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GOLD WIRE FOR BONDING

BACKGROUND OF THE INVENTION

The present invention relates to a bonding gold wire to be used for connection between each electrode and outer lead portion of an IC chip. More particularly, the invention is concerned with an IC chip bonding gold wire capable of greatly reducing the degree of damage of a bonding wire neck portion caused by, for example, an increase of an ultrasonic output at the time of assembling a semiconductor device.

Heretofore, as the method for connection between electrodes and outer lead portions on an IC chip, there has mainly been used a thermosonic wire bonding method which employs a gold wire. With the recent demand for high speed and higher function of a semiconductor device and consequent increase in the number of electrodes and outer leads, the wiring distance from the electrodes to the leads has become longer. On the other hand, as a measure for reducing the size and thickness of a semiconductor device, the distance between an electrode and an outer lead wiring is made extremely short.

As a result, it is required that the wiring be

short despite the use of many lead wires. To meet this demand, in the course of forming a loop by the use of a bonding device, there has been made an attempt to stabilize the loop height and the loop shape by performing what is called reverse deformation, that is, by bending and deforming a ball neck portion severely in the direction opposite to the loop forming direction and thereafter stretching a loop.

However, when the loop formed by such reverse deformation is exposed to a heat cycle environment involved in the generation of heat from a semiconductor device at the stage of operation of device, there occurs the problem of disconnection at the ball neck portion.

In order to prevent such disconnection during operation of the semiconductor device, there is now a demand for developing a gold wire which, when the ball neck portion is bent and deformed severely and a loop is stretched, does not undergo disconnection in a subsequent heat cycle test which is conducted to a severe extent.

There has heretofore been proposed the incorporation of Eu, Ca, Ge and Be each in a predetermined amount into a gold wire for the purpose of

remedying the problem that the neck portion just above a gold ball is broken by vibration (see Japanese Patent Laid-Open No. 9624 /93).

However, such conventional bonding wire as proposed above is not considered satisfactory as a gold wire that is little disconnected at the ball neck portion when exposed to a severe heat cycle environment, vibration and impact after severe bending and deformation at the ball neck portion and subsequent stretching of a loop.

SUMMARY OF THE INVENTION

The present invention has been accomplished in view of the aforementioned circumstances and it is the object of the invention to provide a gold wire for IC chip bonding which gold wire is not broken even when exposed to a severe heat cycle environment and which the neck portion just above a gold ball is broken by vibration and impact after thermosonic bonding at an enhanced ultrasonic wave output and subsequent stretching of a loop, that is, after performing what is called reverse deformation.

Having made extensive studies, the present inventors found that by making a gold alloy wire

consisted essentially of platinum (Pt), silver (Ag), magnesium (Mg) and europium (Eu) each in a predetermined amount, with the balance being gold (Au), said gold having less than 0.001% by weight of incidental impurity, the above-mentioned purpose could be attained by a synergistic effect of those elements. In this way we completed the present invention.

More specifically, the present invention, in the first aspect thereof, resides in a gold wire for use in the bonding of IC chip, consisting essentially of from platinum (Pt): 0.0001-0.005wt%, silver (Ag): 0.0001-0.005 wt%, magnesium (Mg): 0.0005-0.005 wt% and europium (Eu): 0.00005-0.005 wt%; with the balance being gold (Au), said gold (Au) having less than incidental impurity: 0.001 wt%.

The present invention, in the second aspect thereof, resides in a gold wire for use in the bonding of IC chip according to the first aspect thereof, further consisting essentially of at least one additional element selected from the group consisting of from beryllium (Be): 0.00002-0.001 wt%, calcium (Ca): 0.00005-0.004 wt%, germanium (Ge): 0.0005-0.01 wt%.

Further, the present invention, in the third aspect thereof, resides in a gold wire for use in the

bonding of IC chip according to the first aspect thereof, further consisting essentially of from 0.0001-0.02 wt% selected from lantanum (La), yttrium (Y), lead (Pb), erbium (Er), gadolinium (Gd), cerium (Ce), praseodymium (Pr), neodymium (Nd) and samarium (Sm).

Further, the present invention, in the fourth aspect thereof, resides in a gold wire for use in the bonding of IC chip according to the second aspect thereof, further consisting essentially of from 0.0001-0.02 wt% selected from lantanum (La), yttrium (Y), lead (Pb), erbium (Er), gadolinium (Gd), cerium (Ce), praseodymium (Pr), neodymium (Nd) and samarium (Sm).

Further, the present invention, in the fifth aspect thereof, resides in a gold wire for use in the bonding of IC chip according to the first aspect thereof, wherein Ag content is from 0.0005-0.005 wt%.

Further, the present invention, in the sixth aspect thereof, resides in a gold wire for use in the bonding of IC chip according to the second aspect thereof, wherein Ag content is from 0.0005-0.005 wt%.

Further, the present invention, in the seventh aspect thereof, resides in a gold wire for use in the bonding of IC chip according to the third aspect thereof, wherein Ag content is from 0.0005-0.005 wt%.

Further, the present invention, in the eighth aspect thereof, resides in a gold wire for use in the bonding of IC chip according to the fourth aspect thereof, wherein Ag content is from 0.0005-0.005 wt%.

BRIEF DESCRIPTION OF THE DRAWING

Fig. 1 is a schematic diagram showing an outline of an oscillation test according to the present invention.

DETAILED DESCRIPTION OF THE INVENTION

As mentioned above, the bonding gold wire according to the present invention has a composition containing a first group of Pt, Ag, Mg and Eu each in a predetermined amount, or a second group which comprises at least one member selected from Be, Ca and Ge each in a predetermined amount, or a third group which comprises a predetermined amount of at least one member selected from La, Y, P, Er, Gd, Ce, Pr, Nd and Sm.

