the nickel (Ni) as 100 mass% may be replaced with palladium (Pd) or platinum (Pt) is that when either palladium (Pd) and/or platinum (Pt) are present in this range they exhibit the similar effects to nickel (Ni). The content of expensive palladium (Pd) or platinum (Pt) is preferably up to 20 mass% of nickel (Ni), and is more preferably up to 10 mass% of nickel (Ni).

[0036]

In addition, in the copper alloy fine wire for ball bonding according to the present invention, the reason why up to 30 mass% of nickel (Ni) taking the content of the nickel (Ni) as 100 mass% may be replaced with gold (Au) or silver (Ag) is that when either gold (Au) and/or silver (Ag) are present in this range they exhibit the similar effects to nickel (Ni). The content of expensive gold (Au) or silver (Ag) is preferably up to 20 mass% of nickel (Ni), and is more preferably up to 10 mass% of nickel (Ni).

[0037]

Further, in the copper alloy fine wire for ball bonding according to the present invention, the reason why the total amount of other base metal elements is defined to be less than 100 mass ppm is that the formation of an oxide of a base metal element in a copper alloy matrix is prevented. In other words, the reason is that the second backed tail wire tends to deform when an oxide of a base metal element is formed on a crystal grain boundary of copper. The total amount of other base metal elements is preferably 50 mass ppm or less, and when the price

of a base metal material is not considered, the total amount of other base metal elements is more preferably less than 10 mass ppm and is even more preferably 5 mass ppm or less. For example, when copper with a nominal purity of 6N (99.9999 mass%) or more is used as a base metal material, the total amount of other metallic elements is less than 1 mass ppm. However, it is not suitable because copper which is a base metal material is too expensive to be in practical use. Meanwhile, "other base metal elements" mean elements including bismuth (Bi), selenium (Se), tellurium (Te), zinc (Zn), iron (Fe), nickel (Ni), tin (Sn) and the like.

[0038]

In addition, gaseous components other than oxygen such as hydrogen and chlorine which are normally contained in a high purity copper alloy base metal material of 6N to 4N purity do not affect the Young's modulus of a copper alloy fine wire. For example, the amount of hydrogen contained in a high purity copper alloy base metal material of 6N purity is equal to or lower than the detection limit (0.2 mass ppm) of analyzing equipment. Meanwhile, when hydrogen is present in a copper alloy, hydrogen and oxygen are combined to form water vapor during the formation of a molten ball, which makes the molten ball unstable. With regard to hydrogen, in some cases, hydrogen may enter into molten metals from a wall of a melting crucible, and in other cases, hydrogen may be entrained in the surface of a copper base metal material when hydrogen is subjected to rapid cooling in the heat treatment step. Alternatively, when palladium (Pd) coating is conducted by means of wet plating, occluded hydrogen sometimes remains,

and therefore, the entrainment of hydrogen or the like is required to be avoided.

[0039]

In addition, in the copper alloy fine wire for ball bonding according to the present invention, even when the copper alloy fine wire is covered with a stretched layer made of palladium (Pd) or a stretched layer made of palladium (Pd) and a stretched thin layer made of gold (Au), these stretched layers hardly affect the Young's modulus of a core material made of a copper alloy because these coating layers are very thin, that is, thinner than 100 nm. A stretched layer made of palladium (Pd) with a thickness of 20 nm or more and 60 nm or less has an effect of delaying oxidization of a copper alloy fine wire. Further, when the copper alloy fine wire is covered with a stretched thin layer made of gold (Au) with a thickness of 3 nm or less, the exothermic phenomenon of the wire itself occurs subsequent to the surface layer current, and therefore, the stretched thin layer made of gold (Au) has an effect of stabilizing spark discharge of a stretched layer made of palladium (Pd) which has low electric conductivity and an effect of making a uniform molten ball.

