

SPECIFICATION

TITLE OF INVENTION: HIGH PURITY CU BONDING WIRE

FIELD OF THE INVENTION

[0001]

The present invention relates to Cu alloy wire connecting with electrodes of IC chips and such as leads of substrates by Ball Bonding Method using a wire bonder, especially, it relates to room temperature hardness of initial balls (FAB) of bonding wire is soft.

STATE OF THE ART

[0002]

Conventional wiring method of ball bonding using Cu alloy wire instead of Au wire as the bonding method with electrodes of IC chips and leads on substrates is well known.

[0003]

On the method of wiring by ball bonding, high purity Cu wire unwinded from a reel is introduced into a capillary as a bonding tool, then the tip of Cu alloy wire leaded at exit side of the tool by micro electric discharge between a electric torch in inert gas atmosphere and/or deoxidization atmosphere is melted and formed an initial free air ball (FAB), then this molten ball is bonded with ultra-sonic and thermo-compressed operation to an electrode on heated IC chips. Then the capillary is moved in xyz direction (back and forth, left and right, up and downward direction), and the defined shape of loop of Cu alloy wire bonded on a electrode of IC chip is formed, and after it is wedge bonded to an outer lead frame, then high purity Cu alloy wire is cut.

[0004]

However, since high purity Cu alloy wire is apt to be oxidized by oxygen in the air, on the occasion of forming an initial ball (FAB) mentioned before, the surface is covered by oxidized membrane in the air and impurities in the molten Cu alloy are also oxidized by diffused oxygen in the ball. Therefore, in the atmosphere existing oxygen, the molten ball of high purity Cu alloy wire becomes hard, it was used to be a problem that bondability becomes worse and cracks of IC chip are generated at the same time on thermo compressed bonding onto electrodes of IC chip mentioned before. It had been considered so far that crack of IC chip causes oxidized membrane of high purity Cu alloy. In order to prevent to form such oxidized membrane, it had been used to use inert gas under fully closed atmosphere and/or deoxidized effect hydrogen gas mixture in the inert gas to form initial balls (FAB) mentioned before and to prevent oxidization of initial balls (FAB) of Cu alloy wire. [Reference Patent 1, 2 and 3]

[0005]

On the other hand, academic research had been done that purity of Cu metal wire had been tried to improve from 99.99 wt % to 99.999 wt % or 99.9999 wt % as pure as possible, aiming to decrease impurities or elements do not become oxide. Because, the higher purity of Cu metal wire becomes the better sphereness of ball on molten ball forming, the better sphereness of ball becomes the better roundness of deformation at bonding surface by thermo compression. However, the higher purity of Cu metal wire

becomes the lower temperature of recrystallization and becomes the softer of Cu metal wire itself. Hence, though treating work hardening in advance, it has an effect of softening of aging, so it becomes very difficult to handle high purity Cu metal wire softened. Especially, because Cu metal wire for bonding wire is mass produced by drawing, the higher purity of Cu metal wire, it itself softens a copper metal wire of high degree of purity by frictional heat with a copper metal wire and wire drawing dies during drawing, and a wire is apt to be cut. And spending time and effort, it is possible to prototype such high purity Cu metal wire, but thermo compressed bonding with ultrasonic using such high purity Cu metal wire on electrode of IC chip mentioned before, on forming defined loop from bonded Cu metal wire on electrode of IC chip, such high purity Cu metal wire of more than 99.999 wt % be collapsed.

[0006]

As measures for these problems, some reports had been published on high purity Cu alloy wire adding traces of elements to high purity Cu metal wire [Reference Patent 1, 2 and 3]. But, oxygen in the ball bonding atmosphere, though in the case of high purity Cu alloy wire, the initial ball (FAB) would not become true sphere shape, and the initial ball (FAB) becomes too hard, and then cracks of IC chip are generated. Therefore, thermal compressed bonding by the initial ball (FAB) to meet high strength bonding could not be done, and satisfied loop shapes could not be obtainable, so in the case of high purity Cu alloy wire, it had not been realized for practical use so far.