The following description is now provided about a detailed construction of the present invention and the operation thereof.

In the present invention, by making a gold alloy wire consisted essentially of platinum (Pt), silver

(Ag), magnesium (Mg) and europium (Eu) each so as to give the foregoing construction, with the balance being gold (Au), said gold having less than 0.001% by weight of incidental impurity, there can be obtained, by virtue of a synergistic effect of those metal elements, a gold alloy wire superior in reliability and breaking performance when exposed to a heat cycle environment, vibration and impact, of a neck portion thereof as a bonding wire after thermosonic wire bonding at an enhanced ultrasonic wave output and after reverse deformation to form a loop. The reason why the composition of the gold alloy wire of the present invention is limited as above will be stated below.

[First group; Pt]

In combination with Ag, Mg and Eu, Pt exhibits an excellent effect in improving the reliability of the ball neck portion.

At a Pt content of not lower than 0.0001 wt%, in comparison with a Pt content lower than 0.0001 wt%, the ball neck portion becomes more reliable, and if the Pt content exceeds 0.005 wt%, it will become no longer possible to effect ball formation. For this reason the Pt content has been limited in the range of 0.0001 to 0.005 wt%.

In comparison with the case where any one of Ag, Mg and Eu is not present while Pt is present in an amount within the above range, the reliability of the ball neck portion is improved in the presence of Pt with Ag, Mg and Eu. It is thus necessary that Pt be used in the presence of Ag, Mg and Eu.

A more preferred composition comprises the elements plus at least one member selected from Be, Ca and Ge each in a predetermined amount. In this composition the reliability of the ball neck portion is further improved.

[First group; Ag]

In combination with Pt, Mg and Eu, Ag exhibits an excellent effect in improving the reliability of the ball neck portion.

At an Ag content of not lower than 0.0001 wt%, in comparison with an Ag content of lower than 0.0001 wt%, the ball neck portion gets more reliable. A more preferred range of Ag content is more than 0.0005 wt% in which range the reliability of the ball neck portion is further improved under breaking ratio by impact test. If the Ag content exceeds 0.005 wt%, it is impossible to effect ball formation to a satisfactory extent. For this reason, the Ag content is specified in the range of

0.0001 to 0.05 wt%.

In comparison with the case where Ag is present in an amount within the above range but any one of Pt, Mg and Eu is not present, the use of Ag contributes to the improvement of reliability of the ball neck portion in the presence of all of Pt, Mg and Eu. It is necessary that Ag be used in combination with Pt, Mg and Eu.

According to a more preferred composition, at least one of Be, Ca and Ge is used in a predetermined amount in addition to the above elements. This composition is more effective in improving the reliability of the neck portion.

[First group; Mg]

Mg, in combination with Pt, Ag and Eu, exhibits an excellent effect in improving the reliability of the ball neck portion.

If the Mg content is not lower than 0.0005 wt%, the reliability of the ball neck portion is improved in comparison with the case where the Mg content is lower than 0.0005 wt%. If the Mg content exceeds 0.005 wt%, not only it is no longer possible to effect ball formation to a satisfactory extent but also cracking is generated at chip electrodes at the time of bonding.

For this reason, the Mg content has been specified in the range of 0.0005 to 0.005 wt%.

In comparison with the case where Mg is used in an amount within the above range while any one of Pt, Ag and Eu is not used, the use of Mg results in improved reliability of the ball neck portion in the presence of all of Pt, Ag and Eu. It is thus necessary to use Mg in combination with Pt, Ag and Eu.

According to a more preferred composition, at least any one of Be, Ca and Ge is used in a predetermined amount in addition to the above elements. This composition is more effective in improving the reliability of the ball neck portion.

[First group; Eu]

Eu, in combination with Pt, Ag and Mg, exhibits an excellent effect in improving the reliability of the ball neck portion.

If the Eu content is not lower than 0.00005 wt%, in comparison with an Eu content lower than 0.00005 wt%, the reliability of the ball neck portion is improved, and a further improvement of the reliability is attained at an Eu content of not lower than 0.0001 wt%. If the Eu content exceeds 0.005 wt%, cracking occurs at chip electrodes at the time of bonding. For

this reason, the Eu content has been specified in the range of 0.00005 to 0.005 wt%.

In comparison with the case where any one of Pt, Ag and Mg is not present even with Eu present in an amount within the above range, the use of Eu contributes to the improvement in reliability of the ball neck portion in combination of all of Pt, Ag and Mg. It is necessary to use Eu in combination with Pt, Ag and Mg.

A more preferred range of Eu content is 0.0001 to 0.005 wt% in which range the reliability of the ball neck portion is further improved.

A more preferred composition comprises the above elements and at least one of Be, Ca and Ge in a predetermined amount. This composition is more effective in improving the reliability of the ball neck portion.

[Second group; Be, Ca, Ge]

Using at least one member selected from 0.00002-0.001 wt% of Be, 0.00005-0.004 wt% of Ca and 0.0005-0.01 wt% of Ge in combination with Pt, Ag, Mg and Eu is preferred because a further improvement in reliability of the ball neck portion will result.

Such further improvement is not attained if the

Be content is lower than 0.00002 wt%, the Ca content lower than 0.00005 wt% and Ge content lower than 0.0005 wt%.

If the Be content exceeds 0.001 wt%, it is no longer possible to effect ball information to a satisfactory extent.

This is also true of the case where the Ca content is higher than 0.004 wt%.

At a Ge content exceeding 0.01wt%, electrode cracking will occur more easily at the time of bonding.

