# WIRE BUMP MATERIAL

[TECHNICAL FIELD]

[0001]

The present invention relates to material for wire bumping to form bump on an electrode pad by using wire bonding technique.

[BACKGROUND OF THE ART]

[0002]

Conventionally, method of forming metallic bump by using wire bonding method is known as method for bonding electrodes on the IC chips or transistors to leads of TAB (Tape Automated Bonding), lead frames and/or outer terminals on ceramic substrates. This wire bumping method has an advantage to manufacture high density packages and thin type packages, because of direct bonding to electrode pads on IC chips to outer terminals through bump and lower height of bonded part comparing to wire-bonding. For example, flip chip method to form bumps on electrodes of IC chip in advance, then to bond these bumps to molten solder on conductive circuit of printed circuit substrate, and also film carrier method to molten bond with Cu tape plated solder are included in this type of methods.

[0003]

For conventional wire bumping materials, due to the requirement that purity of Au alloy should be more than 99.99 mass %, Au of high purity is used. However, when high purity Au is used, after forming balls on ultra fine wire, ultrasonic bonding to IC chip and tearing off a part of the wire held with a clamp, a problem occurs that a tail, which is principal cause of incorrect contact, remains on the side of bumps, namely on balls remained on IC chips. Hence study on shortening the length of tails had been carried out such as Au matrix alloy consisting of 0.5 to 10 mass % Pd (Japanese Patent No. 2737953) and Au matrix alloy consisting of 0.003 to 5 mass % Pd (Japanese Patent Application Laid-Open Publication No. 9-321076), and Au matrix alloy consisting of 0.001 to 5 weight % Pt, Pd and/or Ru (Japanese Patent Application Laid-Open Publication No. 10-287936). However, because genus of platinum, such as Pd, is very expensive, moreover it requires specific facilities and consumes more costs than Au, conventionally

it had been used with purity of 99.9 %, which contained much impurity. Moreover, increasing additives of genus of platinum causes inside of capillary contaminated, and this contamination makes non-spherical ball attached to wire, and balls become harder and Si chip is broken under Al pad. Because of such problems, practically Au-1% Pd alloy is used.

[0004]

Though this Au-1% Pd alloy has advantage such as effect of repression of Au-Al compound growth between Al pad and Au-Pd alloy bump, at the moment of tearing off, still long tails emerge occasionally. Moreover, recently soldering process tends to be operated at higher temperature such as 200 ℃ to 300 ℃, especially in case of Pb-free Sn matrix soldering, higher temperature operation is noticeable. When operating temperature is higher, phenomena of solder consumption occur, namely Au rapidly melt into solder. Therefore, it is forced to operate soldering under strict temperature control. Though Au-5% Pd alloy with high Pd % has been studied, it is not in practical use because it forms hard balls during bonding in the air and causes greater chip damage against Al pad, and it has a problem of big fluctuation of Pd market price, moreover the problems of said capillary contamination and length of tails still remains.

[0005]

[PATENT DOCUMENT 1] Japanese Patent No. 2737953

[PATENT DOCUMENT 2] Japanese Patent Application Laid-Open Publication No. 9-321076

[PATENT DOCUMENT 3] Japanese Patent Application Laid-Open Publication No. 10-287936

[DISCLOSURE OF INVENTION]

[PROBLEMS TO BE SOLVED BY THE PRESENT INVENTION]

[0006]

The present invention is to solve above-mentioned problems of conventional Au wire bumping material.

The present invention has the following purposes;

(1) approximating Au-Ag alloy bumping balls to bond Al pads to true sphere shape

(2) increasing assurance of Au-Ag alloy bump bonding to Al pads

(3) shortening tail length of Au-Ag alloy bump

(4) improving anti-Au consumption into solder

(5) decreasing contamination of capillary tip by bump wire and hole around tip

[MEANS TO SOLVE THE PROBLEMS]

[0007]

According to the present invention, there are provided following wire bumping materials;

(1) Wire bumping material comprising the content of:

Au-Ag alloy comprising Au-Ag matrix alloy and a particle of additive elements, said Au-Ag matrix alloy consisting of 1 to 25 mass % of Ag which purity is more than 99.99 mass %; said Au-Ag matrix alloy includes 5 to 50 mass ppm of Ca, 1 to 20 mass ppm of Be and/or 5 to 90 mass ppm of rare-earth elements as said additive elements; the residual of Au alloy is Au which purity os more than 99.99 mass %.

