

Specification
COPPER-PLATINUM ALLOY WIRE FOR CONNECTION IN
SEMICONDUCTOR DEVICE

Technical Field

[0001]

The present invention relates to a copper alloy wire to be used for connecting a pad electrode on a semiconductor element and an external electrode to each other by ultrasonic-aided thermocompression bonding and, particularly, to a copper-platinum alloy wire in which a small amount of platinum (Pt) is solid-soluted in a matrix rich in copper (Cu) having purity of 99.995 mass% or more.

Background Art

[0002]

Along with the recent rise in gold price, a copper alloy wire is attracting attention again as a substitute for the 4N gold alloy wire which has heretofore been used.

In the conventional ultrasonic-aided thermocompression bonding adopted to the conventional copper alloy wire, a ball is formed by way of a surface tension by heat-melting a tip of the copper alloy bonding wire through arc heat input while maintaining the wire on an aluminum pad under a non-oxidizing atmosphere such as nitrogen gas atmosphere and a hydrogen-mixed nitrogen gas atmosphere, and then the ball portion of the wire is pressed with a superhard tool against the electrode of a

semiconductor element which is heated within the range of 150°C to 300°C to attain bonding of the copper alloy wire to the aluminum pad by way of the pressing load and energy of ultrasonic wave vibration from the superhard tool.

The effects of the ultrasonic wave application are enlargement of a bonding area for promoting modification of the copper alloy wire and achievement of interatomic bonding between the copper alloy wire and the aluminum pad while progressively enlarging newly-formed surfaces which are in close contact with each other by exposing metal atoms of copper (Cu) and the like at a lower surface through destruction and removal of a surface oxide film of about 100 nm formed on a surface of the copper-platinum alloy wire and by generating a plastic flow on an interface between the surface of the copper-platinum alloy wire and the bonding pad facing to and contacting the surface.

Also, in the ultrasonic wedge bonding adopted to the conventional copper alloy wire, a bonding wire in the form of a loop is positioned on a conductive wiring on a lead frame, and then the bonding wire is wedge-bonded to the conductor of the lead frame by way of ultrasonic vibration which is applied at a room temperature in the state where a superhard tool is pressed against the bonding wire from above in such a manner as to press the bonding wire against the conductor wiring on the lead frame. Subsequently, the wire is clamped, and the bonding wire is moved upward together with the superhard tool to be cut.

The semiconductor element and the lead frame are connected to each other by performing the first bonding and the second bonding.

[0003]

Examples of the copper-rich alloy wires in which a noble metallic element such as platinum (Pt) is solid-soluted in copper (Cu) include those mentioned below, but, since it is difficult to control oxygen (O) in copper (Cu), they have a problem that the second bonding is not satisfactorily performed due to oxidization irregularity caused on a surface of the copper alloy wire.

More specifically, since the irregularity in thickness of the oxide film is formed, the thick part of the oxide film is not decomposed by the application of ultrasonic vibration to undesirably raise the necessity of increasing the bonding area for the purpose of ensuring bonding strength and to cause the problem of unstable second bonding strength when a wire diameter is less than 20 μm .

[0004]

One of the examples of the above-described copper alloy wire is Japanese Examined Patent Application Publication No. 5-20493 (listed as Patent Literature 1 below). The copper alloy wire is "capable of suppressing generation of H_2 , O_2 , N_2 , and CO gases by fixing H, O, N, and C in the alloy" since 0.01 to 2 wt% of 24 elements (a rare earth element is counted as one element) such as

magnesium (Mg), hafnium (Hf), and platinum (Pt) are contained in copper (Cu) (upper right column on page 2 of the publication). However, the technology of controlling the oxide film on the surface of the copper-rich alloy wire is not disclosed at all.

[0005]

Another one of the examples is Japanese Unexamined Patent Application Publication No. 2008-085320 (listed as Patent Literature 2 below). The publication describes a copper alloy bonding wire for semiconductor device characterized in that high purity copper contains at least one of Mg and P in a total amount of 10 to 700 mass ppm, at least one of Ag, Pd, Pt, and Au in a total amount of 10 to 5000 mass ppm, and 6 to 30 mass ppm of oxygen (claim 2 of the publication), which improves a ball binding shape and bonding strength by controlling oxygen on an oxide film on a wire ball surface.