[The preceding technical literature]

[Reference Patents]

[0007]

[Reference Patent 1] Japanese Unexamined Patent Application Publication No. 2003-133364

[Reference Patent 2] Japanese Unexamined Patent Application Publication No. 2008-085320

[Reference Patent 3] Japanese Patent No. Hei 05-20493

DISCLOSURE OF INVENTION

ISSUES TO BE SOLVED BY THE PRESENT INVENTION

[0008]

Therefore, it had been required that even ball bonding Cu alloy wire consisting of high purity Cu alloy, can be drawn easily at room temperature, and does not generate cracks on IC chip by the initial ball (FAB).

[0009]

The present invention has been done in view of the above-mentioned circumstances, the aim is to provide bonding wire, which has higher recrystallization temperature and it is draw-able though Cu alloy wire consisting of high purity Cu alloy, and room temperature hardness of the initial ball (FAB) of Cu alloy wire or molten ball is lower than that of Cu metal wire consisting of high purity Cu metal with no adding impurities. Concretely, high purity Cu alloy wire, which has higher recrystallization temperature by adding trace of P into high purity Cu metal. Adding trace of P, recrystallization

temperature of high purity Cu metal goes up steeply. Therefore, though the volume of P is trace, it becomes possible to draw Cu alloy wire by a dice under room temperature. Moreover, there is a region which room temperature hardness of initial ball (FAB) of Cu alloy wire added P is lower than that of Cu metal wire without P, under appropriate purity of Cu metal and appropriate additive P. The aim of the present invention is to provide such high purity Cu alloy wire.

[Measures to solve issues]

[0010]

The inventors of the present invention searched additive elements, which have effect to soften room temperature hardness of initial balls (FAB) or molten balls, as the room temperature hardness of initial balls (FAB) or molten balls is cause of IC chip cracks. Finally, the inventors of the present invention found that specified quantity of P decreases room temperature hardness of high purity Cu metal initial balls (FAB) or molten balls. Adding effect of P into high purity Cu metal, the higher Cu metal purity has the more outstanding effect, but it depends on the amount of impurities element included in Cu metal. The inventors of the present invention discovered that though recrystallization temperature of high purity Cu metal wire such as 99.9999 wt % goes up, room temperature hardness of initial balls (FAB) or molten balls becomes lower than that of high purity Cu wire without P. It was known that adding some traces of additive elements into high purity Cu metal wire which is more than 99.999 wt %, recrystallization temperature of the Cu alloy wire goes up and room temperature hardness of Cu alloy wire itself becomes harder. Namely, the knowledge on increasing of room temperature hardness of high purity Cu alloy wire had been interpreted that it's being increased with the addition amount of trace additive elements. In fact, also in the case of P, depending on increasing additive amount of from 0 wt ppm to 20 wt ppm, 50 wt ppm, 100 wt ppm, 200 wt ppm, and 400 wt ppm, refining crystal grain size of high purity Cu metal wire, at first sight, it seems that recrystallization temperature goes up and material strength itself increases and room temperature hardness also increases. Therefore, as academic recognition, room temperature hardness of Cu alloy wire added 10 wt ppm of P is almost same high purity Cu metal wire without P, such level of difference is in error area discussion by experiments. On these circumstances in accordance with Reference Patent 1 mentioned before, preventing to form oxide at forming molten ball in the range of 40 – 400 wt ppm of P, decreasing hardness of ball and avoiding chip cracks, and in Reference Patent 2, on a bonding wire, which consist of the range of total amount of 10 – 700 wt ppm of Mg and/or P, at least one element, and 6 – 20 wt ppm of Oxygen, adding of Mg and/or P in the range of above mentioned has an avoiding effect of chip cracks, as these elements are having an hardening effect. Moreover, in Reference Patent 3, a bonding wire, which includes the range of 0.001 – 2 wt % of at least one element and/or more than 2 elements selected from the group of Ti, Hf, V, Nb, Ta, Ni, Pd, Pt, Au, Cd, B, Al, In, Si, Ge, P, Sb, Bi, Se and Te, and residual is Cu substantially, considered as these additive elements are having an hardening effect.