(2) Wire bumping material according to (1), wherein said additive elements include 10 to 90

mass ppm of at least one element selected from a group consisting of Ge, Mg, Sr, Bi, Zn, Si, Ga, Sn, Sb, B and Li.

(3) Wire bumping material according to (1), wherein said additive elements include 5 to 50 mass

ppm of Ca, 1 to 20 mass ppm of Be and/or 5 to 90 mass ppm of at least one element of rare-earth elements, further 10 to 90 mass ppm of at least one element selected from a group consisting of Ge, Mg, Sr, Bi, Zn, Si, Ga, Sn, B and Li, wherein in the case only B or Li is selected, 0.5 to 40 mass ppm.

(4) Wire bumping material according to one of (1) to (3), wherein said Au matrix of Au-Ag alloy

includes 5 to 25 mass % of Ag.

(5) Wire bumping material according to (1) or (3), wherein said additive rare-earth elements

consist of Y, La, Ce, Eu, Nd, Gd and /or Sm.

(6) Wire bumping material according to one of (1) to (5) characterized by being bonded to Pb matrix solder or Sn matrix solder.

(7) Wire bumping material according to one of (1) to (5) characterized by being flip chip bonded to Pb-free Sn matrix solder.

(8) Wire bumping material according to one of (1) to (5) characterized by being flip chip bonded to Pb-free Sn matrix solder, which has melting point of 170 ℃ to 260 ℃.

[EFFECTS OF THE PRESENT INVENTION]

[0008]

Effect of approximating Au-Ag alloy soft bumping ball shape to bond Al pads to true sphere shape is explained hereinafter.

Using Au-Ag alloy of the present invention, because a spherical soft ball is formed during ball forming process in the air, does not damage Al pad on chip. Moreover, because Ca, Be or rare-earth elements, or additive elements such as Ge, Mg, Sr, Bi, Zn, Si, Ga, Sn, Sb, B or Li are oxidized during bonding to Al pad in the air, abnormal shape of balls is not generated. Consequently it is absolutely able to ball-bond for bump-wire to a predetermined circular area at an aimed position even if the pad area is smaller.

[0009]

Effect of increasing assurance of Au-Ag alloy bump bonding to Al pad is explained hereinafter.

High purity Au-Ag alloy matrix of the present invention delays formation of inter-metallic compounds between Al and Au at pure Al or Al alloy pads, does not generate $Au_4Al$ among these inter-metallic compounds. Thus assurance of bonding to Al pads increases. Al pads are enough to be pure Al or Al principal content alloy, for instance, 80% Al-Cu alloy etc. Moreover, in case of plastic mold, because inter-metallic compounds are not generated among Al and Au, corrosion attacked by halogen from contained plastic is prevented.

[0010]

Effect of shortening tail length of Au-Ag alloy bump is explained hereinafter.

In case of high purity Au-Ag alloy matrix of the present invention, additive elements works effectively than that of pure Au matrix. Even if maximum content of a particle of additive elements and impurity

elements is only 100 ppm (excepting Ag), dispersion of bump tails is smaller. The smaller dispersion of bump tails is, the more homogenous bumps are able to be manufactured. Thus the present invention makes a greater deference of neck strength and stability even though a large number of bumps are manufactured.

[0011]

Effect of improving anti-Au consumption into solder is explained hereinafter.

In case of high purity Au-Ag alloy matrix of the present invention, because anti-Au consumption into solder is improved, Au-Ag alloy bump does not disappear into solder during flip chip bonding. For this reason, range of selection of solder is expanded, and stable flip chip bonding strength is attained even through high temperature reflow after soldering. Since range of temperature is broader for usable specific solder, the standard of work condition for soldering can be loosened. Moreover, as dispersion of bump tails is decreased, it is able to disappear selectively only part of tails of Au-Ag alloy bump, therefore distribution of tail length can be made even smaller. Especially in case 5 to 25 mass % of Ag contained in the Au-Ag alloy matrix, anti-Au consumption into solder at high temperature is improved and stable flip chip structure is obtained. Moreover, since consumption of elements such as Au into solder is decreased, fragile compounds do not grow in solder.

