

COPPER ALLOY BONDING WIRE

[Technical Field]

[0001]

The present invention relates to a copper alloy bonding wire suitable for bonding of an IC chip electrode and a substrate, such as an outer lead, used in a semiconductor device.

[Background Art]

[0002]

In general, the first bond of a copper bonding wire to an electrode uses a system called ball bonding, whereas the wedge bond of a copper bonding wire to the wiring on a circuit wiring board for a semiconductor uses a system called wedge bonding. In the first bond, a true sphere called free air ball (FAB) is formed at the tip of a wire by applying arc heat input to the tip of the wire from a torch electrode by an electronic flame off (EFO) system. Ultrasonic waves are applied while the FAB being pressed with a capillary onto an aluminum pad heated in a range of 150°C to 300°C to bond the bonding wire to the aluminum pad.

[0003]

Subsequently, the capillary is raised while pulling out the bonding wire and is moved to the wedge bond point while drawing a loop toward the lead. This will be described using drawings. In wedge bonding with a capillary, as shown in Fig. 1, bonding wire (1) is wedge bonded to lead (3). On this occasion, the end of the wedge bonded bonding wire (1) is crushed with the tip of the capillary (2). Consequently, as shown in Fig. 2, the area of the wire is the smallest at the bonding portion. Furthermore, the bonding wire (1) is then cut off. Therefore, the wire can be readily cut at the tip portion of the remaining bonding wire (1), as shown in Fig. 3, by grasping and pulling up the bonding wire (1) with a wire clasper (4) disposed above the capillary (2).

[0004]

Subsequently, the capillary is moved to the first bond point (not shown). Spark discharge is then performed at the position of a discharge torch to form a free air ball (FAB) at the tip of the bonding wire for first bonding the bonding wire and the aluminum pad. Such a bonding cycle is repeated, and the pad and the lead (3) are sequentially bonded via the bonding wire (1).

[0005]

The bonding wire (1) is crushed with the tip of the capillary (2) shown on the left side of Fig. 1, and the bonding wire (1) to be cut is deformed according to the intrinsic Young's modulus. There is a difference between such deformed shapes of gold (Au) and copper (Cu). The gold bonding wire is soft, but has a firm, fine structure. Accordingly, there is no problem of a J-like shape deformation described below.

[0006]

Similarly, a noble metal bonding wire having a double-core structure also does not have such a problem. Furthermore, a bonding wire utilizing a property of readily forming a wire having a cross-section of a double-core structure has been proposed. For example, Claim 4 of Japanese Patent Laid-Open No. 59-48948 (Patent Literature 1) discloses a gold bonding wire including "a wire having a fiber texture (111) in the core and a wire having a fiber texture (100) in the surface layer".

[0007]

Incidentally, a wire made of a pure copper (Cu) metal or copper (Cu) alloy has a peripheral portion and a central portion having different fiber textures according to the total reduction in area formed by performing continuous casting and then continuous wire drawing to be readily formed into a wire having a double-core cross-sectional structure. In a total reduction in area of 96% to 99%, the preferred orientations are $\langle 111 \rangle$ and $\langle 100 \rangle$ ("Drawing Process", edited by The Japan Society for Technology of Plasticity, 1990, p. 85 (Non Patent Literature 1)). This is regarded that stacking fault energy plays an

important role (N. Brown, Trans. Met. Soc. AIME, Vol. 221 (1961), p. 236). Accordingly, a wire made of pure copper or a copper alloy is usually subjected to process annealing. The time of the process annealing is important and is generally said that "the allowable limit of the primary wire drawing process is presumed to be about 95%" and that "it is important to insert a process annealing step to prevent creation of a {hkl} <111> orientation in the early stage of the secondary process" (Naotsugu Inakazu, et al., J. Japan Inst. Met. Mater. Vol. 47, No. 3, (1983), p. 266 (Non Patent Literature 2)).