The prior art controls oxygen (O) contained in the copper-rich alloy by way of the additive element as in the formerly mentioned prior art and does not disclose the technology of controlling the oxide film on the copper alloy wire surface at all.

[0006]

As can be seen from the above examples, the conventional copper alloy bonding wires eliminate oxygen (O) which is the non-metal component from the copper (Cu) matrix by incorporating the predetermined alloy-forming

component(s) .

As a result, the oxide film on the copper alloy wire surface has generally been removed by ordinary chemical etching or a high temperature treatment under a reductive atmosphere. Therefore, since various oxide films are formed when the clean copper alloy wire surface is subjected to a heat treatment or left in the atmosphere as a post-treatment, the problem of the unstable oxide film on the copper alloy wire surface has been left unsolved.

Citation List

Patent Literatures

[0007]

Patent Literature 1: Japanese Examined Patent
Application Publication No. 5-20493

Patent Literature 2: Japanese Unexamined Patent
Application Publication No. 2008-085320

Summary of Invention

Technical Problem

[0008]

An object of the present invention is to provide a copper-platinum alloy bonding wire which is excellent in second bonding property and long term bonding stability by forming a thin oxide film having a uniform thickness on a surface of the copper-platinum alloy bonding wire as well as prevention of chip breakage and aluminum splash included among first bonding properties by ball bonding and improvement in leaning property.

Solution to Problem

[0009]

The inventors found that there is a tendency that continuous casting of an element wire of a copper-platinum binary alloy wire brings about a structure in which copper (Cu) is precipitated in a superficial layer of the copper-platinum binary alloy to cause a remarkably low concentration of platinum (Pt), and the platinum (Pt) concentration is gradually increased from the surface toward the central part. Further, it was found that, though copper oxide having a uniform thickness is rapidly formed when copper (Cu) contained in the superficial layer is oxidized in the atmosphere, progress of the oxidization is prevented by the presence of platinum (Pt) inside the copper-platinum binary alloy wire. Since it is possible to control the thickness of the oxide film of copper (Cu) which is formed as described above in the superficial layer by controlling the additive amount of platinum (Pt), it is possible to provide a copper-platinum alloy bonding wire which is excellent in second bonding property.

[0010]

The method of producing the conventional copper bonding wire is the same as that of the ordinary copper bar materials and wire materials, wherein a billet obtained by ingot casting or a large-diameter continuously cast material is cut into pieces and then sequentially subjected to drawing processing to reduce the diameter until a

predetermined diameter of the order of micrometers is achieved.

In such a production process, since a thickness of an oxide layer on a surface after the casting is relatively thick to inhibit the subsequent drawing processing, it is necessary to remove the oxide layer by a cutting or acid washing process step. The oxide layer is removed together with a copper layer which is a superficial layer, so that concentrations of impurities and the like are almost the same in a cross-sectional direction of the wire material.

The segregation found by the inventors was observed in the course of producing an element wire having a diameter of 10 mm or less directly by continuous casting, and, since the element wire is formed into a bonding wire having a desired diameter by drawing processing without performing acid washing or the like for removing a surface layer, the segregation structure generated in the course of setting during the formation of element wire is maintained as it is.

Therefore, in the cast element wire, the oxide layer is formed upon contact with the atmosphere after the setting as a result of oxidization of copper (Cu) in the superficial layer in which platinum (Pt) is scarcely contained, and, though oxidization from the outside proceeds when the oxide layer formed on the element wire just after the casting is thinned depending on a processing degree of the wire drawing processing in the course of

obtaining a bonding wire through the wire drawing processing, an oxidized region of the thus-formed oxide layer remains within a certain range corresponding to the platinum (Pt) concentration to maintain an oxide film thickness even and uniform.

[0011]

Though the details of the mechanism have not been clarified, in view of the concentration distributions of copper (Cu) and platinum (Pt) which were measured in a direction from the surface toward the interior of the element wire, the purity of the segregated copper (Cu) layer formed on the element wire surface is considerably high. Therefore, the uniformly dense and very thin oxide layer in which the high purity copper (Cu) strongly bonded to oxygen is formed in the outermost layer, and the oxide layer suppresses invasion of oxygen into the internal part. Simultaneously, in the copper (Cu) matrix below the oxide layer, platinum (Pt) further suppresses the invasion of oxygen into the internal part to maintain the thickness of the oxide layer to be even and constant during the subsequent wire drawing processing and till a bonding wire having a predetermined diameter is obtained.