[DESCRIPTION OF THE MOST PREFERRED EMBODIMENT]

[0012]

Wire bump material of the present invention consists of Au-Ag alloy and additive elements. Content of Ag is 1 to 40 mass %, preferably, 5 to 25 mass %. Purity of Ag is more than 99.99 mass %.

[0013]

In the first preferred embodiment of the present invention, Ca, Be and/or rare-earth elements (so called as Group A elements) are used. These elements can be single or combination of more than 2 elements. Contents of these elements are: for Ca, 5 to 50 mass ppm, and more preferably 8 to 35 mass ppm; for Be, 1 to 20 mass ppm, more preferably 3 to 18 mass ppm; for rare-earth elements, 5 to 90 mass ppm. In case

of plural use of these elements, the total amount of content should be less than 90 mass ppm, more preferably less than 50 mass ppm. As rare-earth elements are selected from Y, La, Ce, Eu, Nd, Gd and Sm, at least one element should be selected preferably.

[0014]

In other preferred embodiment of the present invention, additive elements should be preferably at least one element selected from Ge, Mg, Sr, Bi, Zn, Si, Ga, Sn, Sb, B and Li. Content of these elements (so called as Group B elements) is 10 to 90 mass ppm. Especially preferable elements are Ge, Bi, Si, Sn, Sb, B and/or Li.

[0015]

In case of using Ge, Bi, Si, Sn and/or Sb (so called as Group $B^1$), content is 10 to 90 mass ppm, more preferably 15 to 60 mass ppm. In case of using plural elements of said Group B, the total contents is not more than 90 ppm, preferably not less than 50 ppm.

[0016]

In other preferred embodiment of the present invention, combination of elements of Group A and Group B is used. In this case, content of Group A, in case said element is Ca, content is 5 to 50 mass ppm, more preferably 8 to 35 mass ppm, in case of Be, content is 1 to 20 mass ppm, more preferably 3 to 18 mass ppm, in case of rare-earth elements, content is 3 to 90 mass ppm. In case of plural elements of Group A, the total amount of content should be less than 90 mass ppm, more preferably less than 50 mass ppm.

[0017]

In case said elements are only B and/or Li (so called as Group $B^2$) among Group B, content is 0.5 to 40 mass ppm, more preferable 0.5 to 15 mass ppm. In case plural elements of Group $B^2$ are contained, the total amount of content should be less than 15 mass ppm preferably.

[0018]

In case elements of Group A, Group $B^1$ and Group $B^2$ are contained, the content of said Group $B^2$ is 0.5 to 40 mass ppm, more preferably 0.5 to 15 mass ppm. Moreover, in this case, the total amount of content should be not more than 90 mass ppm, preferably not more than 50 mass ppm.

[0019]

Effect of approximating Au-Ag alloy bumping balls to bond Al pads to true sphere shape is explained hereinafter..

In general, it is easy to obtain ideal spherical balls in case purity of Au alloy comprising Au and additive elements is more than 99.99 mass %. It is so in case of Au-several % Pd alloy in the air. In case of Au-Ag alloy, Ag is apt to capture oxygen from high temperature air, and increased content of Ag causes additive elements oxidized and is apt to form abnormal shape of balls, then damages Al pads during bonding. Hence the upper limit of content of Ag should be less than 40 mass %, so that true sphere balls are obtained on the Al pads through ball-bonding in the air. Moreover, by using Ag of purity of more than 99.99 mass %, though more concentrated Ag is contained, soft balls are obtainable. Further, by adding additives such as 5 to 50 mass ppm of Ca, 1 to 20 mass ppm of Be and/or 5 to 90 mass ppm of rare-earth elements, or the total amount of content of 10 to 90 mass ppm of at least one element selected from Ge, Mg, Sr, Bi, Zn, Si, Ga, Sn, Sb, B or Li, (in case of single use of B and Li respectively, 0.5 to 40 mass ppm), true sphere can be obtained.