[0011]

However, from the research of inventors of the present invention, it had been found that there is an area that the room temperature hardness becomes low than that of Cu alloy wire without P after forming initial balls (FAB) or molten balls, though the

recrystallization temperature is going up under adding a little of P into high purity Cu in the range of 20 wt ppm of P. Then from the precise investigation adding P into high purity Cu in the range of these above mentioned and over 20 wt ppm, the recrystallization temperature goes up with increased P, but room temperature hardness of initial ball (FAB) of Cu alloy wire and after forming of molten ball does not go up with increased P, though on Cu alloy wire included P, it was found that there is an area room temperature hardness becomes lower than that of high purity Cu metal wire. This area is remarkable under the condition of less metallic elements included in high purity Cu wire. And it was found that the reducing hardness effect of P against Cu is not so much influenced though that of existing Ag, Ca, Fe, Mn, Ni, Pb and Si in Cu. (Fig. 1) Fig 1 shows a graph from data of these relationships, the vertical axis shows hardness against the amount of P after forming a molten ball, it is well known that from more than 200 wt ppm of P area the hardness goes up by increasing amount of P, but it shows that under area of around 150 wt ppm of P, once the hardness goes up to 100 mN, then goes down steeply. In the Figure, enlarged area is correspond to it, between around 0.5 to 15 wt ppm of P, the hardness is equivalent to or less than that of high purity Cu metal included 0 wt ppm of P. It is considered that reducing effect of room temperature hardness of P against high purity Cu alloy is based on the following phenomena. Namely, it is considered that when a Cu alloy wire as bonding wire is melted by an electric discharge spark, molten Cu dissolves Oxygen from the air, a part of oxidized membrane of Cu alloy wire surface is broken and evaporated by P. Then, in the case of high purity Cu alloy wire of around more than 99.998 wt % of Cu, as there is only 10 wt ppm level of metallic element except P, absolute amount of impurity elements combined with Oxygen decreases, this is correspond to what room temperature hardness of high purity Cu wire go down without forming a hard oxidized membrane.

[0012]

Namely, when Cu alloy wire is bonded by ultra sonic thermo-compressed bonding method onto an electrode of IC chip, if the room temperature hardness of an initial ball (FAB) of Cu alloy wire is lower, chip damage to IC chip by Cu alloy wire should be possible to reduce. Moreover, mentioned already, conditions required for wire bonding, under same conditions, recrystallization temperature goes up for wire drawing, age softening of Cu alloy wire itself is relieved. The inventors of the present invention have completed from these all knowledge mentioned.

[0013]

Concretely, from the present invention,

- (1) On bonding wire of Cu alloy consists of P and Cu, it is provided high purity Cu alloy wire for ball bonding, which is featured that room temperature hardness of initial balls (FAB) of Cu alloy wire added P is less than that of Cu alloy wire without P.

Moreover, from the present invention,

- (2) On bonding wire of Cu alloy consists of P and Cu, it is provided high purity Cu alloy wire for ball bonding, which is featured that room temperature hardness of initial balls (FAB) of Cu alloy wire added P is less than that of Cu alloy wire without P and total amount of metallic elements except P in Cu is less than added amount of P.

Moreover, from the present invention,

- (3) On bonding wire of Cu alloy consists of P and Cu, it is provided high purity Cu alloy wire for ball bonding, which is featured that the Cu alloy wire consists of 0.5 – 15 wt ppm of P and residual is more than 99.9985 wt % of Cu, and room temperature hardness of initial balls (FAB) of Cu alloy wire added P is less than that of Cu alloy wire, which purity of Cu is more than 99.9985 wt % and no added P. It is preferable that as room temperature hardness of initial balls (FAB) goes down, when Cu alloy wire consists of 0.5 – 10 wt ppm and residual of it is more than 99.9985 wt % of Cu.