[0008]

Claim 1 of Japanese Patent Laid-Open No. 2013-139635 (Patent Literature 2) discloses "an alloy wire made of at least one material selected from the group consisting of silver-gold alloys, silver-palladium alloys, and silver-gold-palladium alloys, wherein the alloy wire has a polycrystalline structure of a face-centered cubic lattice and contains a plurality of crystal grains; the central portion of the alloy wire contains long and thin crystal grains or isometric crystal grains; the other portion of the alloy wire is composed of isometric crystal grains; and the number of crystal grains containing annealing twin crystals is 20% or more of the total number of the crystal grains contained in the alloy wire".

[0009]

Claim 1 of Re-publication of PCT International Publication No. 2013-111642 (Patent Literature 3) also discloses "a bonding wire including a core mainly made of copper and a palladium stretched layer, wherein a fibrous texture of copper extending in the axial direction is present at the center of the core".

[0010]

Claim 1 of Japanese Patent Laid-Open No. 2004-31469 (Patent Literature 4) discloses "a gold bonding wire for a semiconductor device, wherein when the central region from the center to a distance by a half ($R/2$) of the radius R of the wire is defined as the central portion and when the region outside

the central portion is defined as the peripheral portion in the crystal grain texture of a cross section in the longitudinal direction of the bonding wire, the ratio R_c of the area of crystal grains having a [111] orientation to the area of crystal grains having a [100] orientation in the crystal orientations in the wire longitudinal direction in the central portion and the ratio R_s of the area of the crystal grains having a [111] orientation to the area of the crystal grains having a [100] orientation in the crystal orientations in the wire longitudinal direction in the peripheral portion have a relationship such that the absolute value of the differential proportion between the ratios R_s and R_c , $|1 - R_c/R_s| \times 100$ (%), is 30% or more".

[0011]

Furthermore, Claim 1 of Japanese Patent Laid-Open No. 2009-140942 (Patent Literature 5) proposes "a bonding wire for a semiconductor device including a core made of a conductive metal and a stretched thin layer, disposed on the core, mainly made of a metal different from that of the core, wherein the metal of the stretched thin layer has a face-centered cubic crystal structure in which the proportions of the $\langle 111 \rangle$ and $\langle 100 \rangle$ orientations to the crystal orientations $\langle hkl \rangle$ in the longitudinal direction in the crystal plane of the surface of the stretched thin layer are each less than 50%". Claim 1 of Japanese Patent Laid-Open No. 2009-158931 (Patent Literature 6) proposes "a bonding wire for a semiconductor device including a core made of a conductive metal and a stretched thin layer, disposed on the core, mainly made of a metal different from that of the core, wherein the metal of the stretched thin layer has a face-centered cubic crystal structure in which the proportion of the $\langle 111 \rangle$ orientation to the crystal orientations $\langle hkl \rangle$ in the longitudinal direction in the crystal plane of the surface of the stretched thin layer is 50% or more".

[0012]

However, some cases have a problem of slightly bending into a J-like shape, as shown in Fig. 4, when a copper (Cu) bonding wire is cut after wedge bonding.

[0013]

Even in copper bonding wires, if the wire diameter is large, such as 25 μm , the wires are not substantially deformed into a J-like shape. However, when the bonding speed is high in bonding wires having a diameter of less than 20 μm , wires deformed into a J-like shape are exposed. If a loop is drawn by the bonding wire having such a tip portion, the shape of the loop is distorted, and a spark current does not appropriately hit the tip of the bonding wire. Therefore, a flat heteromorphic ball of the FAB may be formed. If the deformation becomes serious, a Z-like shape deformation appears, as conventionally observed, instead of the J-like shape deformation.

[0014]

In a copper alloy bonding wire mainly composed of 10 to 500 ppm of phosphorus (P) and the remainder being copper (Cu) having a purity of 99.9% or more, an enriched layer of phosphorus (P) readily segregates on the surface of the bonding wire. Therefore, there is another problem of difficulty in achievement of homogeneous mechanical properties (Japanese Patent Laid-Open No. 7-122564).