[0020]

Former group of additive elements (Group A) has grater effect against Au-Ag matrix than that of latter Group B elements. Hereinafter, the reason of selecting 5 to 50 mass ppm of Ca among the former group of additive elements is because it is difficult for Au-Ag alloy bump material to approximate shape of balls to true sphere under on Al pads under the condition of less than 5 mass ppm, and shape of balls is apt to deform under condition of excess 50 mass ppm. The upper limit and lower limit for Be and rare-earth elements are determined for the same reason. Especially Y, La, Ce, Eu and Nd among rare-earth elements at the range of content from 10 to 90 mass ppm are apt to obtain true sphere. On the other hand, the latter Group of elements consist of eutectic alloy with Au has more feeble effect to form true spheres in the air than that of former elements to Au-Ag matrix. However, when the total amount of content of at least one element selected from Ge, Mg, Sr, Bi, Zn, Si, Ga, Sn, Sb, B and Li is 10 to 90 mass ppm (in case of single use of B and Li respectively, 0.5 to

40 mass ppm), Au-Ag alloy bumps are formed with no problem in practical use corresponding to small pitch. Moreover it satisfies the purity of 99.99 mass % of Au alloy (excepting content of Ag). If these elements are less than 10 mass ppm of (in the case of single use of B and Li, 0.5 mass ppm), it is not able to obtain preferable true sphere shape.

[0021]

Moreover, if these elements exceed 90 mass ppm, purity of 99.99 mass % Au(excepting Ag) is not fulfilled. Therefore, it is not possible to indicate "High purity Au" and in case of heterogeneous alloy, the Au-Ag alloy bump is difficult to form and approximate the balls to true sphere shape on Al pads. Especially in case of single use of B and Li respectively, if the elements exceed 40 mass ppm, it is apt to difficult to form a ball of sphere shape.

Au alloy of purity of 99.99 mass % contains these former and latter group of additive elements and inevitable impurity elements (excepting Ag), which is less than 100 mass ppm at maximum, therefore it is always able to form stable circular shape.

[0022]

Effect of increasing assurance of Au-Ag alloy bump bonding to Al pads is explained hereinafter.

It is known that Au-Ag alloy matrix, comparing to pure Au matrix and Au-Pd alloy matrix, delays generating inter-metallic compound between Al and Au at Al pad, and there is no $Au_4Al$ generated in this inter-metallic compound. It is also found in case of the Au-Ag matrix alloy for bump material with additive elements, that $Au_4Al$ in pure Au matrix and Au-Pd alloy matrix is not generated, for the additive elements remain in matrix and has no reaction with Al. Thus Au-Ag alloy matrix delays generating inter-metallic compounds comparing to pure Au matrix and Au-Pd alloy matrix. Moreover, Au-Ag alloy matrix added a partial of additive elements mentioned above enables to obtain a true sphere shape. Besides, in case that additive elements contains only less than 100 mass ppm in maximum, purity 99.99 mass % of Au-Ag alloy matrix(where without Ag) is maintained. Therefore, it is able to increase assurance of Au-Ag alloy bump bonding to Al pads. Incidentally it is found that when total content of at least one

element selected of Ge, Mg, Sr, Bi, Zn, Si, Ga, Sn, Sb and Li is 0.009 to 0.3 mass ppm, there is no chip damage to Al pad and additive elements disperse finely through conventional dissolution and casting process.

[0023]

Effect of shortening tail length of Au-Ag alloy bump is accounted hereinafter.

