DESCRIPTION

COPPER WIRE FOR BONDING WIRE AND METHOD OF PRODUCING COPPER WIRE FOR BONDING WIRE

TECHNICAL FIELD

[0001]

The present invention relates to a copper wire for a bonding wire for forming a bonding wire.

Priority is claimed on Japanese Patent Application No. 2013-213114, filed October 10, 2013, the content of which is incorporated herein by reference.

BACKGROUND ART

[0002]

In general, in a semiconductor device on which a semiconductor element is mounted, the semiconductor element and a lead are connected by a bonding wire. In the related art, a Au wire is mainly used as a bonding wire from the viewpoint of wire drawability, conductivity, and the like. However, Au is expensive, and thus, a bonding wire formed of a Cu wire is provided as a bonding wire substituting for the Au wire.

[0003]

For example, a copper wire for a bonding wire is formed by performing wire drawing on a casting material having a wire diameter of 4 mm to 8 mm until the wire diameter becomes 0.5 mm, and then the copper wire for a bonding wire is further subjected to wire drawing until the wire diameter of the copper wire for a bonding wire becomes 30 μm to 50 μm. Therefore, the bonding wire formed of the Cu wire is

produced. For example, in PTL 1 and PTL 2, a bonding wire formed of a Cu wire of high-purity copper (so-called 6NCu) having a purity of 99.9999 mass% or more is proposed. The bonding wire has high purity, and thus, strength is low, the wire is easily formed into a loop shape, and reliability is improved. In addition, since the purity is high, inclusions are fewer, and it is possible to suppress the occurrence of wire break during wire drawing.

CITATION LIST

PATENT LITERATURE

[0004]

[PTL 1] Japanese Unexamined Patent Application, First Publication No. S62-111455

[PTL 2] Japanese Unexamined Patent Application, First Publication No. H04-247630

SUMMARY OF INVENTION

TECHNICAL PROBLEM

[0005]

However, recently, thinning of the bonding wire has been required in order to reduce the size or production cost of the semiconductor device. In the future, it is assumed that the wire diameter of the bonding wire, for example, is thinned to be 10 μm or less. Therefore, it is necessary that the copper wire for a bonding wire for forming the bonding wire have workability in which wire break does not occur during wire drawing even when the copper wire is applied to thinner bonding wire.

[0006]

However, in the production of the bonding wire disclosed in PTL 1 and PTL 2, when the copper wire for a bonding wire is subjected to wire drawing until the wire diameter of the copper wire becomes, for example, 10 μm, elongation of the wire becomes insufficient, and wire break of the wire occurs at a high frequency. In a case where such wire break occurs at the time of performing wire drawing on the copper wire for a bonding wire, productivity considerably decreases.

[0007]

The present invention has been made in consideration of the circumstances described above, and an object of the present invention is to provide a copper wire for a bonding wire of which workability is excellent and in which wire break rarely occurs even when the copper wire is applied to thinner bonding wire.

SOLUTION TO PROBLEM

[0008]

As a result of studies of the present inventors in order to solve the problems described above, it has been found that when a copper wire for a bonding wire is subjected to wire drawing to produce a bonding wire, in the copper wire for a bonding wire, an area ratio of a (001) plane in a cross-section perpendicular to a wire-drawing direction is set to be in a specific range, and thus, it is possible to improve the workability of the copper wire for a bonding wire, and it is possible to suppress wire break during wire drawing.

The present invention has been completed on the basis of the findings described above, and the gist thereof is as follows.

[0009]

That is, a copper wire for a bonding wire according to a first aspect of the

present invention is a copper wire for a bonding wire for forming a bonding wire, in which the copper wire is formed of high-purity copper having a purity of 99.9999 mass% or more, a wire diameter of the copper wire is 0.5 mm to 3.5 mm, and an area ratio of a (001) plane in a cross-section of the copper wire perpendicular to a wire-drawing direction is 15% to 30%.