[0015]

In order to solve these problems, conventionally, bonding apparatuses have been improved, but such a method did not work well. That is, conventionally, the wire clamper is closed after wedge bonding, and the bonding wire is slightly pulled upward. As a result, a part having a reduced diameter is formed in the bonding wire. The wire clamper is opened once in this state. Subsequently, the wire clamper is closed, and the wire is strongly pulled again to cut the bonding wire at the part having the reduced diameter (Japanese Patent Laid-Open No. 2007-66991 (Patent Literature 7)). Conventionally, defects in the mechanical properties of a bonding wire have been solved by such a wire clamper operation.

[0016]

However, in the conventional improvement in bonding

apparatuses, an additional operation for the wire clasper elongates the time for performing one bonding cycle. Consequently, in particular, a bonding wire having a small diameter of 20 μm or less considerably deteriorates the work efficiency of bonding.

[Citation List]

[Non Patent Literature]

[0017]

Non Patent Literature 1: "Drawing Process", edited by The Japan Society for Technology of Plasticity, 1990, p. 85

Non Patent Literature 2: Naotsugu Inakazu, et al., J. Japan Inst. Met. Mater. Vol. 47, No. 3, (1983), p. 266

[Patent Literature]

[0018]

Patent Literature 1: Japanese Patent Laid-Open No. 59-48948

Patent Literature 2: Japanese Patent Laid-Open No. 2013-139635

Patent Literature 3: Re-publication of PCT International Publication No. 2013-111642

Patent Literature 4: Japanese Patent Laid-Open No. 2004-31469

Patent Literature 5: Japanese Patent Laid-Open No. 2009-140942

Patent Literature 6: Japanese Patent Laid-Open No. 2009-158931

Patent Literature 7: Japanese Patent Laid-Open No. 2007-66991

[Summary of Invention]

[Technical Problem]

[0019]

The present invention has been made for solving the problem of deformation of the wire tip into a J-like shape in a wedge bonding step for a second bond when a copper alloy bonding wire is pulled up directly after wedge bonding and is cut within the shortest time. It is an object of the present invention

to provide a copper alloy bonding wire of which the cut end is not deformed into a J-like shape by restricting the crystal grain size and forming a non-oriented state.

[Solution to Problem]

[0020]

The causes of deformation into a J-like shape can be understood as follows, with reference to Fig. 1. A bonding wire (1) is wedge bonded to lead (3), and the capillary (2) is then raised. As a result, the bonding wire (1) is pulled out to the tip of the capillary (2). The bonding wire (1) is extended by a predetermined length from the tip of the capillary (2). The wire clamper (4) above the capillary (2) is then closed while retaining the bonding wire (1) in the extended state, and the wire clamper (4) and the capillary (2) are raised together.

[0021]

Consequently, the bonding wire (1) is stretched according to the Young's modulus and is then torn off by further rise. This cutting releases the elastic energy of the bonding wire (1). On this occasion, if the bonding wire (1) has a mechanically weak part between the wire clamper (4) and the cutting position, energy is concentrated at the weak part and the wire may be slightly bent into a J-like shape (spring back). The present inventors have found that this causes a slight bending of the bonding wire (1) into a J-like shape.

[0022]

The copper alloy bonding wire of the present invention for solving the above-mentioned problems is characterized in that a cross section of the bonding wire contains 50 to 250 crystal grains of a copper alloy, the crystal grains have a maximum grain size of one third or less of the diameter of the bonding wire, and the proportions of specific orientations, including $\langle 111 \rangle$ and $\langle 100 \rangle$ orientations, are each 40% or less to give a non-oriented state. Throughout the present invention, the term "specific orientation" refers to that the orientation is within an allowable angle of $\pm 20^\circ$ with respect to alignment in a certain orientation.

[0023]

One embodiment of the present invention is characterized in that the copper alloy is composed of 100 mass ppm or more and 3,000 mass ppm or less of gold (Au), 10 mass ppm or more and 1,000 mass ppm or less of silver (Ag), 5 mass ppm or more and 500 mass ppm or less of phosphorus (P), 100 mass ppm or less of total other impurity elements, and a remainder of copper (Cu).