Inventors of the present invention considered that dispersion of tail length of bump is caused by difference between strength of bump wire itself and strength of heat affected part (so called "neck strength difference"). In case Ag in the Au-Ag alloy matrix is less than 1 mass %, Au-Ag alloy matrix itself becomes rather soft as pure Au matrix, even though a predetermined amount of additive elements is added. In case bump wire is soft, strength of wire is decreased and neck strength difference is small. Consequently, torn position of bump wire disperses, and tail length is apt to disperse too. Then by using a predetermined ratio of Au-Ag alloy matrix, it is able to make neck strength difference grater than that of Pure Au matrix and Au-Pd alloy matrix. Moreover if a predetermined amount of additive elements is not added into Au-Ag alloy matrix, heat affected part is broader because Au-Ag alloy is composed with high purity of Au and high purity of Ag. Consequently, tail length is apt to have bigger dispersion and additive elements should be added into Au-Ag alloy matrix inevitably. From aspect of neck strength difference, preferable content of Ag in the Au-Ag alloy matrix is in the range of 5 to 25 mass %. At least adding one element from the group of Ca, 5 to 50 mass ppm; Be, 1 to 20 mass ppm or rare-earth elements 5 to 90 mass ppm, though it is very small amount, narrowing effect of heat affected zone is grater than that of pure Au matrix and Au-Pd alloy matrix. Especially Y, La, Ce, Eu and Nd among rare-earth elements have greater effect of narrowing heat affected area. However, if content of these elements is less than lower limit, though content of Ag is in the range of 5 to 25 mass % in Au-Ag alloy matrix, heat affected part becomes broader. Therefore lower limit value is necessary to be set.

[0024]

By the way, if these elements exceed upper limit, there is narrowing

effect of heat affected area. However, as mentioned above, in such a case shape of ball become distorted, therefore upper limit is set. On the other side, group of elements such as Ge, Mg, Sr, Bi, Zn, Si, Ga, Sn, Sb, B or Li has effect of narrowing heat affected area under condition of comparatively much adding. In case that these elements do not exceed 10 ppm, even though the contents of Ag in Au-Ag matrix alloy is in the range of 5 to 25 ppm, effect of narrowing heat affected area is not sufficient. Moreover, by adding these elements exceeding 90 ppm, as far as it is less than 0.3 mass %, effect of heat affected part is obtainable. However, if it exceeds 90 ppm, purity of 99.99 mass % of Au alloy (excepting Ag) is not satisfied. Au alloy of purity of more than 99.99 mass % does not include more than 100 ppm of these additives of former and latter (excepting Ag), therefore stable effect to narrow heat affected area is always obtained. It is found that when content of Ag is in the range of 5 to 25 mass % in Au-Ag alloy matrix, sufficient effect of narrowing heat affected part is obtained in the best way.

[0025]

Effect of improving anti-Au consumption into solder is accounted hereinafter.

It is known as solder alloy such as principal content of Pb alloy (Pb alloy, Pb-0.3 mass % Sn alloy, Pb-5 mass % Sn alloy, etc.), Pb-free alloy (Sn alloy, Sn-3.5 mass % Ag alloy, Sn-0.8 mass % Cu alloy, Sn-0.5 mass % Ni alloy, Sn-1.0 mass % Zn alloy, Sn-3.5 mass Ag alloy, 0.5 mass % Cu alloy, Sn-20 mass % In alloy, etc.). It is found that Au-Ag alloy matrix has better effect to improve anti-Au consumption into these solder comparing to pure Au matrix, especially under higher temperature condition. Especially, when content of Ag is in the range of 5 to 25 mass % in Au-Ag alloy matrix under high temperature condition, it improves anti-Au consumption into solder even more. As additive elements is very small in amount, it merely affects anti-Au consumption into solder in Au-Ag alloy matrix. Au-Ag alloy matrix with a determined amount of additive elements improves anti-Au consumption into solder comparing to pure Au matrix and Au-Pd alloy matrix.

[EMBODIMENT OF THE PRESENT INVENTION]

[0026]

To high purity of Au of purity 99.999 mass % and high purity Ag of purity 99.999 mass % (where unit is mass %), the amount shown in the table attached of additives elements (where unit is mass ppm) is added, then said embodiment was dissolved in the vacuum furnace and was cast. It was drawn and final heat treatment is carried out when diameter reached at 25 μm. By using Sinkawa wire-bonder (UTC-400 type) under condition of 0.5 msec of discharge time, then this ultra fine wire is formed ball on 100μm square Al pad in the air, then in general condition (ball diameter is 62μm, deformed diameter of ball is 80 μm) ball bonding was performed. As a result, all balls were formed within 100μm square of Al pads. The result is shown in the table.