For the above reasons there have been specified the Be content in the range of 0.00002 to 0.001 wt%, Ca content 0.00005 to 0.004 wt% and Ge content 0.0005 to 0.01 wt%.

[Third group; La, Y, Pb, Er, Gd, Ce, Pr, Nd, Sm]

If at least one of the third group components which are La, Y, Pb, Er, Gd, Ce, Pr, Nd and Sm is used in an amount of 0.0001 to 0.02 wt% in addition to the first group components, an equal effect is attained to that attained by the composition which contains only the first group component with respect to the reliability of the ball neck portion.

In this case, even if a component of the third group is present, there a high reliability of the ball

neck portion is not attained if any of the first group components, i.e., Pt, Ag, Mg and Eu, is not present.

Further, if at least one of the third group components which are La, Y, Pb, Er, Gd, Ce, Pr, Nd and Sm is used by an amount of 0.0001 to 0.02 wt% in addition to the first and second group components, an equal or superior effect is attained to that attained by the composition which contains both first and second group components, with respect to the reliability of the ball neck portion.

In this case, if any one of the first group components, Pt, Ag, Mg and Eu, is not used, a high reliability of the ball neck portion is not attained even with the second and third components are used.

[Examples]

The following description is now provided about working examples and comparative examples shown in Tables 1 to 16.

(Example 1)

By adding Pt, Ag, Mg and Eu in the predetermined amount to 99.999 wt% of high purity gold and melt it in a smelting furnace and then cast, gold alloy comprising the composition shown in the table, namely, Pt: 1ppm, Ag: 10ppm, Mg: 20ppm and Eu: 10ppm, with the balance

being Au, said Au having less than incidental impurity: 10ppm. Gold working using grooved rolls and a wire drawing machine and heat treatment are repeated to finish into a fine wire 30 μm in final diameter and 4% elongation. Using this fine wire as a bonding wire and using an automatic high-speed bonder, a thermosonic wire bonding is performed onto IC chip electrodes. After initial ball bonding at an ultrasonic output of 0.5W, the capillary is once moved in the direction opposite to the loop forming direction and that reverse angle was set at 60 ° relative to the vertical direction to bend and deform the ball neck portion severely, followed by bonding with outer leads and formation of a regular loop (wiring). The test material for wiring is 40 pins for 1 IC chip, namely 40 pieces wiring are made.

Next, the shape of ball is checked, electrode cracking is checked, a heat cycle test is conducted, vibration test is conducted, and impact test is conducted. Measurement results obtained are as shown in Table 2.

(Examples 2-159 and Comparative Examples 1-22)

Fine wires are finished and the aforementioned each tests were performed in the same way as in Example

1 except that the composition of gold alloy is used as shown in the tables. The results obtained are as set out in Tables 2, 4, 6, 8, 11, 14 and 16.

The following methods are adopted for the measurements and evaluations.

[Ball shape]

Using an electric torch incorporated in an automatic high-speed bonder, a gold ball is formed, and then using a scanning type electron microscope, the size, sphericity and surface condition of the gold ball were observed.

The size of the gold ball is measured on the basis of 2.5 times that wire diameter, namely, 75μm ϕ, while the sphericity and surface condition are evaluated in comparison with control samples. When all of ten samples measured are good, the result is indicated as "good", while when even one of them is defective, the result is indicated as "bad".

[Electrode Cracking in Bonding]

When there is no electrode cracking in a 100 wiring samples conducted using an automatic high-speed bonder, the result is indicated as "good", while when even one ball was cracked in the same test, the result is indicated as "bad".

[Heat Cycle Test]

After sealing the wiring samples with an epoxy resin, heat cycle tests of -10 ° C, 30 minutes and 150 ° C for 30 minutes are conducted by 2000 times. 100 samples are used in the test and disconnection is checked by a conduction test. The number of sample which has been disconnected is indicated in terms of breaking ratio (%).

[Vibration Test]

Bonding is performed by use of a silver-plated lead frame 1 in place of the IC chip electrodes, wired in the same way as in Example 1, then cut bonding portion of outer lead side and make the samples illustrated in Fig. 1, and the thus-obtained samples are used in a vibration test.

Using a vibration tester 2 illustrated in Fig. 1, a vibration test is conducted under the following conditions, in which a test wire 3 with the front end thereof bonded to the lead frame 1 is oscillated both right and left around a shaft 5 by means of a wire supporting portion 4. And the number of times of oscillation up to breaking was measured.

Span (L_1) : 150 μm

Both-side Amplitude (L_2) : 26 μm

Oscillation Frequency: 40 Hz (40 times/sec)

The same test was repeated three times and a mean value obtained was indicated.

[Impact test]

6 wiring samples (the total number of wire is 240) are made and perform impact accelerated test. Namely, set the samples into magazine, drop it from a level 100mm high and check the number of broken wire by a light microscope. The breaking ratio is shown as the following formula.

$$\text{Breaking ratio} = \frac{\text{the number of broken wire}}{240} \times 100(\%)$$