[0012]

Further, in the present invention, additive amounts of oxygen (O), sulfur (S), and phosphorus (p) which are non-metallic elements are investigated in order to prevent the copper-platinum alloy bonding wire from becoming too

hard when a compression-bonded ball of the first bonding is formed.

More specifically, the inventors noted sulfur (S) which has heretofore been excluded as an impurity of copper (Cu) and, in order to prevent precipitation of sulfur (S) on the copper (Cu) ball surface during molten ball formation, fixed sulfur (S) in the copper (Cu) matrix by solid-soluting oxygen (O) which is the non-metallic component in addition to platinum (Pt) which is the metallic component into copper (Cu). As a result, when the molten ball is subjected to ultrasonic-aided thermocompression bonding, processing hardening does not occur during the compression-bonded ball deformation of the wire to prevent enhancement in dynamic strength. Further, static strength of the bonding wire is reduced by reducing hardness of the bonding wire by a refining heat treatment.

Also, as a result of solid-soluting sulfur (S) and oxygen (O) as well as phosphorus (P) as required in the matrix within suppressed concentration ranges, the static strength and the dynamic strength by the additive elements which are solid-soluted and fixed in the matrix together with platinum (Pt) configuring the matrix are controlled, and, simultaneously, flexibility (toughness) of the wire is improved.

[0013]

A copper-platinum alloy wire to be used for ball bonding in semiconductor device of the present invention is

a copper-platinum binary alloy wire for semiconductor device comprising platinum (Pt) with the balance being copper (Cu) having purity of 99.995 mass% or more and obtainable by continuous wire drawing, wherein 0.1 to 2.0 mass% of platinum (Pt) as a metallic element and 1 to 10 mass ppm of sulfur (S) and 10 to 150 mass ppm of oxygen (O) as non-metallic elements are solid-soluted in a copper (Cu) matrix of the copper-platinum alloy wire, and a uniformly thin oxide film of 6 nm or less covers a surface layer.

[0014]

Also, the copper-platinum alloy wire to be used for ball bonding in semiconductor device of the present invention is a copper-platinum binary alloy wire for semiconductor device comprising platinum (Pt) with the balance being copper (Cu) having purity of 99.995 mass% or more and obtainable by continuous wire drawing, wherein 0.1 to 2.0 mass% of platinum (Pt) and 1 to 5 mass ppm of phosphorus (P) as metallic elements and 1 to 10 mass ppm of sulfur (S) and 10 to 150 mass ppm of oxygen (O) as non-metallic elements are solid-soluted in a copper (Cu) matrix of the copper-platinum alloy wire, and a uniformly thin oxide film of 6 nm or less covers a surface layer.

[0015]

It has been known that platinum (Pt) has the property of preventing oxidization of copper (Cu) with a small amount. However, it has not been revealed that the property is prominently exhibited when purity of copper

(Cu) is increased as a result of copper (Cu) precipitation in a surface layer during setting of the copper-platinum binary alloy element wire. Therefore, in the present invention, a cast article after continuous casting is subjected to atmospheric cooling while maintaining a high temperature state by taking advantage of the above-described property to form the uniformly thin copper (Cu) film on the surface of the copper-platinum binary alloy wire. A change in film thickness of the thin copper (Cu) film was not observed when an intermediate heat treatment was performed as a post-treatment.

[0016]

Also, in the present invention, platinum (Pt) controls the behavior of sulfur (S) in the copper (Cu) matrix together with oxygen (O). The range of platinum (Pt) is set to 0.1 to 2.0 mass% since it is difficult to prevent progress of oxidization of copper (Cu) when the amount is less than 0.1 mass%, while aluminum splash and chip breakage are caused due to excessively high dynamic strength when the amount exceeds 2.0 mass%.

The platinum (Pt) concentration ranges correspond to the thickness of the oxide film (6 nm to 2 nm) shown in Fig. 3 as described later in this specification.

In order to stabilize bonding characteristics of the bonding wire of the present invention, the range of platinum is preferably 0.1 to 0.8 mass%, more preferably 0.1 to 0.3 mass%.

[0017]

In the present invention, sulfur (S) is added in the amount of 1 to 10 mass ppm in order to impart flexibility (toughness) to the bonding wire. It is difficult to impart flexibility (toughness) when sulfur (S) is less than 1 mass ppm, while chip breakage occurs during ball bonding due to sulfur (S) surface segregation when sulfur (S) exceeds 10 mass ppm.