In addition, a method of producing a copper wire for a bonding wire according to a second aspect of the present invention includes: a hot working step of hot-working an ingot formed of high-purity copper having a purity of 99.9999 mass% or more to produce a wire; a wire-drawing step of performing cold wire drawing on the produced wire at an area reduction rate in a range of 80% to 99.6%; and a heat treatment step of performing a heat treatment at a temperature of 200°C to 260°C for 30 minutes to 300 minutes on the wire which is subjected to the wire drawing.

In the method of producing a copper wire for a bonding wire according to the second aspect, the hot working may be hot extrusion which is performed to an area reduction rate of 99% to 99.95% at a temperature of 700°C to 900°C.

In addition, in the heat treatment step, the wire may be heated by using a batch type annealing furnace.

[0010]

According to the copper wire for a bonding wire according to the first aspect of the present invention, the area ratio of the (001) plane in the cross-section perpendicular to the wire-drawing direction is 15% to 30%. Therefore, it is possible to improve workability, and it is possible to suppress the occurrence of wire break during wire drawing.

When the area ratio of the (001) plane in the cross-section perpendicular to the wire-drawing direction is less than 15%, the area ratio of other orientations including a

(111) plane or the like increases, strength decreases, and breaking easily occurs during wire drawing. In addition, when the area ratio of the (001) plane in the cross-section perpendicular to the wire-drawing direction is greater than 30%, elongation of the copper wire decreases, and breaking easily occurs during wire drawing. Therefore, the area ratio of the (001) plane is set to be in the range described above.

Further, the copper wire for a bonding wire is formed of high-purity copper having a purity of 99.9999 mass% or more. Therefore, it is possible to sufficiently decrease strength of the bonding wire formed by using the copper wire for a bonding wire, and it is possible to improve reliability of the bonding wire. In addition, in the high-purity copper having a purity of 99.9999 mass% or more, inclusions are fewer. Therefore, it is possible to suppress the occurrence of wire break caused by the inclusions during wire drawing.

According to the method of producing a copper wire for a bonding wire according to the second aspect of the present invention, it is possible to set the area ratio of the (001) plane in the cross-section perpendicular to the wire-drawing direction of the copper wire for a bonding wire to be 15% to 30%.

ADVANTAGEOUS EFFECTS OF INVENTION

[0011]

According to the present invention, it is possible to provide a copper wire for a bonding wire of which workability is excellent and in which wire break rarely occurs even when the copper wire is applied to thinner bonding wire.

BRIEF DESCRIPTION OF DRAWINGS

[0012]

FIG. 1 is a flow chart of a method of producing a copper wire for a bonding wire according to an embodiment of the present invention.

DESCRIPTION OF EMBODIMENTS

[0013]

Hereinafter, a copper wire for a bonding wire and a method of producing a copper wire for a bonding wire according to an embodiment of the present invention will be described.

[0014]

A copper wire for a bonding wire according to this embodiment is used as a wire at the time of producing a bonding wire having a wire diameter of 80 μm or less, preferably 5 μm to 50 μm. In addition, the copper wire for a bonding wire has a wire diameter of 0.5 mm to 3.5 mm.

[0015]

The copper wire for a bonding wire is formed of high-purity copper (6NCu) having a purity of 99.9999 mass% or more.

Then, in the copper wire for a bonding wire, an area ratio of a (001) plane in a cross-section perpendicular to a wire-drawing direction is 15% to 30%. In this embodiment, the cross-section perpendicular to the wire-drawing direction is a cross-section which includes a center axis of the copper wire for a bonding wire and is orthogonal to the center axis. In addition, in this embodiment, the area ratio of the (001) plane is the total area ratio of crystal planes which are on the cross-section perpendicular to the wire-drawing direction and have a misorientation angle of 15° or less with respect to the (001) plane, that is, an area ratio for a region in which a <001> direction is oriented in a range of 15° or less with respect to the wire-drawing direction.