Table 1

Example	Composition (ppm by weight)							
	Pt	Ag	Mg	Eu	Be	Ca	Ge	Au
1	1	10	20	10	—	—	—	balance
2	10	10	20	10	—	—	—	balance
3	50	10	20	10	—	—	—	balance
4	10	1	20	10	—	—	—	balance
5	10	5	20	10	—	—	—	balance
6	10	50	20	10	—	—	—	balance
7	10	10	5	10	—	—	—	balance
8	10	10	50	10	—	—	—	balance
9	10	10	20	0.5	—	—	—	balance
10	10	10	20	1	—	—	—	balance
11	10	10	20	50	—	—	—	balance
12	1	10	20	10	5	—	—	balance
13	10	10	20	10	5	—	—	balance
14	50	10	20	10	5	—	—	balance
15	10	1	20	10	5	—	—	balance
16	10	5	20	10	5	—	—	balance
17	10	50	20	10	5	—	—	balance
18	10	10	5	10	5	—	—	balance
19	10	10	50	10	5	—	—	balance
20	10	10	20	0.5	5	—	—	balance
21	10	10	20	1	5	—	—	balance
22	10	10	20	50	5	—	—	balance
23	10	10	20	10	0.2	—	—	balance
24	10	10	20	10	10	—	—	balance
25	1	10	20	10	—	10	—	balance
26	10	10	20	10	—	10	—	balance
27	50	10	20	10	—	10	—	balance
28	10	1	20	10	—	10	—	balance
29	10	5	20	10	—	10	—	balance
30	10	50	20	10	—	10	—	balance
31	10	10	5	10	—	10	—	balance
32	10	10	50	10	—	10	—	balance
33	10	10	20	0.5	—	10	—	balance

Table 2

Example	Measurement Results				
	Ball shape	Electrode Cracking in Bonding	Reliability of Bonding Neck Portion		
			Heat cycle test Breaking ratio(%)	Vibration test ($\times 10^3$ times)	Impact test Breaking ratio(%)
1	good	good	1	12.1	5
2	good	good	1	12.3	3
3	good	good	1	12.4	3
4	good	good	1	12.1	12
5	good	good	1	12.2	1
6	good	good	1	12.3	4
7	good	good	1	12.4	2
8	good	good	1	12.6	3
9	good	good	1	11.2	2
10	good	good	1	12.3	2
11	good	good	1	12.2	2
12	good	good	0	13.0 or more	2
13	good	good	0	13.0 or more	2
14	good	good	0	13.0 or more	1
15	good	good	0	13.0 or more	13
16	good	good	0	13.0 or more	2
17	good	good	0	13.0 or more	2
18	good	good	0	13.0 or more	2
19	good	good	0	13.0 or more	1
20	good	good	1	11.2	2
21	good	good	0	13.0 or more	2
22	good	good	0	13.0 or more	2
23	good	good	0	13.0 or more	1
24	good	good	0	13.0 or more	1
25	good	good	0	13.0 or more	1
26	good	good	0	13.0 or more	1
27	good	good	0	13.0 or more	1
28	good	good	0	13.0 or more	13
29	good	good	1	13.0 or more	2
30	good	good	0	13.0 or more	2
31	good	good	0	13.0 or more	2
32	good	good	0	13.0 or more	2
33	good	good	1	11.2	2

Table 3

Example	Composition (ppm by weight)							
	Pt	Ag	Mg	Eu	Be	Ca	Ge	Au
34	10	10	20	1	—	10	—	balance
35	10	10	20	50	—	10	—	balance
36	10	10	20	10	—	0.5	—	balance
37	10	10	20	10	—	40	—	balance
38	1	10	20	10	—	—	40	balance
39	10	10	20	10	—	—	40	balance
40	50	10	20	10	—	—	40	balance
41	10	1	20	10	—	—	40	balance
42	10	5	20	10	—	—	40	balance
43	10	50	20	10	—	—	40	balance
44	10	10	5	10	—	—	40	balance
45	10	10	50	10	—	—	40	balance
46	10	10	20	0.5	—	—	40	balance
47	10	10	20	1	—	—	40	balance
48	10	10	20	50	—	—	40	balance
49	10	10	20	10	—	—	5	balance
50	10	10	20	10	—	—	100	balance
51	1	10	20	10	5	10	—	balance
52	10	10	20	10	5	10	—	balance
53	50	10	20	10	5	10	—	balance
54	10	1	20	10	5	10	—	balance
55	10	5	20	10	5	10	—	balance
56	10	50	20	10	5	10	—	balance
57	10	10	5	10	5	10	—	balance
58	10	10	50	10	5	10	—	balance
59	10	10	20	0.5	5	10	—	balance
60	10	10	20	1	5	10	—	balance
61	10	10	20	50	5	10	—	balance
62	10	10	20	10	0.2	10	—	balance
63	10	10	20	10	10	10	—	balance
64	10	10	20	10	5	0.5	—	balance
65	10	10	20	10	5	40	—	balance

Table 4

Exam-ple	Measurement Results				
	Ball shape	Electrode Cracking in Bonding	Reliability of Bonding Neck Portion		
			Heat cycle test Breaking ratio(%)	Vibration test ($\times 10^3$ times)	Impact test Breaking ratio(%)
34	good	good	0	13.0 or more	1
35	good	good	0	13.0 or more	2
36	good	good	0	13.0 or more	2
37	good	good	0	13.0 or more	1
38	good	good	0	13.0 or more	2
39	good	good	0	13.0 or more	2
40	good	good	0	13.0 or more	2
41	good	good	0	13.0 or more	13
42	good	good	0	13.0 or more	1
43	good	good	0	13.0 or more	2
44	good	good	0	13.0 or more	1
45	good	good	0	13.0 or more	1
46	good	good	1	11.2	3
47	good	good	0	13.0 or more	2
48	good	good	0	13.0 or more	1
49	good	good	0	13.0 or more	2
50	good	good	0	13.0 or more	2
51	good	good	0	13.0 or more	2
52	good	good	0	13.0 or more	1
53	good	good	0	13.0 or more	2
54	good	good	0	13.0 or more	14
55	good	good	0	13.0 or more	2
56	good	good	0	13.0 or more	1
57	good	good	0	13.0 or more	2
58	good	good	0	13.0 or more	2
59	good	good	1	11.2	2
60	good	good	0	13.0 or more	1
61	good	good	0	13.0 or more	2
62	good	good	0	13.0 or more	2
63	good	good	0	13.0 or more	2
64	good	good	0	13.0 or more	2
65	good	good	0	13.0 or more	2