[0024]

Another embodiment of the present invention is characterized in that the copper alloy is composed of 0.02% by mass or more and 1% by mass or less of nickel (Ni), palladium (Pd), or platinum (Pt), 5 mass ppm or more and 500 mass ppm or less of phosphorus (P), 100 mass ppm or less of total other impurity elements, and a remainder of copper (Cu).

[0025]

Another embodiment of the present invention is characterized in that a core of the copper alloy is coated with a palladium (Pd) stretched layer.

[0026]

Another embodiment of the present invention is characterized in that a core of the copper alloy is coated with a palladium (Pd) stretched layer and a gold (Au) stretched thin layer.

[0027]

Another embodiment of the present invention is characterized in that a cross section contains 80 to 200 crystal grains.

[0028]

Another embodiment of the present invention is characterized in that the maximum grain size is one fifth or less of the diameter of the bonding wire.

[0029]

Another embodiment of the present invention is characterized in that the proportions of specific orientations are each 38% or less to give a non-oriented state.

[0030]

In the present invention, a cross section contains 50 to 250 crystal grains of a copper alloy, which allows the bonding wire to be readily torn off along the grain boundary after wedge bonding even if a texture of a double core structure is formed in the longitudinal direction of the bonding wire. If the number of the crystal grains is less than 50, coarse crystal grains are readily formed in the bonding wire in the final refining heat treatment. In contrast, if the number of the crystal grains is larger than 250, the bonding wire becomes hard, resulting in unstable loop formation. The number of the crystal grains is preferably 80 to 240 and more preferably 100 to 220.

[0031]

In the present invention, the maximum grain size of the crystal grains is one third or less of the diameter of the bonding wire. If the bonding wire includes a large crystal grain, the wire is readily bent at the position of the large crystal grain. The bending of the bonding wire causes defects in leaning and in loop formation and wire sweep. The maximum grain size is preferably one fifth or less, more preferably one eighth or less, of the diameter of the bonding wire.

[0032]

In the present invention, the proportions of specific orientations are each 40% or less to give a non-oriented state, which prevents the bonding wire from forming a double core structure. If the proportion of a specific orientation, such as a $\langle 100 \rangle$ orientation, within a range from 0° to less than 20° is higher than 40%, the tearing-off of the bonding wire varies depending on whether the specific orientation is present or not. The proportion of the specific orientation is preferably 38% or less and more preferably 37% or less. The range of the specific orientation is determined to be less than 20° , instead of 15° , for collecting as much information as possible from a fine bonding wire.

[0033]

The copper alloy of the present invention is preferably composed of 100 mass ppm or more and 3,000 mass ppm or less of gold (Au), 10 mass ppm or more and 1,000 mass ppm or less of silver (Ag), 5 mass ppm or more and 500 mass ppm or less of phosphorus (P), 100 mass ppm or less of total other impurity elements, and a remainder of copper (Cu). The content of the phosphorus (P) is more preferably 200 mass ppm or less. Gold (Au) and silver (Ag) synergistically fix oxygen contained in the copper alloy ingot and can prevent segregation of phosphorus (P) at the surface. Accordingly, the coexistence of the three elements is particularly preferred. In addition, gold (Au) in the specified amount increases the Young's modulus of the copper alloy.

[0034]

The copper alloy of the present invention is preferably composed of 0.02% by mass or more and 1% by mass or less of nickel (Ni), palladium (Pd), or platinum (Pt); 5 mass ppm or more and 500 mass ppm or less of phosphorus (P); 100 mass ppm or less of total other impurity elements; and a remainder of copper (Cu). The content of phosphorus (P) is more preferably 200 mass ppm or less. Nickel (Ni) fixes to oxygen contained in the copper alloy ingot and can prevent segregation of phosphorus (P) at the surface. Nickel (Ni) in the specified amount is finely dispersed in the copper alloy matrix and fixes to oxygen. In addition, nickel (Ni) in the specified amount increases the Young's modulus of the copper alloy.