[0040]

Meanwhile, the reason why the expressions "stretched" layer and "stretched thin" layer are used is that it can distinguish the "stretched" layer of the present invention from a coating layer which is left as it is just after being simply subjected to wet/dry plating. The object of the present invention cannot be achieved when a wire is coated with a coating material made of a noble metal such as palladium

(Pd) and gold (Au) after the wire is subjected to the secondary wire drawing until the final wire diameter is reached. This is because the final coating layer cannot fill in an irregular vertically long groove caused by die wear, and therefore, the final coating layer cannot cover the whole circumference of a wire in nano order.

[0041]

In order to form a very thin stretched thin layer according to the present invention, it is generally required to reduce the diameter by 90% or more in terms of the diameter of the wire, though the degree of the reduction of the diameter also depends on a kind of a combination of a core material and a coating material. Meanwhile, both a stretched layer made of palladium (Pd) and a stretched thin layer made of gold (Au) according to the present invention, which is very thin, on the surface of the wire, disappears at a bonding position during the ultrasonic bonding in the second bonding, but both the stretched layer made of palladium (Pd) and the stretched thin layer made of gold (Au) remains on a tail wire.

[Advantageous Effects of Invention]

[0042]

According to the copper alloy fine wire for ball bonding having the composition range according to the present invention, the second back during the second bonding tends not to bend and an effect of an extreme decrease in the bending of a tail wire is exhibited compared to a conventional fine wire. In addition, when the shape of the tail wire is stabilized, an effect of reducing the number of FABs which are irregular shaped balls during the first bonding is

exhibited. Further, when the shape of the tail wire is stabilized, an FAB during the first bonding can be smaller with a true sphere shape with less heat energy. Accordingly, the wire diameter can be reduced such that the wire diameter is from 20  $\mu\text{m}$  to 15  $\mu\text{m}$ , and therefore, an effect which enables high-density wiring of a bonding wire by using a small diameter ball is exhibited. Further, when a wire is covered with a stretched layer made of palladium (Pd) and a stretched thin layer made of gold (Au) in nano order, a molten ball can be stably formed.

[0043]

Furthermore, according to the copper alloy fine wire for ball bonding according to the present invention, no base metal oxides are dispersed in a copper matrix, and therefore, the wire itself is soft. In addition, the position of spark discharge during the first bonding is also stabilized, and therefore, an effect of stabilizing an FAB during the first bonding is exhibited even when the wire is covered with a stretched layer made of palladium (Pd) or a stretched layer made of palladium (Pd) and a stretched thin layer made of gold (Au) having the thickness thinner than that of a conventional fine wire.

[0044]

Further, according to the copper alloy fine wire for ball bonding according to the present invention, when a stretched layer made of gold (Au) is formed on the outermost surface of the wire, the wires are not stuck to each other even when the wire is multiply wound such that 10,000 meters of the wire is wound up. As a result, an unwinding property of the wire improves. Furthermore, as a side benefit, slipperiness of the

surface of the wire against a capillary improves. In addition, according to the copper alloy fine wire for ball bonding according to the present invention, fine particles of gold (Au) at the outermost surface of the wire do not peel off from a stretched layer made of palladium (Pd). Accordingly, no oxide of copper (Cu) adheres to a capillary even when bonding is repeated many times, and therefore, the capillary is not contaminated.

[Examples]

[0045]

As a core material, copper (Cu) of purity of 99.9998 mass% (5N) was used, and phosphorus (P) and nickel (Ni) as well as palladium (Pd), platinum (Pt), gold (Au) and silver (Ag) were added thereto as additive elements. As base metal elements, elements which are generally contained in high purity copper were selected. In other words, bismuth (Bi), selenium (Se), tellurium (Te), zinc (Zn), iron (Fe), nickel (Ni) and tin (Sn) were appropriately selected. They were mixed in a predetermined range to obtain each of Example 1 to Example 23.