Also, since sulfur (S) allows dynamic recrystallization during deformation of the wire during molten ball bonding to suppress working hardening to a relatively low level even when the wire is plastically deformed, chip breakage is reduced compared to when bonding wire does not include sulfur (S).

[0018]

Also, in the present invention, oxygen (O) is added in the amount of 10 to 150 mass ppm in order to control the behavior of sulfur (S) in the copper (Cu) matrix in cooperation with platinum (Pt). The effect is not attained when oxygen (O) is less than 10 mass ppm, while an oxide film is readily formed on a ball surface during molten ball formation when oxygen (O) exceeds 150 mass ppm. In order to ensure the control on the behavior of sulfur (S), the content of oxygen (O) is preferably larger than that of sulfur (S).

[0019]

Further, in the present invention, 1 to 5 mass ppm of

phosphorus (P) is preferably solid-soluted in the copper (Cu) matrix. When 1 to 5 mass ppm of phosphorus (P) is contained in the copper (Cu) matrix, movement of oxygen (O) is limited so that the flexibility (toughness) of the bonding wire is enhanced. The effect is not attained when phosphorus is less than 1 mass ppm, while a balance between sulfur (S) and oxygen (O) is lost when phosphorus (P) exceeds 5 mass ppm.

[0020]

Examples of impurity elements in copper (Cu) having purity of 99.995 mas% or more in the present invention includes silver (Ag), iron (Fe), nickel (Ni), lead (Pb), tin (Sn), antimony (Sb), arsenal (As), bismuth (Bi), chromium (Cr), and the like.

The purity of copper (Cu) is preferably 99.998 mass% or more in order to enable the copper (Cu) matrix to exhibit dynamic strength and flexibility (toughness).

[0021]

In the present invention, Vickers hardness of the copper-platinum alloy wire subjected to a refining heat treatment after continuous wire drawing is preferably 77 to 105 Hv. Since the additive amount of platinum (Pt) is relatively large, a higher Vickers hardness value causes increases in static strength and dynamic strength of the copper-platinum alloy wire after the continuous wire drawing, thereby causing aluminum splash and chip breakage. The Vickers hardness is more preferably 75 to 85 Hv.

A temperature of the refining heat treatment may appropriately be selected depending on a composition of the copper-platinum alloy wire, and the refining heat treatment is generally performed at 300°C to 500°C for several seconds under a non-oxidizing atmosphere. Since the wire is subjected to the cold continuous wire drawing before the refining heat treatment, a copper (Cu) matrix structure of fine recrystallization in which strain is relaxed is formed by the refining heat treatment. The refining heat treatment temperature is decided depending on a reduction in area (ratio of a wire diameter before wire drawing to a wire diameter after the wire drawing) of the continuous wire drawing. Further, wire drawing strain may be eliminated by performing the refining heat treatment while applying certain tension to the copper-platinum alloy wire after continuous wire drawing.

The continuous wire drawing is preferably cold working of 90% or more of the wire diameter before continuous wire drawing in order to form a wire-drawn structure from a cast structure in the bonding wire. More preferably, cold working of 99% or more of the wire diameter is performed. The continuous wire drawing is preferably wire drawing through dies, particularly preferably wire drawing through diamond dies. It is possible to readily form elongated fine recrystallized structures arranged in a concentric pattern by the drawing.

In the present invention, it is unnecessary to

perform an intermediate heat treatment of the element wire before the continuous wire drawing. It is known to perform the intermediate heat treatment at a temperature of 400°C to 800°C for 60 to 180 minutes under a non-oxidizing atmosphere, but the thickness of the copper (Cu) thin film or the oxide film once formed on the surface of the copper-platinum alloy thick wire is hardly or never changed.

Advantageous Effects of Invention

[0022]

Since the bonding wire of the present invention comprises 0.1 to 2.0 mass% of platinum (Pt) as the metallic element in the copper (Cu) matrix, the oxide film on the surface of the copper-platinum alloy wire is thin, and a molten ball is not hardened by the oxide film when the molten ball is formed during first bonding.

Also, since the oxide film thickness once formed on the wire surface is uniform and stable as described above, the copper-platinum alloy bonding wire of the present invention is stably bonded by ultrasonic bonding of a constant output in second bonding.