[0027]

In the table, "Formability of balls" means appearance of 100 balls evaluated by stereo microscope at magnification of 400 X, wherein good appearance is shown as "A", small cavity but usable is shown as "B", deformed ball with cavity and unusable is shown as "C". Moreover "Ultrasonic bonding ball diameter" is the mean of ball size on Al pad of each of 100 balls measured in the directions of vertical(Y) and horizontal(X) by Olympas length measurement microscope. Then the difference from the mean was introduced by minimum mean square method (shown as "Ultrasonic bonding ball stability X/Y"), value not less than 0.96 is shown as "A", 0.90 to less than 0.96 is shown as "B", less than 0.90 is shown as "C". Moreover, "Shear strength" is the mean of tensile strength when each if 100 wires is given tensile upward (Z direction) by the Dage Holdings Shear Strength Tester (PC-2400). Then the mean of tail length of bump was measured as "Dispersion of neck height (range)". Then dispersion of neck height (range) smaller than 20μm is shown as "A", 20μm to less

than 30μm is shown as "B", not less than 30μm is shown as "C". Moreover "Chip damage" is shown as number of cracks around ball on Al pad observed by 400X stereo microscope. No crack is shown as "A", 1 to 4 cracks is shown as "B", not less than 5 cracks is shown as "C".

[0028]

Moreover, "Heat test" was conducted by holding 100 Au alloy bumps against Sn-3.5 % Ag alloy with flip-chip structure and by reflowing by heating at 250 ℃ for 60 seconds. Then for each 10 section areas were observed by 400X stereoscope. Not less than 50 % of before reflow section area is shown as "A", 30 % to less than 50 % is shown as "B", 10 % to less than 30 % is shown as "C", not more than 10 % is shown as "D". At this point, it was found that all of "A" specimens, which have more than 50 % of before reflow section area, have homogeneous bump heights in solder because tails looking like a whisker at tear off moment melted into Sn-3.5 % Ag alloy. On the other hand, "C" specimens, which have not more than 10 % of before reflow section area, have bumps melted into Sn-3.5 % Ag alloy and disappear, hence bump bonding was not completed.

[0029]

[TABLE 1-1]

TABLE 1-1

| | Au | Ag % | Ca ppm | Be ppm | Rare-earth element (ppm) | | | | | | | Others (ppm) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Y | La | Ce | Nd | Sm | Eu | Gd | Ge | Mg | Sr | Bi | Zn | Si | Ga | Sn | Sb | B | Li |
| Comparative1 | Bal. | 0.3 | 20 | | | | | | | | | | | | | | | | | | | 0 |
| Comparative2 | Bal. | 45 | 10 | 10 | | | | | | | | | | | | | | | | | | |
| Comparative3 | Bal. | 15 | | | | | | | | | | | | | | | | | | | | |
| Comparative4 | Bal. | 3 | 20 | | | | | | | | | | | | | | | | | | | |
| Comparative5 | Bal. | 30 | | 10 | | | | | | | | | | | | | | | | | | |
| Comparative6 | Bal. | 10 | 5 | | | | | | | | | | | | | | | | | | | |
| Comparative7 | Bal. | 15 | 60 | | | | | | | | | | | | | | | | | | | |
| Comparative8 | Bal. | 20 | | 0.3 | | | | | | | | | | | | | | | | | | |
| Comparative9 | Bal. | 10 | | 30 | | | | | | | | | | | | | | | | | | |
| Comparative10 | Bal. | 15 | | | 2 | | | | | | | | | | | | | | | | | |
| Comparative11 | Bal. | 20 | | | 20 | 20 | 20 | 20 | 20 | | | | | | | | | | | | | |
| Example 1 | Bal. | 10 | 20 | | | | | | | | | | | | | | | | | | | |
| Example2 | Bal. | 15 | | 10 | | | | | | | | | | | | | | | | | | |
| Example3 | Bal. | 20 | | | 20 | | | | | | | | | | | | | | | | | |
| Example4 | Bal. | 10 | | | | 20 | | | | | | | | | | | | | | | | |
| Example5 | Bal. | 15 | | | | | 20 | | | | | | | | | | | | | | | |
| Example6 | Bal. | 20 | | | | | | 20 | | | | | | | | | | | | | | |
| Example7 | Bal. | 10 | | | | | | | 20 | | | | | | | | | | | | | |
| Example8 | Bal. | 15 | | | | | | | | 20 | | | | | | | | | | | | |
| Example9 | Bal. | 20 | | | | | | | | | 20 | | | | | | | | | | | |
| Example10 | Bal. | 10 | | | | | | | | | | 50 | | | | | | | | | | |
| Example11 | Bal. | 15 | | | | | | | | | | | 20 | | | | | | | | | |
| Example12 | Bal. | 20 | | | | | | | | | | | | 50 | | | | | | | | |
| Example13 | Bal. | 10 | | | | | | | | | | | | | 50 | | | | | | | |
| Example14 | Bal. | 15 | | | | | | | | | | | | | | 50 | | | | | | |
| Example15 | Bal. | 20 | | | | | | | | | | | | | | | 50 | | | | | |
| Example16 | Bal. | 10 | | | | | | | | | | | | | | | | 50 | | | | |