[0046]

Next, each of the obtained mixtures were subjected to continuous casting, and thereafter, were subjected to the primary wire drawing to give a thick wire (with a diameter of 1.0 mm) before being covered with a stretching material. Then, the thick wire was subjected to intermediate heat treatment ( $400^{\circ}\text{C} \times 4$  hours). Thereafter, as needed, a noble metal coating layer which becomes each of a stretched thin layer made of gold (Au) and a stretched layer made of palladium (Pd) was formed. Each of these semifinished wire products were subjected to the

secondary wire drawing continuously in a wet manner by using a diamond die and were subjected to refining heat treatment of  $480^{\circ}\text{C} \times 1 \text{ sec}$  to give a copper alloy fine wire for ball bonding with a diameter of  $15 \mu\text{m}$  finally. Meanwhile, the mean rate of diameter reduction is 6 to 20%, and the final speed of the wire is 100 to 1,000 m/min. In addition, the purity of gold (Au) is 99.99 mass% or more, and the purity of palladium (Pd) is 99.9 mass% or more.

[0047]

[Table 1]

| No.                   | Core material | Additive element |         |      |       |      |      | Other impurity element |    |    |    |    |    | Pd layer<br>(Thickness nm) | Au layer<br>(Thickness nm) | Number of wires with bending of tail wire<br>(per 1,000 wires) |
|-----------------------|---------------|------------------|---------|------|-------|------|------|------------------------|----|----|----|----|----|----------------------------|----------------------------|----------------------------------------------------------------|
|                       |               | P                | Ni      | Pt   | Pd    | Au   | Ag   | Bi                     | Se | Te | Zn | Fe | Ni | Sn                         |                            |                                                                |
|                       | 6N Cu         | (mass ppm)       | (mass%) |      |       |      |      | (mass ppm)             |    |    |    |    |    |                            |                            |                                                                |
| Example 1             | Reminder      | 560              | 1.8     |      |       |      |      | 5                      | 5  | 5  | 5  | 5  | 5  | 5                          | -                          | 0                                                              |
| Example 2             | Reminder      | 80               | 0.2     |      |       |      |      | 5                      | 5  | 5  | 5  | 5  | 5  | 5                          | -                          | 0                                                              |
| Example 3             | Reminder      | 160              | 1.4     |      |       |      |      | 5                      | 5  | 5  | 5  | 5  | 5  | 5                          | -                          | 0                                                              |
| Example 4             | Reminder      | 400              | 0.3     |      |       |      |      | 5                      | 5  | 5  | 5  | 5  | 5  | 5                          | -                          | 0                                                              |
| Example 5             | Reminder      | 520              | 1.7     |      |       |      |      | 5                      | 5  | 5  | 5  | 5  | 5  | 5                          | -                          | 0                                                              |
| Example 6             | Reminder      | 320              | 1.8     |      |       |      |      | 5                      | 5  | 5  | 5  | 5  | 5  | 5                          | -                          | 0                                                              |
| Example 7             | Reminder      | 760              | 0.7     |      |       |      |      | 5                      | 5  | 5  | 5  | 5  | 5  | 5                          | -                          | 0                                                              |
| Example 8             | Reminder      | 680              | 0.6     |      |       |      |      | 5                      | 5  | 5  | 5  | 5  | 5  | 5                          | -                          | 0                                                              |
| Example 9             | Reminder      | 360              | 0.08    | 0.01 |       |      |      | 5                      | 5  | 5  | 5  | 5  | 5  | 5                          | -                          | 0                                                              |
| Example 10            | Reminder      | 120              | 1.3     |      | 0.100 |      |      | 5                      | 5  | 5  | 5  | 5  | 5  | 5                          | -                          | 0                                                              |
| Example 11            | Reminder      | 240              | 1.9     |      |       | 0.2  |      | 10                     | 10 | 10 | 10 | 10 | 10 | 10                         | -                          | 0                                                              |
| Example 12            | Reminder      | 280              | 1.6     |      |       |      | 0.15 | 10                     | 10 | 10 | 10 | 10 | 10 | 10                         | -                          | 0                                                              |
| Example 13            | Reminder      | 200              | 0.5     |      |       | 0.01 | 0.01 | 10                     | 10 | 10 | 10 | 10 | 10 | 10                         | 60                         | 0                                                              |
| Example 14            | Reminder      | 8                | 1.5     | 0.1  | 0.100 |      |      | 10                     | 10 | 10 | 10 | 10 | 10 | 10                         | 60                         | 0                                                              |
| Example 15            | Reminder      | 40               | 0.1     |      |       |      |      | 10                     | 10 | 10 | 10 | 10 | 10 | 10                         | 60                         | 0                                                              |
| Example 16            | Reminder      | 120              | 0.04    |      |       |      |      | 10                     | 10 | 10 | 10 | 10 | 10 | 10                         | 60                         | 0                                                              |
| Example 17            | Reminder      | 280              | 1.1     | 0.1  |       |      |      | 1                      | 1  | 1  | 1  | 1  | 1  | 1                          | 60                         | 0                                                              |
| Example 18            | Reminder      | 440              | 1.2     |      |       | 0.05 |      | 1                      | 1  | 1  | 1  | 1  | 1  | 1                          | 60                         | 0                                                              |
| Example 19            | Reminder      | 480              | 0.06    |      | 0.005 |      |      | 1                      | 1  | 1  | 1  | 1  | 1  | 1                          | 60                         | 0                                                              |
| Example 20            | Reminder      | 600              | 0.8     |      |       |      | 0.08 | 1                      | 1  | 1  | 1  | 1  | 1  | 1                          | 60                         | 0                                                              |
| Example 21            | Reminder      | 640              | 0.12    |      |       |      |      | 1                      | 1  | 1  | 1  | 1  | 1  | 1                          | 60                         | 0                                                              |
| Example 22            | Reminder      | 720              | 0.4     |      |       | 0.03 | 0.02 | 1                      | 1  | 1  | 1  | 1  | 1  | 1                          | 60                         | 0                                                              |
| Example 23            | Reminder      | 760              | 0.9     | 0.05 | 0.030 |      |      | 1                      | 1  | 1  | 1  | 1  | 1  | 1                          | 30                         | 0                                                              |
| Comparative Example 1 | Reminder      | 880              | 0.02    |      |       | 0.02 | 0.02 | 10                     | 10 | 10 | 10 | 10 | 10 | 10                         | -                          | 2                                                              |
| Comparative Example 2 | Reminder      | 12               | 2.6     |      |       |      |      | 0                      | 20 | 20 | 20 | 20 | 20 | 20                         | 60                         | 1                                                              |
| Comparative Example 3 | Reminder      | 40               | 1.5     |      | 0.400 |      | 1200 | 5                      | 5  | 5  | 5  | 5  | 5  | 5                          | 30                         | 1                                                              |