Since sulfur (S) and oxygen (O) as the non-metallic elements are fixed, the bonding loop is smoothly formed owing to the flexibility (toughness) of the bonding wire, and bonding strength after the bonding is stabilized for a long time.

Since an element which is more easily oxidized by copper (Cu) is not added in the bonding wire of the present

invention, it is possible to fix oxygen (O) in the copper (Cu) matrix, and, therefore, chip breakage is not caused by surface oxidization during the molten ball formation. Further, since surface segregation of sulfur (S) does not occur during the molten ball deformation, the dynamic strength is not increased, and a unit load to be applied on the chip from the wire during plastic deformation is not increased, thereby preventing the chip breakage. Also, phosphorus (P) is bonded to oxygen (O) to cause a flux action for the copper-platinum alloy wire.

Brief Description of Drawing

[0023]

Fig. 1 is a graph showing measurement results of concentration distributions of copper (Cu) and platinum (Pt) from a surface toward an interior of an element wire of Example (No. 3).

Fig. 2 is a graph showing a measurement result of a concentration distribution of oxygen from the surface toward the interior of the element wire of Example (No. 3).

Fig. 3 is a graph showing a relationship between a platinum concentration and an oxide film thickness on a wire surface.

Description of Embodiments

[0024]

As Examples 1 to 30 and Comparative Examples 1 to 6, copper alloy thick wires each having a diameter of 5 mm were prepared by melting alloys of compositions shown in

Table 1 and performing continuous casting.

From a surface of the copper-platinum alloy thick wire of Example 1, concentrations of platinum (Pt) and copper (Cu) (Fig. 1) and oxygen (O) were measured respectively by a SIMS mass spectrometer. The horizontal axis of the graph indicates a depth (μm) from the thick wire surface, and the vertical axis indicates relative secondary ion intensity (log) of the depth.

According to Fig. 1, platinum (Pt) is not present on the surface layer and has lower relative secondary ion intensity than a matrix of a solid solution until 50 nm. In contrast, it is apparent that copper (Cu) has the remarkably high purity near the surface.

According to Fig. 2, oxygen (O) is reduced linearly from the surface layer to 50 nm and does not invade further toward the center from 50 nm. It is considered that the oxide film thickness is about 0.05 μm (50 nm) from the drawing.

Next, the copper-platinum alloy thick wire of Example 3 was subjected to an intermediate heat treatment. The intermediate heat treatment was performed at a temperature up to 500°C for 120 minutes, followed by quenching in water. The surface oxide film thickness was measured in the same manner to find that there was little or no change in thickness.

Shown in Fig. 3 is a result of measurement of a relationship between the platinum (Pt) concentration and

the oxide layer thickness of a bonding wire having a diameter of 17 μm obtained by performing wire drawing of the thick wire.

The oxide film thickness is sharply reduced along with the increase in platinum (Pt) concentration from the oxide film thickness of 10 nm when the platinum (Pt) concentration is 0. After that, the curve becomes flatter, and the oxide film thickness is almost saturated at 2 nm in the region where the platinum concentration is 1 to 2 mass%.

As described later in this specification, the practical effects of the present invention are exhibited when the oxide film thickness is 6 to 2 nm.

[0025]

The wire of each of Examples and Comparative Examples was subjected to cold continuous wire drawing, followed by a refining heat treatment at 400°C for less than one second, thereby obtaining a bonding wire having a diameter of 17 μm . Vickers hardness of each of the bonding wires after the refining heat treatment was measured by using a Vickers hardness meter (MVK-G3, product of Akashi Co. Ltd.). The Vickers hardness value is the hardness of the bonding wire when a drawing ratio was 4%.

[0026]

(Thermocompression Bonding-Aided Ultrasonic Bonding Conditions)

A wire diameter of the copper alloy wire was 17 μm , a

loop length was 5 mm, and a loop height was 170 μm . Ball bonding of the copper alloy wire on an 0.5 mass%-aluminum (Al)-copper (Cu) alloy film having a thickness of 0.8 μm which was plated on a chip (thickness: 0.5 mm) was performed by using a Maxam Plus type automatic bonder (product of Kuliche & Soffa). As bonding conditions, frequency of 120 kHz was selected. As FAB production conditions and load and ultrasonic conditions, a FAB diameter was 1.6 times of the wire diameter and a compression bonded ball diameter was twice of the wire diameter in first bonding. In second bonding, the FAB production conditions and the load and ultrasonic conditions were arbitrarily adjusted so that favorable bonding was attained. The first bonding and the second bonding were performed 100 times for each sample of the example and the comparative example under the same conditions. As a capillary, the one which matched the wire size and was produced by SPT-Group was used.