Table 5

Example	Composition (ppm by weight)							
	Pt	Ag	Mg	Eu	Be	Ca	Ge	Au
66	1	10	20	10	5	—	40	balance
67	10	10	20	10	5	—	40	balance
68	50	10	20	10	5	—	40	balance
69	10	1	20	10	5	—	40	balance
70	10	5	20	10	5	—	40	balance
71	10	50	20	10	5	—	40	balance
72	10	10	5	10	5	—	40	balance
73	10	10	50	10	5	—	40	balance
74	10	10	20	0.5	5	—	40	balance
75	10	10	20	1	5	—	40	balance
76	10	10	20	50	5	—	40	balance
77	10	10	20	10	0.2	—	40	balance
78	10	10	20	10	10	—	40	balance
79	10	10	20	10	5	—	5	balance
80	10	10	20	10	5	—	100	balance
81	1	10	20	10	—	10	40	balance
82	10	10	20	10	—	10	40	balance
83	50	10	20	10	—	10	40	balance
84	10	1	20	10	—	10	40	balance
85	10	5	20	10	—	10	40	balance
86	10	50	20	10	—	10	40	balance
87	10	10	5	10	—	10	40	balance
88	10	10	50	10	—	10	40	balance
89	10	10	20	0.5	—	10	40	balance
90	10	10	20	1	—	10	40	balance
91	10	10	20	50	—	10	40	balance
92	10	10	20	10	—	0.5	—	balance
93	10	10	20	10	—	40	—	balance
94	10	10	20	10	—	—	5	balance
95	10	10	20	10	—	—	100	balance
96	1	10	20	10	5	10	40	balance
97	10	10	20	10	5	10	40	balance

Table 6

Exam-ple	Measurement Results				
	Ball shape	Electrode Cracking in Bonding	Reliability of Bonding Neck Portion		
			Heat cycle test Breaking ratio(%)	Vibration test ($\times 10^3$ times)	Impact test Breaking ratio(%)
66	good	good	0	13.0 or more	2
67	good	good	0	13.0 or more	1
68	good	good	0	13.0 or more	2
69	good	good	0	13.0 or more	13
70	good	good	0	13.0 or more	1
71	good	good	0	13.0 or more	1
72	good	good	0	13.0 or more	1
73	good	good	0	13.0 or more	2
74	good	good	1	11.2	3
75	good	good	0	13.0 or more	2
76	good	good	0	13.0 or more	1
77	good	good	0	13.0 or more	1
78	good	good	0	13.0 or more	2
79	good	good	0	13.0 or more	2
80	good	good	0	13.0 or more	1
81	good	good	0	13.0 or more	1
82	good	good	0	13.0 or more	2
83	good	good	0	13.0 or more	1
84	good	good	0	13.0 or more	14
85	good	good	0	13.0 or more	2
86	good	good	0	13.0 or more	2
87	good	good	0	13.0 or more	1
88	good	good	0	13.0 or more	2
89	good	good	1	11.2	3
90	good	good	1	13.0 or more	2
91	good	good	1	13.0 or more	1
92	good	good	1	13.0 or more	1
93	good	good	1	13.0 or more	1
94	good	good	1	13.0 or more	2
95	good	good	1	13.0 or more	2
96	good	good	1	13.0 or more	1
97	good	good	1	13.0 or more	2

Table 7

Example	Composition (ppm by weight)							
	Pt	Ag	Mg	Eu	Be	Ca	Ge	Au
98	50	10	20	10	5	10	40	balance
99	10	1	20	10	5	10	40	balance
100	10	5	20	10	5	10	40	balance
101	10	50	20	10	5	10	40	balance
102	10	10	5	10	5	10	40	balance
103	10	10	50	10	5	10	40	balance
104	10	10	20	0.5	5	10	40	balance
105	10	10	20	1	5	10	40	balance
106	10	10	20	50	5	10	40	balance
107	10	10	20	10	0.2	10	40	balance
108	10	10	20	10	10	10	40	balance
109	10	10	20	10	5	0.5	40	balance
110	10	10	20	10	5	40	40	balance
111	10	10	20	10	5	40	5	balance
112	10	10	20	10	5	40	100	balance

Table 8

Example	Measurement Results				
	Ball shape	Electrode Cracking in Bonding	Reliability of Bonding Neck Portion		
			Heat cycle test Breaking ratio(%)	Vibration test ($\times 10^3$ times)	Impact test Breaking ratio(%)
98	good	good	0	13.0 or more	2
99	good	good	0	13.0 or more	15
100	good	good	0	13.0 or more	2
101	good	good	0	13.0 or more	1
102	good	good	0	13.0 or more	2
103	good	good	0	13.0 or more	2
104	good	good	1	11.2	3
105	good	good	0	13.0 or more	1
106	good	good	0	13.0 or more	2
107	good	good	0	13.0 or more	1
108	good	good	0	13.0 or more	1
109	good	good	0	13.0 or more	2
110	good	good	0	13.0 or more	2
111	good	good	0	13.0 or more	1
112	good	good	0	13.0 or more	2