[0035]

Herein, the amount of total other impurity elements is regulated to 100 mass ppm or less for preventing formation of oxides of base metal elements in the copper alloy matrix. Formation of oxides of base metal elements at the grain boundaries of copper readily deforms the spring-backed bonding wire. The amount of total other impurity elements is preferably 50 mass ppm or less, and is more preferably 5 mass ppm or less when the cost of the ingot is ignored. For example, in the use of a copper ingot having a nominal purity of 6N (99.9999% by

mass) or more, the total amount of other metal elements is less than 1 mass ppm. The term "other impurity elements" refers to, for example, sulfur (S) and oxygen (O). The presence of 10 mass ppm of sulfur (S) hardens the FAB, which may cause tip cracking during first bonding. However, the content of sulfur (S) in the copper alloy for an ordinary bonding wire does not exceed 10 mass ppm.

[0036]

In the copper alloy of the present invention, the base material can be a copper alloy having a high purity of 4N to 6N. Such a base material usually contains 0.2 mass ppm or more and 50 mass ppm or less of oxygen. This oxygen amount in the copper alloy composition of the present invention does not substantially change even after, for example, re-melting and casting, primary wire drawing, intermediate heat treatment, secondary wire drawing, final heat treatment, and storage. If the copper (Cu) matrix contains oxygen, the base metal elements readily form oxides. Therefore, an amount of oxygen as less as possible is preferred. Incidentally, in a high-purity copper alloy, gas components are generally excluded (Shoji AOKI, et al., Copper and copper alloy, January, 2003, Vol. 42, No. 1, p. 21).

[0037]

In the present invention, the core of a copper alloy is preferably coated with a palladium (Pd) stretched layer. Furthermore, the core of a copper alloy is more preferably coated with a palladium (Pd) stretched layer and a gold (Au) stretched thin layer. In such a case, the bonding wire after wedge bonding is readily torn off. Herein, although the expression "stretched layer" or "stretched thin layer" does not necessarily express actual surface properties correctly, the area containing fine grains of palladium (Pd) or gold (Au) in the depth direction from the surface of the bonding wire is defined as a theoretical thickness and is conveniently expressed as a "layer" having a thickness. In the bonding wire of the present invention, the thickness is significantly small.

Accordingly, when the fine grains are detected by high-frequency inductively coupled plasma emission spectrometry (ICP-AES) from the surface of the bonding wire, it is regarded that there is a "stretched layer" or "stretched thin layer".

[0038]

In the copper alloy bonding wire of the present invention, even if the core is coated with a palladium (Pd) stretched layer or with a palladium (Pd) stretched layer and a gold (Au) stretched thin layer, since the thicknesses of these stretched layers are very small, the Young's modulus of the copper alloy core is not substantially affected by these layers. The palladium (Pd) stretched layer has an effect of delaying the oxidation of the copper alloy thin wire. When the gold (Au) stretched thin layer is coated, effects of fixing elements, such as sulfur (S), deposited on the surface from the copper alloy and of stabilizing the spark discharge of the palladium (Pd) stretched layer, which does not allow electrical current to flow easily, are provided.

[0039]

In the present invention, a known technology can be used for producing a thin wire in which a cross section contains 50 to 250 crystal grains of a copper alloy, the crystal grains have a maximum grain size of one third or less of the diameter of the thin wire, and the proportions of specific orientations, including $\langle 111 \rangle$ and $\langle 100 \rangle$ orientations, are each 40% or less to give a non-oriented state. A relationship between the primary/secondary wire drawing processes and the process annealing of high-purity copper is described in detail in, for example, "9.3 Nizikakosei to sen-i soshiki (Secondary workability and fiber structure)" in Chapter 9 "Saikessyo sen-i syugo soshiki to nizikako ni oite (In recrystallization fiber aggregate structure and secondary working)" of "Kinzoku hikinuki (Metal Drawing)" written by Naotsugu Inakazu, published by Kindai Hensyu-sha on July 1, 1985 (Showa 60). In the wire drawing process of a bonding wire, the final reduction of area

stated in this book is 99% or more, and refining heat treatment is further performed. In the present invention, intermediate annealing is appropriately performed at a primary wire-drawing rate of 95% to 99.99% to produce a copper alloy bonding wire of the present invention.