Moreover, from the present invention,

- (4) On bonding wire of Cu alloy consists of P and Cu, it is provided high purity Cu alloy wire for ball bonding, which is featured that the Cu alloy wire consists of 0.5 – 15 wt ppm of P and residual is more than 99.9985 wt % of Cu, and room temperature hardness of initial balls (FAB) is lower than that of residual is more than 99.9985 wt % of Cu metal wire no added P.

EFFECTS OF THE PRESENT INVENTION

[0014]

Cu alloy wire for ball bonding of the present invention has an effect of decreasing chip damage because of no formation of oxidized membrane on the surface of initial balls (FAB) by deoxidizing effect of trace amount of P. Moreover, as in same manner, at the second bonding to lead, breaking load of bonding wire is improved by deoxidizing effect of P at pull strength measurement. In this case, as pull strength measurement using bonding strength tester, broken ratio at wire portion is greater than broken ratio at compressed bonding of second bond, it is found that these characteristics are improved.

[0015]

On Cu alloy wire for ball bonding of the present invention, it is preferable that metallic elements included in the Cu, which purity is more than 99.999 wt % are Ag, Ca, Mn, Mg, Ni, Al, Pb and Si. It is because that the room temperature hardness of initial balls (FAB) of Cu does not go up if total amount of these elements coexisted with P is lower than a defined amount. By the way, including these metallic elements, it is well known that so far, any metallic element has an effect of making recrystallization temperature higher.

[0016]

On Cu alloy wire for ball bonding of the present invention, it is more preferable that metallic elements included in the Cu, which purity is more than 99.999 wt % is less than 10 wt ppm except P. It is because that deoxidizing effect of P, which makes room temperature hardness of initial balls (FAB) low, is more exemplified.

BRIEF DESCRIPTION OF THE DRAWINGS

[0017]

[Fig 1] Fig 1 shows relationship between content amount of P of high purity Cu alloy bonding wire of the present invention and breaking strength which means hardness.

DESCRIPTION OF THE MOST PREFERRED EMBODIMENT

[0018]

The bonding wire of the present invention was manufactured by following manner, and confirmation of age softening, recrystallization temperature, room temperature hardness of initial ball, and number of chip cracks was done concretely by followings.

[Example 1]

[0019]

[Manufacturing method of Cu wire for ball bonding]

Manufacturing method of Cu wire for ball bonding on the present invention is explained. As raw material of high purity Cu metal more than 99.9999 wt % (matrix metal of Cu is shown as "A".) and high purity Cu metal more than 99.999 wt % (matrix metal of Cu is shown as "B"), composition shown in Table 1, adding desirable amount of P, is prepared. These composition is drawn to a bonding wire as same as high purity Au wire manufacturing method. First of all, raw material of specified quantity is casted as an ingot after melting in a vacuum melting furnace. This ingot is rolled by a Caliber Rolling Roll, then it is treated annealing and anticorrosive treatment, high purity Cu alloy wire with 25 μ meters diameter is formed.

[0020]

[Confirmation of age softening effect]

Age softening effect is confirmed for high purity Cu wire (diameter is 200 μ meters) shown in Table 1 which are high purity Cu more than 99.9999 wt % and adding specified quantity of P into this high purity Cu. The results are shown in Table 2.

[0021]
[Table 1]