[0048]

In Table 1, Examples 1 to 8 are Examples according to claim 1 of the present invention. In addition, Examples 15 and 16 are Examples according to claim 2 of the present invention. Further, Example 21 is Example according to claim 3 of the present invention. On the other hand, Examples 9, 10, 14, 17, 19 and 23 are Examples according to claim 4 of the present invention. Examples 11 to 13, 18, 20 and 22 are Examples according to claim 5 of the present invention.

[0049]

(Bending Test of Bonding Wire and the like)

The bending test of a bonding wire was conducted as follows. That is, a wire bonder (manufactured by SHINKAWA LTD.: UTC-3000) was used to perform wedge bonding of 100 wires on a silver (Ag) plated copper (Cu) plate under a condition of 25°C, which is an ambient temperature, with an ultrasonic output of 100 mA, and with a bonding load of 90 gf. Then, after the wedge bonding was finished, as shown in Figure 1, a capillary (2) was raised and a bonding wire (1) was delivered at the tip of the capillary (2), and thereafter, a wire clasper (4) was closed, and then the capillary (2) and the wire clasper (4) were raised together, and the wire was cut in a state where a predetermined length of the bonding wire (1) was extended from the tip of the capillary (2), as shown in Figure 3. This was repeated 1,000 times, and the number of the bonding wires with bending was examined by using an enlarging projector. The result of this measurement is shown in the right column in Table 1. Meanwhile, the Young's modulus was also measured, and all the copper alloy wires showed high values.