[0016]

Here, when the area ratio of the (001) plane in the cross-section perpendicular to the wire-drawing direction is less than 15%, the area ratio of other orientations including a (111) plane or the like increases, strength decreases, and breaking easily occurs during wire drawing. In addition, when the area ratio of the (001) plane in the cross-section perpendicular to the wire-drawing direction is greater than 30%, elongation of the copper wire decreases, and breaking easily occurs during wire drawing.

Due to such reasons, the area ratio of the (001) plane in the cross-section perpendicular to the wire-drawing direction is set to be in the range described above. The area ratio of the (001) plane is preferably 18% to 28%, and is not limited thereto.

[0017]

The area ratio of the (001) plane in the cross-section perpendicular to the wire-drawing direction can be measured by an Electron Back Scatter Diffraction Patterns method (an EBSD method). The EBSD method is a method in which an EBSD detector is connected to a scanning electron microscope (SEM), the orientation of a diffraction pattern (EBSD) of each crystal generated by irradiating a sample surface with a focused electron beam is analyzed, and the crystal orientations in a material are measured based on orientation data obtained by the analysis and positional information from a measurement point.

[0018]

Next, a method of producing a copper wire for a bonding wire according to this embodiment will be described. The method of producing a copper wire for a bonding wire, for example, as illustrated in FIG. 1, includes a hot working step S1, a wire-drawing step S2, and a heat treatment step S3. Hereinafter, each of the steps will be described in detail.

[0019]

(Hot Working Step S1)

First, a billet (an ingot) is prepared, which is formed of high-purity copper with a purity of 99.9999 mass% or more, and has a diameter of 250 mm and a length of 700 mm.

Then, the billet is heated to a temperature range of 700°C to 900°C and is subjected to hot extrusion at an area reduction rate in a range of 99% to 99.95%, and thereby, a wire with a wire diameter of 6 mm to 20 mm is produced. In the hot working step S1, in order to break a cast structure of the billet (the ingot) and to obtain a finer and more homogeneous hot-worked structure compared to the cast structure, hot extrusion is performed at the area reduction rate and in the temperature range described above.

In this embodiment, the billet is heated to 800°C and subjected to hot extrusion at an area reduction rate of 99.9%, thereby producing a wire with a wire diameter of 8 mm.

[0020]

(Wire-Drawing Step S2)

The wire produced in the hot working step S1 described above is subjected to wire drawing (cold wire drawing) at an area reduction rate in a range of 80% to 99.6% such that a wire diameter thereof is 0.5 mm to 3.5 mm. Here, the wire drawing may be performed in a single path, while it is preferable that the wire drawing be performed in a plurality of paths. In the wire-drawing step S2, a hot-worked structure (crystal grains) formed in the hot working step S1 is elongated in the wire-drawing direction, thereby becoming a fibrous metal structure.

In this embodiment, the wire drawing is performed in 15 paths until the diameter (the wire diameter) becomes 1 mm from 8 mm, and the area reduction rate is 98%.

Furthermore, in the wire-drawing step S2, peeling wire drawing may be performed.

[0021]

(Heat Treatment Step S3)

A heat treatment is performed on the wire which is subjected to wire drawing in the wire-drawing step S2 described above at a temperature of 200°C to 260°C for 30 minutes to 300 minutes. Here, the heat treatment step S3 is performed in a batch type annealing furnace in which a reducing atmosphere is set. In the heat treatment step S3, a part of a fibrous metal structure obtained in the wire-drawing step S2 is recrystallized, and thus, a metal structure is obtained in which the fibrous metal structure and an isometric recrystallization structure are coexistent.

In this embodiment, the wire is subjected to a heat treatment using the batch type annealing furnace at 220°C for 60 minutes under a reducing gas atmosphere.

[0022]

As described above, the copper wire for a bonding wire according to this embodiment is produced.

