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[54]	Title:	BONDING WIRE FOR SEMICONDUCTOR DEVICE		
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[57]	Abstract:	Provided is a Cu bonding wire having a Pd coating layer on the surface thereof, the bonding wire being suitable for vehicle-mounted devices and having improved bonding reliability at ball joints in a high-temperature high-humidity environment. This bonding wire for semiconductor devices includes: a Cu alloy core material; and a Pd coating layer formed on the surface thereof. The bonding wire includes a total of from 0.1 to 100 ppm by mass of one or more types of elements among As, Te, Sn, Sb, Bi, and Se. Thus, the bonding life of ball joints in a high-temperature high-humidity environment is improved, and bonding reliability can be improved. When the Cu alloy core material further includes from 0.011 to 1.2 mass pcnt of one or more of Ni, Zn, Rh, In, Ir, Pt, Ga, and Ge, ball joint reliability in a high-temperature environment of 170oC or higher can be improved. Further, when an alloy skin layer including Au and Pd is formed on the surface of the Pd coating layer, wedge bondability is improved.		

(Method of Evaluation)

A crystal structure was evaluated with a surface of wire as an observation surface. An electron backscattered diffraction method (EBSD) was used as a method of evaluation. The EBSD method is characterized in that it can observe crystal orientations on an observation surface and graphically shows an angle difference of the crystal orientations between adjacent measurement points. The EBSD method can relatively easily observe the crystal orientations with high accuracy, even for a thin wire like the bonding wire.

Care should be taken when performing EBSD method with a curved surface like the wire surface as a subject. When a region with a large curvature is measured, measurement with high accuracy is difficult. However, a bonding wire to be measured is fixed to a line on a plane, and a flat part near the center of the bonding wire is measured, whereby measurement with high accuracy can be performed. Specifically, the following measurement region will work well. The size in the circumferential direction is 50% or less of the wire diameter with a center in the wire longitudinal direction as an axis, and the size in the wire longitudinal direction is 100 μm or less. Preferably, the size in the circumferential direction is 40% or less of the wire diameter, and the size in the wire longitudinal direction is 40 μm or less, whereby measurement efficiency can be improved by reducing a measurement time. In order to further improve accuracy, it is desirable that three or more points are measured to obtain average information with variations taken into account. The measurement sites may be apart from each other by 1 mm or more so as not to be close to each other.

The orientation proportion of <111> on surface was determined by calculating the proportion (areal percentage) of the crystal orientation <111> angled at 15 degrees or less to the longitudinal direction of the bonding wire with all crystal orientations identified by a dedicated software (OIM analysis manufactured by TSL Solutions, for example) as a population.

The bonding reliability of the ball bonded part in a high-temperature and high humidity environment or a high-temperature environment was determined by manufacturing a sample for bonding reliability evaluation, performing HAST and HTS evaluation, and by evaluating the bonding longevity of the ball bonded part in each test. The sample for bonding reliability evaluation was manufactured by performing ball bonding onto an electrode, which has been formed by forming an alloy of Al-1.0%Si-0.5%Cu as a film with a thickness of 0.8 μm on a Si substrate on a general metallic frame, using a commercially available wire bonder and sealing it with a commercially available epoxy resin. A ball was formed while flowing an N_2 + 5%H_2 gas at a flow rate of 0.4 to 0.6 L/min, and its size was a diameter of a range from 33 to 34 μm.

For the HAST evaluation, the manufactured sample for bonding reliability evaluation was exposed to a high-temperature and high-humidity environment of a temperature of 130°C and a relative humidity of 85% using an unsaturated type pressure cooker tester and was biased with 5 V. A shear test on the ball bonded part was performed every 48 hours, and a time until a value of shear strength became half of the initial shear strength was determined to be the bonding longevity of the ball bonded part. The shear test after the high-temperature and high-humidity test was carried out after removing a resin by acid treatment and exposing the ball bonded part.

A tester manufactured by DAGE was used for a shear tester for the HAST evaluation. An average value of measurement values on 10 ball bonded parts randomly selected was used for the value of the shear strength. In the above evaluation, the bonding longevity being less than 96 hours was determined to be practically problematic to be marked with a symbol of "cross," being 96 hours or more and less than 144 hours was determined to be practicable but somewhat problematic to be marked with a symbol of "triangle," being 144 hours or more and less than 288 hours was determined to be practically no problem to be marked with a symbol of "circle," being 288 hours or more and less than 384 hours was determined to be excellent to be marked with a symbol of "double circle," and being 384 hours or more was determined to be especially excellent to be marked to with a symbol of "a pair of double circle" in the column "HAST" in Table 1.