[Comparative Examples]

[0050]

Bonding wires having compositions shown in Table 1 were used as Comparative Examples 1, 2 and 3. The wires of Comparative Example 1 and Comparative Example 2 have compositions where phosphorus (P) and nickel (Ni) are out of the range defined by the present invention. The wire of Comparative Example 3 has a composition where palladium (Pd) and gold (Au) are out of the range defined by the present invention. The bonding wires of these Comparative Examples 1 to 3 were subjected to the bending test of tail wire in a similar

manner to Examples, and the results are shown in the right column in Table 1.

[0051]

As apparent from these test results, with regard to each of the Examples according to the present invention, a high Young's modulus was exhibited and there was no wire with bending in the bending test of tail wire, and the results were extremely excellent. On the other hand, with regard to each of the wires of Comparative Examples 1 to 3, there was/were wire(s) with bending in the bending test.

[Industrial Applicability]

[0052]

The copper alloy fine wire for ball bonding according to the present invention is useful for semiconductor applications such as general ICs, discrete ICs, and memory ICs, as well as IC packages for LEDs which require low cost though the use is for a high-temperature and high-humidity atmosphere and IC packages for semiconductors for automobiles. Accordingly, the copper alloy fine wire for ball bonding according to the present invention will replace a conventional gold alloy wire.

[Brief Description of Drawings]

[0053]

[Fig. 1] is a cross section view of a bonding wire obtained by wedge bonding of the copper alloy fine wire according to the present invention.

[Fig. 2] is a perspective view which shows a step of the wedge bonding of a copper alloy fine wire.

[Fig. 3] is a schematic cross section view which shows a state of cutting immediately after the wedge bonding of a

copper alloy fine wire.

[Fig. 4] is a schematic cross section view of a bonding wire having J-shaped bending.

[Reference Signs List]

[0054]

- 1: Bonding wire
- 2: Capillary
- 3: Lead
- 4: Wire clamper

[Title of Document] Claims

[Claim 1] A copper alloy fine wire for ball bonding, comprising: 0.02 mass% or more and 2 mass% or less of nickel (Ni), 5 mass ppm or more and 800 mass ppm or less of phosphorus (P), less than 100 mass ppm in total of other base metal elements and the remainder of copper (Cu).

[Claim 2] A copper alloy fine wire for ball bonding, comprising: a core material made of a copper alloy which comprises 0.02 mass% or more and 2 mass% or less of nickel (Ni), 5 mass ppm or more and 800 mass ppm or less of phosphorus (P), less than 100 mass ppm in total of other base metal elements and the remainder of copper (Cu), wherein the core material made of the copper alloy is covered with a stretched layer made of palladium (Pd).

[Claim 3] A copper alloy fine wire for ball bonding, comprising: a core material made of a copper alloy which comprises 0.02 mass% or more and 2 mass% or less of nickel (Ni), 5 mass ppm or more and 800 mass ppm or less of phosphorus (P), less than 100 mass ppm in total of other base metal elements and the remainder of copper (Cu), wherein the core material made of the copper alloy is covered with a stretched layer made of palladium (Pd) and a stretched thin layer made of gold (Au).

[Claim 4] The copper alloy fine wire for ball bonding according to any one of claims 1 to 3, wherein the upper limit of said nickel (Ni) is 1 mass% or less.

[Claim 5] The copper alloy fine wire for ball bonding according to any one of claims 1 to 3, wherein the upper limit of said phosphorus (P) is 200 mass ppm or less.

[Claim 6] The copper alloy fine wire for ball bonding according

to any one of claims 1 to 3, wherein up to 30 mass% of nickel (Ni) taking the content of said nickel (Ni) as 100 mass% is replaced with palladium (Pd) or platinum (Pt).

[Claim 7] The copper alloy fine wire for ball bonding according to any one of claims 1 to 3, wherein up to 30 mass% of nickel (Ni) taking the content of said nickel (Ni) as 100 mass% is replaced with gold (Au) or silver (Ag).