When the copper wire for a bonding wire is worked into a bonding wire, for example, the copper wire is subjected to wire drawing at an area reduction rate of 99.96%, and thereby, a bonding wire of 20 μm is obtained.

[0023]

According to the copper wire for a bonding wire according to this embodiment having the configuration described above, the area ratio of the (001) plane in the cross-section perpendicular to the wire-drawing direction is 15% to 30%. Therefore, it is possible to improve workability, and it is possible to suppress the occurrence of wire break during wire drawing.

[0024]

Further, the copper wire for a bonding wire is formed of high-purity copper having a purity of 99.9999 mass% or more. Therefore, it is possible to sufficiently decrease strength of the bonding wire formed by using the copper wire for a bonding wire, and it is possible to improve reliability of the bonding wire. In addition, in the high-purity copper having a purity of 99.9999 mass% or more, inclusions are fewer. Therefore, it is possible to suppress the occurrence of wire break caused by the inclusions during wire drawing.

[0025]

In addition, the method of producing a copper wire for a bonding wire according to this embodiment includes the hot working step S1 of hot-working the ingot formed of high-purity copper to produce a wire, the wire-drawing step S2 of performing wire drawing on the wire at an area reduction rate in a range of 80% to 99.6%, and the heat treatment step S3 of performing a heat treatment at a temperature of 200°C to 260°C for 30 minutes to 300 minutes on the wire which is subjected to wire drawing. Therefore, it is possible to produce the copper wire for a bonding wire in which the area ratio of the (001) plane in the cross-section perpendicular to the wire-drawing direction is 15% to 30%.

[0026]

By performing the wire-drawing step S2 on the wire produced in the hot working step S1 at an area reduction rate of 80% to 99.6%, a metal structure is obtained in which the crystal grains are elongated into a fibrous shape in the wire-drawing direction, and the area of the (001) plane increases in the cross-section perpendicular to the wire-drawing direction. Since the metal structure with the crystal grains elongated into the fibrous shape is difficult to be elongated (has less elongation), there are some

cases where breaking occurs by further subjecting the wire to wire drawing. Therefore, the heat treatment step S3 is performed under the conditions described above to recrystallize a part of the metal structure with the crystal grains elongated into the fibrous shape, the area ratio of the (001) plane is controlled to have a predetermined range to improve the elongation of the metal structure, and thereby workability of the wire during wire drawing is improved. The area reduction rate in the wire-drawing step S2 is preferably 89% to 99.5%, and is not limited thereto.

[0027]

In the heat treatment step S3, a heat treatment is performed on the wire which is subjected to wire drawing in the wire-drawing step S2, using a batch type annealing furnace at a temperature of 200°C to 260°C for 30 minutes to 300 minutes. Therefore, the area ratio of the (001) plane in the cross-section perpendicular to the wire-drawing direction can be reliably set to be 15% to 30%.

[0028]

In the heat treatment step S3, when the heating temperature is lower than 200°C, a recrystallized grain is not sufficiently generated, and thus it is difficult to set the area ratio of the (001) plane to be 30% or less. Therefore, elongation is decreased, and as a result thereof, breaking during wire drawing may occur. In addition, when the heating temperature is higher than 260°C, the recrystallization excessively progresses, and thus it is difficult to set the area ratio of the (001) plane to be 15% or more. Therefore, strength decreases, and breaking easily occurs during wire drawing. The heating temperature in the heat treatment step S3 is preferably 210°C to 250°C, and is not limited thereto.

[0029]

In the heat treatment step S3, when the heating time is less than 30 minutes, the recrystallized grain is not sufficiently generated, and it is difficult to set the area ratio of the (001) plane to be 30% or less. In addition, when the heating time is greater than 300 minutes, the recrystallization excessively progresses, and it is difficult to set the area ratio of the (001) plane to be 15% or more. The heating temperature is preferably 60 minutes to 180 minutes, and is not limited thereto.