[0027]

Next, each of the bonded copper-platinum alloy wires was subjected to an aluminum splash test, a leaning test, and a second bonding property test.

[0028]

(Aluminum Splash Test)

The sample after the bonding was observed from above the sample with an optical microscope (STM6, measurement microscope manufactured by Olympus Corporation) at a

magnification of $\times 20$ to confirm whether or not the aluminum pad was thermally deformed to be turned up in the vicinity of the bonding portion. The aluminum splash test is an index for FAB hardness when preparing a molten ball by using a FAB and compression bonding. One hundred parts of each of the wires of Examples and Comparative Examples were observed, and generation of even one aluminum splash was evaluated as $\times$, and no aluminum splash was evaluated as O. Chip breakage was not observed with all of Examples and Comparative Examples.

[0029]

(Leaning Test)

One hundred loop tops of each of the bonding wires were observed by using an optical microscope (STM6, measurement microscope manufactured by Olympus Corporation) from a position which is on an extended line from a line connecting bonding portions of the first bonding and the second bonding to confirm each of inclinations, and a standard deviation (σ) of the inclinations was detected. The wire of which the standard deviation (σ) was $4\text{ }\mu\text{m}$ or less was evaluated as $\odot$ (excellent leaning), the wire of which the standard deviation (σ) was 4 to $8\text{ }\mu\text{m}$ was evaluated as O (good leaning), and the wire of which the standard deviation (σ) was more than $8\text{ }\mu\text{m}$ was evaluated as $\times$ (leaning defect).

[0030]

(Second Bonding Property Test)

A lead substrate was obtained by electroplating 10 μm of nickel (Ni) on a copper (Cu) plate, electroplating 1 μm of palladium (Pd) on the nickel (Ni) plating, and autocatalytic plating 0.5 μm of gold (Au) on the palladium (Pd) plating. The lead substrate was subjected to wedge bonding of the copper alloy wire while heating to 175°C, and then a bonding wire pull test was conducted. As a result, the bonding property of the second bonding was evaluated depending on presence/absence of peeling of the second bonding. The one which had mechanical strength of 6.0 gf or more was evaluated as $\odot$ (excellent), the one which had mechanical strength of 5.2 to 6.0 gf or more was evaluated as $\circ$, the one which had mechanical strength of 4.5 to 5.2 gf or more was evaluated as Δ , and the one which had mechanical strength of 4.5 gf or less was evaluated as $\times$.

[0031]

The test results of Examples 1 to 30 and Comparative Examples 1 to 6 are shown in Table 1. The oxygen concentration values were measured by employing a burning method (using TC-436AR, oxygen-nitrogen analyzer manufactured by LECO JAPAN CORPORATION), and each of them is the value of solid solution oxygen in matrix + oxygen in surface oxide film. However, since the thickness of the oxide film is the order of several nanometers, it is considered that oxygen influences only slightly. Also, since the oxygen concentration is substantially the same as

the solid solution oxygen concentration in matrix, the oxygen concentration is considered as the solid solution oxygen concentration in the following description.

Also, the Vickers hardness is added to Table 1 for reference purpose.

[Table 1]