[Advantageous Effects of Invention]

[0040]

The copper alloy bonding wire of the present invention is cut at the thinnest position of the bonding wire formed during wedge bonding. As a result, the tip of the bonding wire is prevented from bending into a J-like shape. Thus, the present invention has an effect of providing a copper alloy bonding wire of which the cut end does not protrude from a cross section of the bonding wire. The stabilization of the shape of a bonding wire has an effect of preventing the FAB in the first bonding from becoming a heteromorphic ball. Furthermore, the bonding wire can be easily cut only by pulling the bonding wire upward and also therefore has an effect of shortening the time for the bonding. In addition, the effects of the present invention can be more exhibited by further reducing the wire diameter from 20 μm to 15 μm .

[0041]

In the copper alloy bonding wire according to an embodiment of the present invention, since no base metal oxide is dispersed in the copper matrix, the wire itself is flexible. In addition, since the position of the spark discharge in the first bonding is also stabilized, the copper alloy has an effect of stabilizing the FAB in the first bonding, even if the thickness of the palladium (Pd) stretched layer or the thicknesses of the palladium (Pd) stretched layer and gold (Au) stretched thin layer are smaller than those of conventional layers.

[0042]

Furthermore, in the copper alloy bonding wire according to an embodiment of the present invention, the wire does not attach to the surface of the multiply wound wire, even if the

wire is 10,000 meters long, by disposing a gold (Au) stretched layer on the outermost surface of the wire. As a result, the wire has excellent rewinding properties. In addition, an increased smoothness of the wire surface against the capillary is achieved as an accompanying effect. In the copper alloy bonding wire of the present invention, the gold (Au) fine grains on the outermost surface of the wire do not detached from the palladium (Pd) stretched layer. Accordingly, oxide of copper (Cu) does not attach to the capillary and does not contaminate the capillary, even if bonding is repeated a large number of times.

[Examples]

[0043]

Copper (Cu) having a purity of 99.9998% by mass (5N) was used as the core material. Phosphorus (P), nickel (Ni), palladium (Pd), platinum (Pt), gold (Au), and silver (Ag) were used as additional elements. Elements that are usually contained in high-purity copper were selected as base metal elements. That is, bismuth (Bi), selenium (Se), tellurium (Te), zinc (Zn), iron (Fe), nickel (Ni), and tin (Sn) were appropriately selected. These elements were blended at predetermined ratios in Examples 1 to 5.

[0044]

Subsequently, the mixtures were each molten and subjected to continuous casting, followed by primary wire drawing with a reduction in area of 95% to 99.99% to prepare a thick wire (diameter: 1.0 mm) before being coated with a stretching material. Subsequently, intermediate heat treatment (at 300°C to 600°C for 0.5 to 3 hours) was performed (Examples 4 and 5) or was not performed (Examples 1 to 3). Then, optionally, a gold (Au) stretched thin layer (Examples 4 and 5) or a palladium (Pd) stretched layer (Examples 3 to 5) was disposed. These semi-processed wires were subjected to wet-type continuous secondary wire drawing with a reduction in area of 99% or more using a diamond die and then to refining heat treatment at 480°C for 1 second to prepare a copper alloy bonding wire having a

final diameter of 15 μm . The average diameter reduction rate was 6% to 20%, and the final linear velocity was 100 to 1000 m/min. The gold (Au) had a purity of 99.9999% by mass or more, and the palladium (Pd) had a purity of 99.999% by mass or more.