For the reasons described above, the heat treatment conditions in the heat treatment step are in a range of 200°C to 260°C for 30 minutes to 300 minutes.

[0030]

For example, in a heat treatment such as electric current annealing, which is performed at a high temperature for a short period of time, it is not possible to stably form the recrystallization structure in the fibrous structure formed by wire drawing, and it is difficult to set the area ratio of the (001) plane in the cross-section perpendicular to the wire-drawing direction to be in the range described above. In contrast, in this embodiment, a heat treatment is performed by using the batch type annealing furnace under the heat conditions described above, and thus, it is possible to stably set the area ratio of the (001) plane to be in the range described above.

[0031]

As described above, the embodiment of the present invention has been described, but the present invention is not limited thereto, and suitable modification can be performed in a range not departing from the technical ideas of the present invention.

[0032]

Furthermore, the shape or the size of the ingot formed of high-purity copper having a purity of 99.9999 mass% or more is not limited, and is not limited to this embodiment.

EXAMPLES

[0033]

Hereinafter, the results of a verification experiment for verifying the effectiveness of the present invention will be described.

(Invention Examples 1 to 5)

First, a billet was prepared, which was formed of high-purity copper having a purity of 99.9999 mass% or more, and had a diameter of 250 mm and a length of 700 mm. The billet was heated to 800°C and was subjected to hot extrusion, and thus, a wire having a diameter of 8 mm was produced.

Next, wire drawing including cold peeling wire drawing was performed on the wire with a diameter of 8 mm until the diameter became 1 mm. In the wire drawing, an area reduction rate was 98%, and the number of paths was 15 times.

Next, the wire which was subjected to wire drawing was placed into a batch type annealing furnace, and then was subjected to a heat treatment at a heating temperature and for a heating time shown in Table 1. The atmosphere inside the batch type annealing furnace was a reducing atmosphere.

As described above, copper wires for a bonding wire of Invention Examples 1 to 5 were produced.

[0034]

(Comparative Example 1)

In Comparative Example 1, a copper wire for a bonding wire was produced without performing the heat treatment after the wire drawing. That is, a copper wire for a bonding wire of Comparative Example 1 was produced by the same method as that in the Invention Examples described above except that the heat treatment after the wire drawing was not performed.

[0035]

(Comparative Example 2)

First, an ingot formed of high-purity copper having a purity of 99.9999% or more was prepared. By using the ingot as a raw material, a wire having a diameter of 8 mm was cast.

Next, wire drawing including cold peeling wire drawing was performed on the wire with a diameter of 8 mm until the diameter became 1 mm. In the wire drawing, an area reduction rate was 98%, and the number of paths was 15 times.

Thus, a copper wire for a bonding wire of Comparative Example 2 was produced. In Comparative Example 2, the heat treatment after the wire drawing was not performed.

[0036]

In each of the copper wires for a bonding wire which were produced as described above, EBSD measurement was performed on a cross-section perpendicular to a wire-drawing direction, and thereby an area ratio of a (001) plane was measured.

The sequence of the EBSD measurement will be described below. First, the cross-section of the copper wire for a bonding wire which was perpendicular to the wire-drawing direction, was subjected to mechanical polishing by using waterproof polishing paper and a diamond abrasive grain, and then was subjected to finish polishing by using a colloidal silica solution. Then, the crystal orientation of the cross-section of the copper wire for a bonding wire which was perpendicular to the wire-drawing direction, was measured by an EBSD measurement device (S4300-SEM, manufactured by Hitachi, Ltd. and OIM Data Collection, manufactured by EDAX/TSL Inc.) and analysis software (OIM Data Analysis ver. 5.2, manufactured by EDAX/TSL Inc.). Specifically, each measurement points in a measurement range on a sample surface (the

cross-section of the copper wire for a bonding wire which was perpendicular to the wire-drawing direction) was irradiated with an electron beam, the sample surface was two-dimensionally scanned by an electron beam, and orientation was analyzed based on electron backscatter diffraction. Furthermore, a gap between the measurement points was 1.80 μm, and a region of 600 μm × 940 μm was subjected to the EBSD measurement.