Table 1

	No	Raw material copper (Cu) purity (%)	Pt concentration (%)	Coating layer (nm)	S concentration (ppm)	O concentration (ppm)	P concentration (ppm)	Wire hardness (Hv)	Al splash	Leaning	2nd bonding property
Examination Plate	1	99.999	1.68	None	9.	106	0	101	o	o	o
	2	99.999	1.37	None	1.3	85	0	96	o	o	o
	3	99.999	1.20	None	6.3	78	0	93	o	o	⊙
	4	99.999	0.87	None	1.5	48	0	88	⊙	o	⊙
	5	99.999	1.87	None	5.9	75	0	105	o	⊙	o
	6	99.999	1.09	None	7.3	119	0	91	o	o	⊙
	7	99.999	0.46	None	7.3	134	0	81	o	o	⊙
	8	99.995	1.83	None	3.0	12	0	104	⊙	o	o
	9	99.996	1.12	None	9.1	119	0	92	o	o	⊙
	1	99.996	0.22	None	9.0	16	0	77	⊙	o	⊙
	1	99.996	0.29	None	3.3	91	0	78	o	o	⊙
	1	99.996	1.56	None	6.4	60	0	99	⊙	o	o
	1	99.996	1.32	None	5.3	113	0	95	o	⊙	⊙
	1	99.996	0.26	None	4.5	116	0	77	o	⊙	⊙
	1	99.999	1.78	None	8.6	137	0	103	o	o	o
	1	99.999	0.92	None	4.9	93	0	88	o	⊙	⊙
	1	99.997	1.71	None	2.9	17	3.2	102	⊙	o	o
	1	99.997	1.05	None	2.9	72	1.2	91	o	o	⊙
	1	99.997	1.82	None	6.2	81	4.2	104	o	o	o
	2	99.997	1.16	None	5.0	51	1.8	92	⊙	⊙	⊙
	2	99.997	0.54	None	4.8	74	4.8	82	o	⊙	⊙
	2	99.998	1.54	None	7.8	31	1.6	99	⊙	o	o
	2	99.998	0.27	None	7.0	134	2.8	78	o	o	⊙
	2	99.998	1.56	None	4.4	42	3.6	99	⊙	⊙	o
	2	99.998	1.28	None	1.2	102	1.4	94	o	o	⊙
	2	99.998	1.78	None	7.4	29	4.6	103	⊙	o	o
	2	99.999	1.89	Au(20)	5.2	12	0	105	⊙	⊙	o
	2	99.999	1.68	Au(2000)	9.7	130	2.4	101	o	o	o
	2	99.995	1.88	Pd(10)	4.3	18	0	105	⊙	⊙	o
	3	99.995	1.01	Pd(300)	8.9	60	4	90	⊙	o	⊙
Comparative Example	1	99.9998	0	None	0.06	170	0	73	x	x	o
	2	99.991	0	Pd(600)	0	192	0	74	x	o	o
	3	99.992	2.2	None	5.8	14.1	3	110	x	o	x
	4	99.996	0.09	None	16	2	0	74	x	o	o
	5	99.997	0.02	None	0.0	24.9	2	73	o	x	o
	6	99.993	0.1	None	5	240	0	75	x	o	o

[0032]

Comparisons of the wire composition ranges, the presence/absence of coating layers, and the aluminum splash, leaning, and second bonding property test results of Examples and Comparative Examples shown in Table 1 are as follows.

In Comparative Example 1, the sulfur (S) concentration is 0.06 mass ppm which is less than the lower limit. Also, the oxygen (O) concentration is 170 mass ppm which exceeds the upper limit. Therefore, Comparative Example 1 has the low wire hardness, has poor leaning property, and is increased in hardness by work hardening to result in the undesirable aluminum splash. Also, the oxygen distribution on the surface layer is irregular, and the second bonding property is not favorable.

[0033]

In Comparative Example 2, the raw material copper (Cu) purity is 99.991 mass% which is less than the lower limit. Also, sulfur (S) is not contained, and the oxygen (O) concentration exceeds the upper limit. Therefore, the wire of Comparative Example 2 is excessively hard and results in the undesirable aluminum splash, too. The second bonding property is a little inferior despite the Pd coating.

[0034]

In Comparative Example 3, the raw material copper (Cu) purity is 99.992 mass% which is less than the lower

limit as in Comparative Example 2. Also, platinum (Pt) concentration is 2.2 mass% which exceeds the upper limit. Therefore, the wire of Comparative Example 3 is excessively hard and results in the undesirable aluminum splash.

[0035]

In Comparative Example 4, the platinum (Pt) concentration is low, and the sulfur (S) concentration is 16 mass% which exceeds the upper limit. Therefore, though the hardness of the wire of Comparative Example 4 is low, the dynamic strength thereof is exhibited to result in the excessively hard wire and to cause the undesirable aluminum splash.

[0036]

In Comparative Example 5, the platinum (Pt) concentration is 0.02 mass% which is less than the lower limit. Also, the sulfur (S) concentration is 0.08 mass ppm which is less than the lower limit, too. Therefore, the wire of Comparative Example 4 is excessively soft and has the poor leaning property.

[0037]

In Comparative Example 6, the raw material copper (Cu) purity is 99.993 mass% which is less than the lower limit as in Comparative Examples 2 and 3. Also, since the oxygen (O) concentration is high, the wire of Comparative Example 6 is excessively hard and results in the undesirable aluminum splash.