[0045]

[Table 1]

	Core material	Additional element (mass ppm)				Other impurity element (mass ppm)						Pd layer (Thickness: nm)	Au layer (Thickness: nm)	Number of crystal grains	Preferred orientation (%)	Number of bending into J-like shape (per 100 wires)	Number of protrusion from cross section (per 1000 wires)
		P	Au	Ag	Bi	Se	Te	Zn	Fe	Ni	Sn						
Example 1	remainder	45	450	25	5	5	5	5	5	5	5	–	–	205	<100>(37%)	0	0
Example 2	remainder	180	1200	45	10	10	10	10	10	10	10	–	–	103	<100>(35%)	0	0
Example 3	remainder	10	200	550	10	10	10	10	10	10	10	60	–	230	<100>(35%)	0	0
Example 4	remainder	60	600	55	1	1	1	1	1	1	1	60	1	170	<100>(38%)	0	0
Example 5	remainder	199	1450	850	1	1	1	1	1	1	1	30	1	65	<100>(36%)	0	0
Comparative Example 1	remainder	400	120	450	10	10	10	10	10	10	10	–	–	13	<100>(57%)	5	8
Comparative Example 2	remainder	2	70	0	20	20	20	20	20	20	20	60	–	Countless	<111>(45%)	3	14

(Measurement of crystal grains)

[0046]

The number of crystal grains in a cross section of a bonding wire was measured as follows: The bonding wire of Example 1 was cut with an ion milling apparatus (model: IM 4000, manufactured by Hitachi High-Technologies Corporation). Subsequently, the cross section was observed with an FE-SEM (JSM-7800F, manufactured by JEOL Ltd.). The number of crystal grains in the cross section was counted with an EBSD apparatus (OIM Data Collection System, manufactured by TSL). The results of the measurement are shown in right column of Table 1.

(Measurement of orientation)

[0047]

The orientation of a bonding wire was measured with an FE-SEM (JSM-7800F, manufactured by JEOL Ltd.) and an EBSD apparatus (OIM Data Collection System, manufactured by TSL). The results of the measurement are shown in the right column of Table 1.

(Bending test of bonding wire)

[0048]

A bending test of a bonding wire was performed as follows: A hundred wires were wedge bonded to a silver (Ag) plated copper (Cu) plate with a wire bonder (UTC-3000, manufactured by Shinkawa Ltd.) at an ambient temperature of 25°C under

conditions of a ultrasonic power of 100 mA and a bonding load of 90 gf. After completion of the wedge bonding, as shown in Fig. 1, the capillary (2) was raised to pull out the bonding wire (1) at the tip of the capillary (2). The wire clasper (4) was then closed, and the capillary (2) and the wire clasper (4) were then raised together to cut the wire in a state that a predetermined length of the bonding wire (1) was extended from the tip of the capillary (2). This procedure was repeated 1000 times, and the number of bent bonding wires was investigated with an enlarging projector. The results of the measurement are shown in the right column of Table 1.

[Comparative Examples]

[0049]

The compositions of the bonding wires of Comparative Examples 1 and 2 are shown in Table 1. The wires of Comparative Examples 1 and 2 each contained crystal grains of which numbers were outside the definition in the present invention and respectively had intrinsic preferred orientations. That is, in the wire of Comparative Example 1, the temperature for intermediate heat treatment was higher than that in the wire of Example 5, and the number of crystal grains was small, i.e., 13, and the proportion of the preferred orientation $\langle 100 \rangle$ was 57% of the total orientations. In the wire of Comparative Example 2, the reduction in area in the primary wire drawing process was higher than that in the wire of Example 3, and no crystal grains were observed. This result is shown as "countless". In addition, the proportion of the preferred orientation $\langle 111 \rangle$ was 45% of the total orientations, and the proportion of the preferred orientation $\langle 100 \rangle$ was 10% of the total orientations.

[0050]

The bonding wires of Comparative Examples 1 and 2 were subjected to measurement of crystal grains, measurement of orientation, and bending test and protrusion test of bonding wires, as in Examples. The results are shown in the right column of Table 1.