In the cross-section of the copper wire for a bonding wire which was subjected to the EBSD measurement, crystal planes having a misorientation angle with respect to the (001) plane of 15° or less (crystal planes having an angle with respect to the (001) plane of 15° or less) were regarded as the (001) plane, and the area ratio of the (001) plane in the measurement region was evaluated.

[0037]

In addition, each of the produced copper wires for a bonding wire was further subjected to wire drawing such that the diameter of the copper wire became 5 μm. Specifically, the wire drawing was performed such that the diameter became 100 μm from 1 mm (1000 μm), became 50 μm from 100 μm, became 25 μm from 50 μm, became 10 μm from 25 μm, and then became 5 μm from 10 μm. At this time, the number of wire breaks was measured while the wire drawing was performed until the diameter became each size from 100 μm to 5 μm. This wire drawing was performed such that a wire has a total length of 100 m at the time of that the diameter became 5 μm through the wire drawing.

In Comparative Example 1, wire break frequently occurred during the wire drawing, and thus, the production of the wire (wire drawing) was stopped on the way.

The measurement results are shown in Table 1.

[0038]

[Table 1]

	Heat Treatment Conditions		EBSD Measurement	Number of Wire Breaks			
	Heating Temperature	Time	Area Proportion of (001)	100 μm →50 μm	50 μm →25 μm	25 μm →10 μm	10 μm →5 μm
	°C	Minutes	%	Times	Times	Times	Times
Invention Example 1	220	60	20	0	0	0	0
Invention Example 2	200	60	22	0	0	0	1
Invention Example 3	255	60	18	0	0	1	2
Invention Example 4	220	30	28	0	0	0	1
Invention Example 5	220	300	19	0	0	0	1
Comparative Example 1	-	-	35	3	6	10	Production was Stopped
Comparative Example 2	-	-	9	0	1	2	18

[0039]

As shown in Table 1, in Invention Examples 1 to 5, it was verified that even when the wire drawing was performed until the diameter each of the wires became 5 μm from 100 μm, the number of wire breaks was low, and thus workability was excellent. That is, in Invention Examples 1 to 5, it was verified that wire break rarely occurred in the copper wire for a bonding wire even when the copper wire was applied to thinner bonding wire.

[0040]

In Comparative Example 1, the heat treatment was not performed after the wire drawing was performed until the diameter became 1 mm. Therefore, the area ratio of the (001) plane was greater than 30%, and the number of wire breaks was greater than that of Invention Examples.

In addition, in Comparative Example 2, the wire with a diameter of 8 mm was cast, and then the wire was subjected to the wire drawing until the diameter became 1 mm. Thus, the area reduction rate of the wire drawing until the diameter became 1 mm was insufficient compared to the present examples. Therefore, the area ratio of the (001) plane was less than 15%, and the number of wire breaks was greater than that of the present examples.

INDUSTRIAL APPLICABILITY

[0041]

According to the copper wire for a bonding wire according to the present invention, workability of the copper wire is excellent and wire break of the copper wire rarely occurs even when the copper wire is applied to thinner bonding wire, and thus, it is possible to make the bonding wire thin.

REFERENCE SIGNS LIST

[0042]

S1: HOT WORKING STEP

S2: WIRE-DRAWING STEP

S3: HEAT TREATMENT STEP

CLAIMS

1. A copper wire for a bonding wire for forming a bonding wire,

wherein the copper wire is formed of high-purity copper having a purity of 99.9999 mass% or more,

a wire diameter of the copper wire is 0.5 mm to 3.5 mm, and

an area ratio of a (001) plane in a cross-section of the copper wire perpendicular to a wire-drawing direction is 15% to 30%.