For the HTS evaluation, the manufactured sample for bonding reliability evaluation was exposed to a high-temperature environment of a temperature of 200°C using a high-temperature thermostatic device. A shear test on the ball bonded part was performed every 500 hours, and a time until a value of shear strength became half of the initial shear strength was determined to be the bonding longevity of the ball bonded part. The shear test after the high-temperature and high-humidity test was performed after removing a resin by acid treatment and exposing the ball bonded part.

A tester manufactured by DAGE was used for a shear tester for the HTS evaluation. An average value of measurement values on 10 ball bonded parts randomly selected was used for the value of the shear strength. In the above evaluation, the bonding longevity being 500 or more to less than 1,000 hours was determined to be practicable but desirably to be improved to be marked with a symbol of "triangle," being 1,000 or more to less than 3,000 hours was determined to be practically no problem to be marked with a symbol of "circle," and being 3,000 hours or more was determined to be especially excellent to be marked with a symbol of "double circle."

For the evaluation of ball formability (FAB shape), a ball before performing bonding was collected and observed, and the presence or absence of voids on a surface of the ball and the presence or absence of deformation of the ball, which is primarily a perfect sphere. The occurrence of any of the above was determined to be faulty. The formation of the ball was performed while an N_2 gas was sprayed at a flow rate of 0.5 L/min in order to reduce oxidation in a melting process. The size of the ball was 34 μm. For one condition, 50 balls were observed. A SEM was used for the observation. In the evaluation of the ball formability, a case where five or more failures occurred was determined to be problematic to be marked with a symbol of "cross," a case of three or four failures was determined to be practicable but somewhat problematic to be marked with a symbol of "triangle," a case of one or two failures was determined to be no problem to be marked with a symbol of "circle," and a case where no failure occurred was determined to be excellent to be marked with a symbol of "double circle" in the column "FAB shape" in Table 1.

The evaluation of wedge bondability on the wire bonded part was determined by performing 1,000 pieces of bonding on leads of a lead frame and evaluating by the occurrence frequency of peeling of the bonded part. An Fe-42 at% Ni alloy lead frame plated with 1 to 3 μm Ag was used for the lead frame. In this evaluation, assuming more rigorous bonding conditions than normal, a stage temperature was set to be 150°C, which was lower than a generally set temperature range. In the above evaluation, a case where 11 or more failures occurred was determined to be problematic to be marked with a symbol of "cross," a case of 6 to 10 failures was determined to be practicable but somewhat problematic to be marked with a symbol of "triangle," a case of 1 to 5 failures was determined to be no problem to be marked with a symbol of "circle," and a case where no failure occurred was determined to be excellent to be marked with a symbol of "double circle" in the column "wedge bondability" in Table 1.

The evaluation of a crushed shape of the ball bonded part was determined by observing the ball bonded part from immediately above after bonding and evaluating by its circularity. For an object to be bonded with the bonding wire, an electrode in which an Al-0.5 % Cu alloy was formed as a film with a thickness of 1.0 μm on a Si substrate was used. The observation was performed using an optical microscope, and 200 sites were observed for one condition. Being elliptic with large deviation from a perfect circle and being anisotropic in deformation were determined to be faulty in the crushed shape of the ball bonded part. In the above evaluation, a case where six or more failures occurred was determined to be problematic to be marked with a symbol of "cross," a case of four or five failures was determined to be practicable but somewhat problematic to be marked with a symbol of "triangle," being one to three was determined to be no problem to be marked with a symbol of "circle," and a case where a favorable perfect circle was obtained for all was determined to be especially excellent to be marked with a symbol of "double circle" in the column "crushed shape" in Table 1.

[Leaning]

To a lead frame for evaluation, 100 pieces of bonding were performed with a loop length of 5 mm and a loop height of 0.5 mm. As a method of evaluation, a wire upright part was observed from a chip horizontal direction, and evaluation was performed based on spacing when spacing between a perpendicular line passing through the center of the ball bonded part and the wire upright part was maximized (leaning spacing). If the leaning spacing was smaller than the wire diameter, leaning was determined to be favorable, whereas if the leaning spacing was larger, the upright part leaned, and the leaning was determined to be faulty. One hundred bonded wires were observed with an optical microscope, and the number of leaning failures was counted. A case where seven or more failures occurred was determined to be problematic to be marked with a symbol of "cross," a case of four to six failures was determined to be practicable but somewhat problematic to be marked with a symbol of "triangle," a case of one to three failures was determined to be no problem to be marked with a symbol of "circle," and a case in which no failure occurred was determined to be excellent to be marked with a symbol of "double circle" in the column "leaning" in Table 1.

(Evaluation Results)

The bonding wires according to Working Examples 1 through 109 each include a Cu alloy core material and a Pd coating layer formed on the surface of the Cu alloy core material, and the bonding wire contains at least one or more elements selected from As, Te, Sn, Sb, Bi and Se, a concentration of the elements in total is 0.1 to 100 ppm by mass relative to the entire wire. It has been revealed that with this configuration the bonding wires according to

Working Examples 1 through 109 can achieve the reliability of the ball bonded part in the HAST test in the high-temperature and high-humidity environment of a temperature of 130°C and a relative humidity of 85%.