Table 1: Content amount of P to high purity Cu

	No.	Adding amount of P (wt ppm)	Matrix Metal of Cu	Ag	Ca	Fe	Mn	Mg	Ni	Al	Pb	Si	Others
Examples	1	5	B	<= 1	<= 1	<= 1	<= 1	<= 1	<= 1	<= 1	<= 1	<= 1	4
	2	2.5	B	<= 1	<= 1	<= 1	<= 1	<= 1	<= 1	<= 1	<= 1	<= 1	2
	3	1.5	B	<= 1	<= 1	<= 1	<= 1	<= 1	<= 1	<= 1	<= 1	<= 1	2
	4	7	B	<= 1	<= 1	<= 1	<= 1	<= 1	<= 1	<= 1	<= 1	<= 1	3
	5	10	B	<= 1	<= 1	<= 1	<= 1	<= 1	<= 1	<= 1	<= 1	<= 1	5
	6	12.5	B	<= 1	<= 1	<= 1	<= 1	<= 1	<= 1	<= 1	<= 1	<= 1	2
	7	3	A	<= 1	<= 1	<= 1	<= 1	<= 1	<= 1	<= 1	<= 1	<= 1	<= 1
	8	6	A	<= 1	<= 1	<= 1	<= 1	<= 1	<= 1	<= 1	<= 1	<= 1	<= 1
	9	13	A	<= 1	<= 1	<= 1	<= 1	<= 1	<= 1	<= 1	<= 1	<= 1	<= 1
Controls	10	0	A	<= 1	<= 1	<= 1	<= 1	<= 1	<= 1	<= 1	<= 1	<= 1	<= 1
	11	0.5	B	<= 1	<= 1	<= 1	<= 1	<= 1	<= 1	<= 1	<= 1	<= 1	2
	12	10	B	13	5	<= 1	<= 1	<= 1	<= 1	3	7	<= 1	5
	13	50	B	<= 1	<= 1	<= 1	<= 1	<= 1	<= 1	<= 1	<= 1	<= 1	51
	14	100	B	27	<= 1	<= 1	<= 1	<= 1	<= 1	<= 1	<= 1	<= 1	34
	15	200	B	<= 1	9	<= 1	<= 1	<= 1	<= 1	<= 1	<= 1	<= 1	28

[0022]
[Table 2]

Table 2: Age softening effect and recrystallization temperature

		[Decreasing ratio of strength %]					Recrystallization Temperature (°C)	
No.	Leaving time (hr)					Criteria is less than 10 %		
	0	12	48	144	288			
Examples	1	0	4.1	5.5	7.1	7.3	OK	450
	2	0	3.2	3.9	4.3	5.5	OK	450
	3	0	2.5	4	3.9	5.4	OK	450
	4	0	2.4	3.8	3.9	4.8	OK	450
	5	0	2.2	3.5	3.7	4.5	OK	470
	6	0	2.2	3.6	3.6	4.4	OK	480
	7	0	1.2	1.7	2.2	2.6	OK	450
	8	0	1.1	1.2	1.5	1.7	OK	470
	9	0	0.5	0.8	0.8	1	OK	500
Controls	10	0	9	35	62	67	NG	350
	11	0	6.5	8	14.5	15.5	NG	370
	12	0	2.2	3.1	3.8	4.7	OK	420
	13	0	1.1	1.4	2.1	2.3	OK	470
	14	0	1	1.3	1.3	1.6	OK	520
	15	0	0.8	1.5	1.7	1.7	OK	600

[0023]

Using high purity Cu alloy wire shown in Table 1, thermo-compressed with ultra sonic bonding test by ball bonding was done. In the method of ball bonding, on wiring by a bonding wire, especially with Al electrode consists of Al metal and/or Al alloy and outer lead, the bonding is done with molten Cu initial balls (FAB) and Al electrode heated at around 200 degrees Celsius at the first bonding, the second bonding is done without forming a molten ball with a side wall of wire and an Ag plated lead frame heated at around 200 degrees Celsius by ultra sonic bonding. At this test, ball bonding of a side of IC chip was done under following condition of the atmosphere of 95 % Nitrogen + 5 % Hydrogen, with a load of 0.2 N, ball bonding time of 10 msec and ball bonding power of 0.30 watts. And the second bonding of a side of outer lead was done under following condition of load of 0.30 N, ball bonding time of 10 msec and ball bonding power of 0.40 watts.

[0024]

[30 thousands cycles test]

This high purity Cu alloy wire was tested 30 thousand times continuously using the ball bonding equipment (UTC 1000 Type from Shinkawa Company Ltd.) with Al electrode heated at around 200 degrees Celsius of IC chip and Ag plated lead frame heated at around 200 degrees Celsius by ultra sonic ball bonding. The condition of IC chip side bonding was as follows: the atmosphere was 95 % Nitrogen + 5 % Hydrogen, the load was 0.2 N, the ball bonding time was 10 msec, and the ball bonding power was 0.40 watts. At this test, times of non compressed bonded caused Al membrane peel of the first bonding was counted. The results of the measurement are shown in the right column of Table 3.