[0051]

As obvious from these results of the tests, in all examples of the present invention, the bonding wire contained appropriate particle grains and did not have a preferred orientation. The tip of the bonding wire was therefore not bent into a J-like shape. In contrast, the tips of 8 bonding wires of Comparative Example 1 and 14 bonding wires of Comparative Example 2 were bent into a J-like shape. It was thus demonstrated that the wires of Comparative Examples also affect the FAB.

[Industrial Applicability]

[0052]

The copper alloy bonding wire of the present invention can replace conventional gold alloy wires and can be applied to not only versatile ICs, discrete ICs, and memory ICs but also semiconductors, such as IC packages for LEDs or for automobile semiconductors, which are required to be low cost regardless of being used under high-temperature and high-humidity.

[Brief Description of Drawings]

[0053]

[Fig. 1] Fig. 1 is a cross-sectional view of a bonding wire prepared by wedge bonding of a copper alloy thin wire of the present invention.

[Fig. 2] Fig. 2 is a perspective view illustrating the step of wedge bonding a copper alloy thin wire.

[Fig. 3] Fig. 3 is a cross-sectional view illustrating a bonding state prepared by wedge bonding of a copper alloy thin wire.

[Fig. 4] Fig. 4 is a cross-sectional view of a bonding wire bent in a J-like shape.

Reference Signs List

[0054]

- 1 bonding wire
- 2 capillary
- 3 lead
- 4 wire clamper

CLAIMS

[Claim 1]

A copper alloy bonding wire having a wire diameter of 15 μm or more and 20 μm or less, wherein

the copper alloy is composed of 100 mass ppm or less of total impurity elements and the remainder of copper (Cu), where the impurity elements include multiple elements consisting of bismuth (Bi), selenium (Se), tellurium (Te), zinc (Zn), iron (Fe), nickel (Ni), and tin (Sn) in a total amount of 7 mass ppm or more and 70 mass ppm or less; a cross section of the bonding wire cut perpendicularly to the longitudinal direction contains 50 to 250 crystal grains of the copper alloy when measured at a high-angle grain boundary of 20° ; the crystal grains have a maximum grain size of one third or less of the diameter of the bonding wire; and proportions of every specific orientation are each 40% or less.

[Claim 2]

A copper alloy bonding wire having a wire diameter of 15 μm or more and 20 μm or less, wherein

the copper alloy is composed of 100 mass ppm or more and 3,000 mass ppm or less of gold (Au), 10 mass ppm or more and 1,000 mass ppm or less of silver (Ag) or 5 mass ppm or more and 500 mass ppm or less of phosphorus (P), 100 mass ppm or less of total impurity elements, and a remainder of copper (Cu), where the impurity elements include multiple elements consisting of bismuth (Bi), selenium (Se), tellurium (Te), zinc (Zn), iron (Fe), nickel (Ni), and tin (Sn) in a total amount of 7 mass ppm or more and 70 mass ppm or less; a cross section of the bonding wire cut perpendicularly to the longitudinal direction contains 50 to 250 crystal grains of the copper alloy when measured at a high-angle grain boundary of 20° ; the crystal grains have a maximum grain size of one third or less of the diameter of the bonding wire; and the proportions of every specific orientation are each 40% or less.

[Claim 3]

The copper alloy bonding wire according to Claim 1 or 2, wherein a core of the copper alloy is coated with a palladium (Pd) stretched layer.

[Claim 4]

The copper alloy bonding wire according to Claim 1 or 2, wherein a core of the copper alloy is coated with a palladium (Pd) stretched layer and a gold (Au) stretched thin layer.

[Claim 5]

The copper alloy bonding wire according to Claim 1 or 2, wherein the cross section contains 80 to 200 crystal grains.

[Claim 6]

The copper alloy bonding wire according to Claim 1 or 2, wherein the maximum grain size is one fifth or less of the diameter of the bonding wire.