Table 9

Example	Composition (ppm by weight)							
	Pt	Ag	Mg	Eu	Be	Ca	Ge	La
113	1	10	20	10	—	—	—	20
114	10	10	20	10	—	—	—	20
115	50	10	20	10	—	—	—	20
116	10	1	20	10	—	—	—	20
117	10	5	20	10	—	—	—	20
118	10	50	20	10	—	—	—	20
119	10	10	5	10	—	—	—	20
120	10	10	50	10	—	—	—	20
121	10	10	20	0.5	—	—	—	20
122	10	10	20	1	—	—	—	20
123	10	10	20	50	—	—	—	20
124	10	10	20	10	—	—	—	1
125	10	10	20	10	—	—	—	200
126	10	10	20	10	—	—	—	—
127	10	10	20	10	—	—	—	—
128	10	10	20	10	—	—	—	—
129	10	10	20	10	—	—	—	—
130	10	10	20	10	—	—	—	—
131	10	10	20	10	—	—	—	—
132	10	10	20	10	—	—	—	—
133	10	10	20	10	—	—	—	—
134	10	10	20	10	—	—	—	20
135	10	10	20	10	—	—	—	20
136	10	10	20	10	0.2	—	—	20
137	10	10	20	10	5	—	—	20
138	10	10	20	10	10	—	—	20
139	10	10	20	10	—	0.5	—	20
140	10	10	20	10	—	20	—	20
141	10	10	20	10	—	40	—	20
142	10	10	20	10	—	—	5	20
143	10	10	20	10	—	—	100	20

Table 10

Example	Composition (ppm by weight)								
	Y	Pb	Er	Gd	Ce	Pr	Nd	Sm	Au
113	—	—	—	—	—	—	—	—	balance
114	—	—	—	—	—	—	—	—	balance
115	—	—	—	—	—	—	—	—	balance
116	—	—	—	—	—	—	—	—	balance
117	—	—	—	—	—	—	—	—	balance
118	—	—	—	—	—	—	—	—	balance
119	—	—	—	—	—	—	—	—	balance
120	—	—	—	—	—	—	—	—	balance
121	—	—	—	—	—	—	—	—	balance
122	—	—	—	—	—	—	—	—	balance
123	—	—	—	—	—	—	—	—	balance
124	—	—	—	—	—	—	—	—	balance
125	—	—	—	—	—	—	—	—	balance
126	20	—	—	—	—	—	—	—	balance
127	—	20	—	—	—	—	—	—	balance
128	—	—	20	—	—	—	—	—	balance
129	—	—	—	20	—	—	—	—	balance
130	—	—	—	—	20	—	—	—	balance
131	—	—	—	—	—	20	—	—	balance
132	—	—	—	—	—	—	20	—	balance
133	—	—	—	—	—	—	—	20	balance
134	20	—	—	—	—	—	—	—	balance
135	20	20	—	—	—	—	—	—	balance
136	—	—	—	—	—	—	—	—	balance
137	—	—	—	—	—	—	—	—	balance
138	—	—	—	—	—	—	—	—	balance
139	—	—	—	—	—	—	—	—	balance
140	—	—	—	—	—	—	—	—	balance
141	—	—	—	—	—	—	—	—	balance
142	—	—	—	—	—	—	—	—	balance
143	—	—	—	—	—	—	—	—	balance

Table 11

Exam -ple	Measurement Results				
	Ball shape	Electrode Cracking in Bonding	Reliability of Bonding Neck Portion		
			Heat cycle test Breaking ratio(%)	Vibration test ($\times 10^3$ times)	Impact test Breaking ratio(%)
113	good	good	1	12.3	3
114	good	good	1	12.1	5
115	good	good	1	12.4	4
116	good	good	1	12.0	13
117	good	good	1	12.1	2
118	good	good	1	12.2	3
119	good	good	1	12.3	3
120	good	good	1	12.6	2
121	good	good	1	11.2	2
122	good	good	1	12.3	3
123	good	good	1	12.2	3
124	good	good	1	12.1	4
125	good	good	1	12.5	4
126	good	good	1	12.0	3
127	good	good	1	12.6	4
128	good	good	1	12.0	4
129	good	good	1	12.3	3
130	good	good	1	12.0	5
131	good	good	1	12.4	3
132	good	good	1	12.5	3
133	good	good	1	12.3	4
134	good	good	1	12.1	5
135	good	good	1	12.0	5
136	good	good	0	13.0 or more	2
137	good	good	0	13.0 or more	1
138	good	good	0	13.0 or more	1
139	good	good	0	13.0 or more	2
140	good	good	0	13.0 or more	1
141	good	good	0	13.0 or more	1
142	good	good	0	13.0 or more	2
143	good	good	0	13.0 or more	1

Table 12

Example	Composition (ppm by weight)							
	Pt	Ag	Mg	Eu	Be	Ca	Ge	La
144	10	10	20	10	5	20	—	20
145	10	10	20	10	5	—	40	20
146	10	10	20	10	—	20	40	20
147	10	10	20	10	5	20	40	20
148	10	10	20	10	5	20	—	1
149	10	10	20	10	5	20	—	200
150	10	10	20	10	5	20	—	—
151	10	10	20	10	5	20	—	—
152	10	10	20	10	5	20	—	—
153	10	10	20	10	5	20	—	—
154	10	10	20	10	5	20	—	—
155	10	10	20	10	5	20	—	—
156	10	10	20	10	5	20	—	—
157	10	10	20	10	5	20	—	—
158	10	10	20	10	5	20	—	20
159	10	10	20	10	5	20	—	20

Table 13

Example	Composition (ppm by weight)								
	Y	Pb	Er	Gd	Ce	Pr	Nd	Sm	Au
144	—	—	—	—	—	—	—	—	balance
145	—	—	—	—	—	—	—	—	balance
146	—	—	—	—	—	—	—	—	balance
147	—	—	—	—	—	—	—	—	balance
148	—	—	—	—	—	—	—	—	balance
149	—	—	—	—	—	—	—	—	balance
150	20	—	—	—	—	—	—	—	balance
151	—	20	—	—	—	—	—	—	balance
152	—	—	20	—	—	—	—	—	balance
153	—	—	—	20	—	—	—	—	balance
154	—	—	—	—	20	—	—	—	balance
155	—	—	—	—	—	20	—	—	balance
156	—	—	—	—	—	—	20	—	balance
157	—	—	—	—	—	—	—	20	balance
158	20	—	—	—	—	—	—	—	balance
159	20	20	—	—	—	—	—	—	balance