[0030]

[TABLE 1-2]

TABLE 1-2

| | Au | Ag | Ca | Be | Rare-earth element (ppm) | | | | | | | Others (ppm) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | % | ppm | ppm | Y | La | Ce | Nd | Sm | Eu | Gd | Ge | Mg | Sr | Bi | Zn | Si | Ga | Sn | Sb | B | Li |
| Example17 | Bal. | 15 | | | | | | | | | | | | | | | | | 50 | | | |
| Example18 | Bal. | 20 | | | | | | | | | | | | | | | | | | 50 | | |
| Example19 | Bal. | 10 | | | | | | | | | | | | | | | | | | | 1 | |
| Example20 | Bal. | 15 | | | | | | | | | | | | | | | | | | | | 10 |
| Example31 | Bal. | 15 | 20 | 10 | | | | | | | | | | | | | | | | | | |
| Example32 | Bal. | 20 | 20 | | | 10 | | | | | 10 | | | | | | | | | | | |
| Example33 | Bal. | 10 | | | | | | | | | | | 10 | 10 | 10 | | | | | | | |
| Example34 | Bal. | 15 | | | | | | | | | | | | | | | | 10 | 10 | 10 | | |
| Example35 | Bal. | 20 | | | | | | | | | | | | | | 10 | 10 | | | | 1 | 10 |
| Example39 | Bal. | 20 | | | 10 | | 10 | | 10 | | 10 | | | | | | | | | | | |
| Example40 | Bal. | 5 | | | | 20 | | 20 | | 20 | | | | | | | | | | | | |
| Example41 | Bal. | 15 | | | | 50 | | | 10 | 10 | 10 | | | | | | | | | | | |
| Example42 | Bal. | 20 | | | 10 | | 10 | | | | 10 | | | | | | | | | | | |
| Example43 | Bal. | 5 | 10 | 15 | | | | | | 30 | 10 | | | | | | | | | | | |
| Example44 | Bal. | 15 | 10 | | | | | | | | 30 | 10 | | | | | | | | | | |
| Example45 | Bal. | 20 | | 10 | | | | | | | | 50 | 20 | | | | | | | | | |
| Example46 | Bal. | 5 | 10 | 15 | | | | | | | | | 10 | 10 | | | | | | | | |
| Example47 | Bal. | 15 | | 5 | | | | | | | | | | 50 | 10 | | | | | | | |
| Example48 | Bal. | 20 | 10 | 10 | | | | | | | | | | | 20 | 10 | | | | | | |
| Example49 | Bal. | 5 | 10 | 15 | | | | | | | | | | | | 10 | 10 | | | | | |
| Example50 | Bal. | 15 | 10 | 5 | | | | | | | | | | | | | 50 | 10 | | | | |
| Example51 | Bal. | 20 | 10 | 10 | | | | | | | | | 10 | 10 | | | 10 | 10 | 30 | | | |
| Example52 | Bal. | 5 | 10 | 15 | | | | | | | | | | | 10 | 10 | 10 | | 30 | 10 | | |
| Example53 | Bal. | 15 | 10 | 5 | | | | | | | | | | | | | | 10 | | 50 | | |
| Example58 | Bal. | 15 | 30 | 5 | | | | | | | | | | | | | | | | | | |
| Example59 | Bal. | 5 | 10 | 15 | 10 | | | | | | | | | | | | | | | | | |
| Example60 | Bal. | 15 | | 5 | 30 | 10 | | | | | | | | | | | | | | | | |