[0025]

[Recrystallization temperature of wire and room temperature hardness of initial balls (FAB)]

Recrystallization temperature is defined as temperature of which the material completely softened from the state after drawing, and it is shown in Table 2.

Evaluation on the room temperature hardness of initial balls (FAB) of Cu alloy wire melted and solidified at the first bonding and room temperature of molten ball were calculated as an average of random sampling of 10 pieces from 30 thousand times bonding measured by the Micro Vickers Tester (Type DMH-1 from Akashi Seisakusyo Ltd.)

[0026]
[Table 3]

Table 3: Room temperature hardness of initial ball and relationship with Al membrane peels by bonding

	No.	FAB room temperature hardness (Hv)			[30 thousands cycles test]
		Average	Maximum Value	Minimum Value	Number of Al membrane peels
Examples	1	79.5	86.2	75.7	0
	2	78.8	85.4	74.2	0
	3	79	84	75.5	0
	4	82.6	84.7	72.1	0
	5	81.8	87.6	76.5	0
	6	80.7	86.1	72.1	0
	7	83.4	86.8	77.5	0
	8	83.7	86.8	78.9	0
	9	83.1	87.2	77.4	0
Controls	10	85.5	90.1	79.2	0
	11	84	89.7	80.1	0
	12	88	92.8	83.6	3
	13	87.9	94.1	86.5	14
	14	88.5	93.1	84.1	22
	15	88.9	94.5	84.2	48

[0027]

On recrystallization temperature shown in the Table 2, it is recognized that Cu alloy wires added specific amount of P as Example No.1 – 9 have higher recrystallization temperature comparing with high purity Cu wire entirely no added P as Control 10 and high purity Cu wire with extremely traceable added P as Control 11.

[0028]

On the other hand, it is recognized that on high purity Cu alloy wires of around 99.999 wt % of Cu added specific amount of P as Example 6 and 7, room temperature hardness are lower than that of high purity Cu wire entirely no added P as Control 10 and that of Cu alloy wire added much amount of P as Control 15 and the number of Al membrane peels shown in the Table 2 are lesser than them (30 thousands cycles test number is zero.9).

[0029]

As mentioned the above, the bonding wires of the present invention has lower room temperature hardness of initial balls (FAB), though recrystallization temperature is high, every Example has no Al membrane peel at 30 thousands cycles test, it had been greatly improved.

Therefore, as the bonding wires of the present invention have higher recrystallization temperature, and they have less age softening effect, these wires keep characteristics of wire drawing and at ball bonding these wires prevent efficiently chip cracks because of lower room temperature hardness of initial ball.

[POSSIBILITY FOR INDUSTRIAL USE]

[0030]

According to the bonding wires of the present invention, Cu alloy wires added specific amount of P are superior at preventing chip cracks caused initial balls (FAB), moreover, they can be draw-able as same manner of conventional bonding wire, and they have superior effect on improving reliability of semiconductor devices.

CLAIMS

What is claimed is:

[Claim 1]

Cu alloy wire for ball bonding comprising: 0.5 – 15 wt ppm of P and residual is more than 99.9985 wt % of Cu, and decreasing room temperature hardness of initial balls (FAB) of the Cu alloy wire than that of Cu wire of 99.9999 wt % Cu no added P.

[Claim 2]

High purity Cu alloy wire for ball bonding comprising: 0.5 – 15 wt ppm of P and residual is more than 99.9985 wt % of Cu and total amount of metallic elements except P in Cu is less than the amount of added P, and decreasing room temperature hardness of initial balls (FAB) of the Cu alloy wire than that of Cu wire of 99.9999 wt % Cu no added P.

[Claim 3]

High purity Cu alloy wire for ball bonding in Claim 2 comprising: metallic element(s) except P in Cu are one or more than two among Pt, Au, Ag, Pd, Ca, Fe, Mn, Ni, Al, Pb and Si.