In contrast, in Comparative Examples 1, 2, 4 through 6, and 11 through 14, a concentration of the elements was out of the lower limit, and the reliability of the ball bonded part was not obtained in the HAST test. In Comparative Examples 3 and 7 through 10, a concentration of the elements was out of the upper limit, and the FAB shape was faulty. In Comparative Examples 1, 3, and 5 through 10, the areal percentage of the crystal orientation <111> was out of the preferable range of the present invention, and the evaluation result of the leaning was a symbol of "triangle."

In the working examples further including an alloy skin layer containing Au and Pd on the Pd coating layer, it has been revealed that excellent wedge bondability can be obtained when a thickness of the alloy skin layer containing Au and Pd is 0.0005 to 0.050 μm.

In Working Examples 27 through 92, 100, 102, and 104 through 109, it has been revealed that the high-temperature reliability of the ball bonded part by the HTS evaluation is favorable because the bonding wire further contains at least one or more elements selected from Ni, Zn, Rh, In, Ir, Pt, Ga, Ge and Pd, and a concentration of each of the elements other than Pd is 0.011 to 1.2% by mass relative to the entire wire, and a concentration of Pd contained in the Cu alloy core material is 0.05 to 1.2% by mass.

In some of Working Examples 28 through 92, the FAB shape was favorable and the wedge bondability was favorable when the bonding wire further contains at least one or more elements selected from B, P, Mg, Ca and La, and a concentration of each of the elements is 1 to 100 ppm by mass relative to the entire wire.

In Working Examples 99 through 109, the wire contains As, Te, Sn, Sb, Bi and Se, and Cu was present at an outermost surface of the wire. With this configuration, Working Examples 99, 101, 103, 105, 106, 108, and 109 were a symbol of "a pair of double circle" or a symbol of "double circle" in the HAST evaluation results, which revealed the effect of causing Cu to be present at an outermost surface. In Working Examples 100, 102, 104, and 107, in addition, the purity of Cu of the wire was as low as 2N or less, and all of them were extremely favorable in the HAST evaluation results, a symbol of "a pair of double circle." In contrast, these working examples revealed a slight decrease in the wedge bondability.

In Comparative Examples 13 and 14, not only the HAST evaluation but also the HTS evaluation results were faulty, the FAB shape and the crushed shape were faulty, and further the wedge bondability and the leaning also degraded because the wire did not contain As, Te, Sn, Sb, Bi and Se, while Cu was present at an outermost surface of the wire.

CLAIMS

1. A bonding wire for a semiconductor device comprising:

a Cu alloy core material; and

a Pd coating layer formed on a surface of the Cu alloy core material, wherein

the bonding wire contains at least one or more elements selected from As and Te, and

a concentration of the elements in total is 0.1 ppm by mass or more and 100 ppm by mass or less relative to the entire wire.

2. The bonding wire for a semiconductor device according to claim 1, wherein the concentration of the at least one or more elements selected from As and Te in total is 1 ppm by mass or more and 100 ppm by mass or less relative to the entire wire.

3. The bonding wire for a semiconductor device according to claim 1, wherein a thickness of the Pd coating layer is 0.015 μm or more and 0.150 μm or less.

4. The bonding wire for a semiconductor device according to claim 1, further comprising an alloy skin layer containing Au and Pd on the Pd coating layer.

5. The bonding wire for a semiconductor device according to claim 4, wherein a thickness of the alloy skin layer containing Au and Pd is 0.0005 μm or more and 0.050 μm or less.

6. The bonding wire for a semiconductor device according

to claim 1, wherein

the bonding wire further contains at least one or more elements selected from Ni, Zn, Rh, In, Ir, Pt, Ga and Ge, and

a concentration of each of the elements is 0.011% by mass or more and 1.2% by mass or less relative to the entire wire.

7. The bonding wire for a semiconductor device according to claim 1, wherein

the Cu alloy core material contains Pd, and

a concentration of Pd contained in the Cu alloy core material is 0.05% by mass or more and 1.2% by mass or less.

8. The bonding wire for a semiconductor device according to claim 1, wherein

the bonding wire further contains at least one or more elements selected from B, P, Mg, Ca and La, and

a concentration of each of the elements is 1 ppm by mass or more and 100 ppm by mass or less relative to the entire wire.

9. The bonding wire for a semiconductor device according to claim 1, wherein, in a measurement result when measuring crystal orientations on a surface of the bonding wire, a crystal orientation <111> angled at 15 degrees or less to a longitudinal direction of the bonding wire has a proportion of 30% or more and 100% or less.

10. The bonding wire for a semiconductor device according to any one of claims 1 to 9, wherein Cu is present at an outermost surface of the bonding wire.