Table 14

Exam-ple	Measurement Results				
	Ball shape	Electrode Cracking in Bonding	Reliability of Bonding Neck Portion		
			Heat cycle test Breaking ratio(%)	Vibration test ($\times 10^3$ times)	Impact test Breaking ratio(%)
144	good	good	0	13.0 or more	2
145	good	good	0	13.0 or more	2
146	good	good	0	13.0 or more	1
147	good	good	0	13.0 or more	1
148	good	good	0	13.0 or more	2
149	good	good	0	13.0 or more	1
150	good	good	0	13.0 or more	1
151	good	good	0	13.0 or more	2
152	good	good	0	13.0 or more	1
153	good	good	0	13.0 or more	1
154	good	good	0	13.0 or more	2
155	good	good	0	13.0 or more	1
156	good	good	0	13.0 or more	2
157	good	good	0	13.0 or more	2
158	good	good	0	13.0 or more	1
159	good	good	0	13.0 or more	1

Table 15

Compa-rative	Composition (ppm by weight)									
	Pt	Ag	Mg	Eu	Be	Ca	Ge	Ce	Y	Au
1	—	—	—	—	—	—	—	—	—	Balance
2	—	10	20	10	—	—	—	—	—	Balance
3	—	10	20	10	5	—	—	—	—	Balance
4	—	10	20	10	5	—	—	20	—	Balance
5	10	—	20	10	—	—	—	—	—	Balance
6	10	10	—	10	—	—	—	—	—	Balance
7	10	10	—	10	5	—	—	—	—	Balance
8	10	10	—	10	—	10	—	—	—	Balance
9	10	10	—	10	—	—	40	—	—	Balance
10	10	10	—	10	5	—	—	20	—	Balance
11	10	10	—	10	5	10	—	20	—	Balance
12	10	10	20	—	—	—	—	—	—	Balance
13	10	10	20	—	5	—	—	—	—	Balance
14	10	10	20	—	—	10	—	—	—	Balance
15	10	10	20	—	—	—	40	—	—	Balance
16	10	10	20	—	5	—	—	20	—	Balance
17	10	10	20	—	5	10	—	20	—	Balance
18	10	10	20	—	5	—	—	20	20	Balance
19	100	10	20	10	5	—	—	20	—	Balance
20	10	100	20	10	5	—	—	20	—	Balance
21	10	10	100	10	5	—	—	20	—	Balance
22	10	10	20	100	5	—	—	20	—	Balance

Table 16

Comparative	Measurement Results				
	Ball shape	Electrode Cracking in Bonding	Reliability of Bonding Neck Portion		
			Heat cycle test Breaking ratio(%)	Vibration test ($\times 10^3$ times)	Impact test Breaking ratio(%)
1	good	good	15	6.4	38
2	good	good	9	8.8	36
3	good	good	7	9.3	34
4	good	good	7	9.6	33
5	good	good	8	9.0	37
6	good	good	6	10.6	27
7	good	good	5	10.5	25
8	good	good	5	10.5	25
9	good	good	5	10.4	24
10	good	good	5	10.3	24
11	good	good	5	10.0	21
12	good	good	7	9.8	35
13	good	good	6	10.2	20
14	good	good	6	10.5	25
15	good	good	6	10.3	24
16	good	good	6	10.6	27
17	good	good	6	10.1	22
18	good	good	6	10.4	24
19	bad	good	2	11.5	13
20	bad	good	2	11.5	13
21	bad	bad	2	11.6	14
22	good	bad	2	11.3	12

As is evident from the above measurement results, in Examples 1 to 11 using predetermined amounts of the first group components, Pt, Ag, Mg and Eu, the ball shape is good and electrode cracking hardly occurs at the time of bonding; besides, the breaking ratio after the heat cycle test is 1%, the number of times of oscillation up to breaking in the vibration test was 11,000 times or more and the breaking ratio under the impact test is 12 % or less, thus exhibiting an excellent effect in the improvement of reliability of the ball neck portion.

Above all, in Examples wherein the content of Eu is 0.0001 wt% or more, the number of times of oscillation up to breaking in the vibration test is 12,000 times or more and in Examples wherein the content of Ag is 0.0005 wt% or more, the breaking ratio under the impact test is 5 % or less, thus exhibiting a superior effect in improving the reliability of the ball neck portion.

In examples 12 to 112 using at least one member selected from the second group components of Be, Ca and Ge in addition to the first group components, the ball shape is good, with no electrode cracking in bonding, the breaking ratio after the heat cycle test is not

higher than 1%, and the number of times of oscillation up to breaking in the vibration test is 11,000 times or more and the breaking ratio under the impact test is 15 % or less, thus exhibiting an excellent effect.

Particularly, in Examples having an Eu content of 0.0001 wt% or more, the breaking ratio after the heat cycle test is 0% and the number of times of oscillation up to breaking in the vibration test is 13,000 times, and in Examples wherein the content of Ag is 0.0005 wt% or more, the breaking ratio under the impact test is 3 % or less, thus exhibiting a more excellent effect in improving the reliability of the ball neck portion.