[0038]

In contrast to Comparative Examples, each of Examples which satisfy the conditions of the component ranges of the present invention attains the favorable results of aluminum splash, leaning, and second bonding property. The ranges includes the platinum (Pt) concentration of 0.1 to 2.0 mass%, the sulfur (S) concentration of 1 to 10 mass ppm, and the oxygen (O) concentration of 10 to 150 mass ppm. The wire hardness is increased along with the increase in platinum (Pt) concentration, but the aluminum splash test result is favorable when the wire hardness exceeds 100 Hv (Examples 1, 5, 8, 15, 17, 20, and 26), and the dynamic strength is not increased by the plastic flow in the ball compression bonding.

Also, each of the wires of the present invention exhibits the effects when the platinum (Pt) concentration is 0.1 to 2.0 mass%, and, as the wire structure, the oxide film has the thickness of 6 to 2 nm corresponding to the platinum (Pt) concentration as shown in the graph of Fig. 3.

The evaluation of the oxide film thickness is not shown in Table 1, but, in general, the second bonding property is deteriorated when the thickness exceeds 6 nm, and the thickness is saturated at the lower limit of 2 nm relative to the platinum (Pt) concentration as described in the foregoing. On the other hand, the platinum (Pt) concentration is regulated since the dynamic strength becomes excessively high when the platinum (Pt)

concentration exceeds 2.0 mas% to cause chip breakage as described in the foregoing.

Further, even when the wire hardness is less than 80 Hv (Examples 10, 11, 14, and 23), the leaning test results and the second bonding test results are favorable to prove the effects attained by the addition of both of sulfur (S) and oxygen (O). It is understood that the effects are favorable when the intermediate values are set or when the components complement with each another within the concentration ranges.

The addition of phosphorus (P) enhances the effects together with sulfur (S) and oxygen (O), and the effect attained by the coating layer formed of gold (Au) and palladium (Pd) is exhibited in addition to the above-described effects.

Industrial Applicability

[0039]

The present invention enables to largely improve the first bonding property, the second bonding property, and the loop formation property as compared to the conventional bonding wires and, therefore, enables to improve reliability of the wire bonding and to perform the wire bonding processing at a lower cost as compared to the conventional examples, thereby attaining the great industrial applicability.

Claims

1. A copper-platinum alloy wire to be used for ball bonding in semiconductor device which is a copper-platinum binary alloy wire for semiconductor device comprising platinum (Pt) with the balance being copper (Cu) having purity of 99.995 mass% or more and obtainable by continuous wire drawing, wherein

0.1 to 2.0 mass% of platinum (Pt) as a metallic element as well as 1 to 10 mass ppm of sulfur (S) and 10 to 150 mass ppm of oxygen (O) as non-metallic elements are solid-soluted in a copper (Cu) matrix of the copper-platinum alloy wire, and

an oxide film of 6 nm or less covers a surface layer.

2. A copper-platinum alloy wire to be used for ball bonding in semiconductor device which is a copper-platinum binary alloy wire for semiconductor device comprising platinum (Pt) with the balance being copper (Cu) having purity of 99.995 mass% or more and obtainable by continuous wire drawing, wherein

0.1 to 2.0 mass% of platinum (Pt) and 1 to 5 mass ppm of phosphorus (P) as metallic elements as well as 1 to 10 mass ppm of sulfur (S) and 10 to 150 mass ppm of oxygen (O) as non-metallic elements are solid-soluted in a copper (Cu) matrix of the copper-platinum alloy wire, and

an oxide film of 6 nm or less covers a surface layer.

3. The copper-platinum alloy wire to be used for ball bonding in semiconductor device according to claim 1

or claim 2, wherein the purity of the balance copper (Cu) of the copper-platinum alloy wire is 99.998 mass% or more.

4. The copper-platinum alloy wire to be used for ball bonding in semiconductor device according to claim 1 or claim 2, wherein the copper-platinum alloy wire has Vickers hardness of 77 to 105 Hv.

5. The copper-platinum alloy wire to be used for ball bonding in semiconductor device according to claim 1 or claim 2, wherein the content of oxygen (O) is larger than the content of sulfur (S).

6. The copper-platinum alloy wire to be used for ball bonding in semiconductor device according to claim 1 or claim 2, wherein the continuous wire drawing is cold working of 90% or more of a wire diameter of the wire after formation of the oxide film before the continuous wire drawing.