Further, in Examples 113 to 135 using at least one of the third group components of La, Y, Pb, Er, Gd, Ce, Pr, Nd and Sm in a predetermined amount in addition to the first group components, an equal effect is attained to that attained in Examples 1 to 11 using only the first group of components.

In examples 136 to 159 using at least one of the third group of components of La, Y, Pb, Er, Gd, Ce, Pr, Nd and Sm in a predetermined amount in addition to the first and second group components, an equal or superior effect is attained to that attained in Examples 11 to

112 using both first and second group components.

On the other hand, in comparative example 1 using none of the first to the third group components, the breaking ratio after the heat cycle test is 15%, the number of times of oscillation up to breaking in the vibration test is 6,400 times or so and the breaking ratio under the breaking test is 38%.

In comparative examples 2 to 18 containing none of the first group components, the breaking ratio after the heat cycle test is 5% to 9% and the number of times of oscillation up to breaking in the vibration test is 8,800 times or more and 10,600 times or less and the breaking ratio under the impact test is 20 to 37 %. Thus it turns out that these comparative examples are inferior to the present invention though improved over Comparative Example 1.

Further, comparative examples 19 to 22 using all of the first group components but with the amount of any one of those components being outside the range specified therein are inferior to the present invention in point of either ball shape or chip electrode cracking though similar to the present invention in point of breaking ratio after the heat cycle test which is 2% and the number of times of oscillation up to breaking in

the vibration test which is 11,000 times or more and the breaking ratio under the breaking test is 12 to 14 %.

As set forth, since the gold wire for IC chip bonding in the first aspect of the present invention has a composition consisting essentially of predetermined amounts of Pt, Ag, Mg and Eu; with the balance being Au, said Au having less than 0.001 % by weight of incidental impurity, it is superior in the breaking performance thereof when exposed to a heat cycle environment, vibration and impact can be greatly improved, in the neck portion of a loop formed by reverse deformation after thermosonic wire bonding at an enhanced ultrasonic output.

Therefore, a high reliability is attained in the assembly of a semiconductor device wherein wiring is short despite the use of many lead wires, and this point is extremely useful in promoting speed-up, higher function and reduction of both size and wall thickness of a semiconductor device.

Further, in the case of the gold wire for IC chip bonding in the second aspect of the present invention has a composition consisting essentially of predetermined amounts of Pt, Ag, Mg and Eu and further

containing at least one of Be, Ca and Ge in a predetermined amount, with the balance being Au, and said Au having less than 0.001% by weight of incidental impurity, there can be attained a further improvement in breaking performance when exposed to a heat cycle environment, vibration and impact, in the neck portion of a loop formed by reverse deformation after thermosonic output. Thus, the foregoing effects could be further enhanced.

Further, in the case of the gold wire for IC chip bonding in the third aspect of the present invention has a composition consisting essentially of predetermined amounts of Pt, Ag, Mg and Eu and further containing at least one of La, Y, Pb, Er, Gd, Ce, Pr, Nd, Sm in a predetermined amount, with the balance being Au, and said Au having less than 0.001% by weight of incidental impurity. Thus, the same effects as the foregoing effects in the first aspect of the present invention could be attained.

Further, in the case of the gold wire for IC chip bonding in the fifth aspect of the present invention has a composition consisting essentially of predetermined amounts of Pt, Ag, Mg and Eu, further containing at least one of La, Y, Pb, Er, Gd, Ce, Pr,

Nd, Sm in a predetermined amount and further containing at least one of Be, Ca and Ge in a predetermined amount, with the balance being Au, and said Au having less than 0.001% by weight of incidental impurity. Thus, the same effects as the foregoing effects in the second aspect of the present invention could be attained.

Further, in the case of the gold wire for IC chip bonding in the fifth to eighth aspects of the present invention have the lowest limit amount of a composition Ag in each of the aforementioned first, second, third and fourth inventions is 0.0005 wt%, in the neck portion of loop forming by a thermosonic wire bonding in which increase an ultrasonic output and performing the reverse deformation, it is superior in the breaking performance thereof when exposed to vibration and impact can be greatly improved and the aforementioned effect can be further effective.

Having described specific preferred embodiments of the invention with reference to the accompanying drawings, it will be appreciated that the present invention is not limited to those precise embodiments, and that various changes and modifications can be effected therein by one of ordinary skill in the art

without departing from the scope and spirit of the invention as defined by the appended claims.

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semiconductor device according to claim 1 characterised in that the Ag content is from 0.0005 to 0.005% by weight.

6. A fine gold alloy wire for use in the bonding of a semiconductor device according to claim 2, characterised in that the Ag content is from 0.0005 to 0.005% by weight.

7. A fine gold alloy wire for use in the bonding of a semiconductor device according to claim 3, characterised in that the Ag content is from 0.0005 to 0.005% by weight.

8. A fine gold alloy wire for use in the bonding of a semiconductor device according to claim 4, characterised in that the Ag content is from 0.0005 to 0.005% by weight.

9. A fine gold alloy wire for use in the bonding of a semiconductor device characterised in that the semiconductor device is an IC chip.

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semiconductor device according to claim 1 characterised in that the Ag content is from 0.0005 to 0.005% by weight.

6. A fine gold alloy wire for use in the bonding of a semiconductor device according to claim 2, characterised in that the Ag content is from 0.0005 to 0.005% by weight.

7. A fine gold alloy wire for use in the bonding of a semiconductor device according to claim 3, characterised in that the Ag content is from 0.0005 to 0.005% by weight.

8. A fine gold alloy wire for use in the bonding of a semiconductor device according to claim 4, characterised in that the Ag content is from 0.0005 to 0.005% by weight.

9. A fine gold alloy wire for use in the bonding of a semiconductor device characterised in that the semiconductor device is an IC chip.

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