[0051]

[TABLE 2-1]

TABLE 2-1

| | Formability of balls | Ultrasonic bonding ball diameter | | Ultrasonic bonding ball stability | | Shear strength | Chip damage | | Dispersion of neck height | | Heat test | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | X | Y | X / Y | Judgement | | No. of cracks | Judgement | μm | Judgement | Bump area | Judgement |
| | | μm | μm | | | kg/mm $^2$ | | | | | % | |
| Comparative1 | A | 73,0 | 75,0 | 0,973 | B | 9,1 | 0 | A | 55 | D | 1 | D |
| Comparative2 | D | - | - | - | - | - | 28 | D | - | - | - | - |
| Comparative3 | A | 68,0 | 71,2 | 0,955 | D | 10,5 | 0 | A | 36 | D | 70 | A |
| Comparative4 | A | 72,5 | 74,4 | 0,974 | B | 9,2 | 0 | A | 51 | D | 16 | C |
| Comparative5 | A | 65,3 | 66,6 | 0,980 | B | 11,7 | 2 | | 38 | D | 85 | A |
| Comparative6 | A | 68,7 | 69,2 | 0,993 | A | 10,2 | 0 | A | 42 | D | 60 | A |
| Comparative7 | D | - | - | - | - | - | - | - | - | - | - | - |
| Comparative8 | A | 67,2 | 71,2 | 0,944 | D | 11,0 | 0 | A | 40 | D | 72 | A |
| Comparative9 | D | - | - | - | - | - | - | - | - | - | - | - |
| Comparative10 | A | 68,1 | 71,7 | 0,950 | | 10,3 | 0 | A | 39 | D | 64 | A |
| Comparative11 | D | - | - | - | - | - | - | - | - | - | - | - |
| Example 1 | A | 68,2 | 70,1 | 0,973 | B | 11,2 | 0 | A | 20 | A | 71 | A |
| Example 2 | A | 68,5 | 70,5 | 0,972 | B | 11,5 | 0 | A | 29 | B | 76 | A |
| Example 3 | A | 67,5 | 69,3 | 0,974 | B | 11,9 | 0 | A | 18 | A | 83 | A |
| Example 4 | A | 67,0 | 69,7 | 0,961 | B | 11,2 | 0 | A | 19 | A | 70 | A |
| Example 5 | A | 67,4 | 70,3 | 0,959 | D | 11,4 | 0 | A | 19 | A | 77 | A |
| Example 6 | A | 67,2 | 69,5 | 0,967 | B | 11,9 | 0 | A | 17 | A | 81 | A |
| Example 7 | A | 68,5 | 70,0 | 0,979 | B | 11,1 | 0 | A | 19 | A | 70 | A |
| Example 8 | A | 68,7 | 70,5 | 0,974 | B | 11,4 | 0 | A | 20 | A | 75 | A |
| Example 9 | A | 67,6 | 69,4 | 0,974 | B | 11,9 | 0 | A | 16 | A | 80 | A |
| Example 10 | A | 68,5 | 69,3 | 0,988 | B | 11,1 | 0 | A | 18 | A | 70 | A |
| Example 11 | A | 67,6 | 69,1 | 0,978 | B | 11,4 | 0 | A | 20 | A | 74 | A |
| Example 12 | A | 67,3 | 68,5 | 0,982 | B | 11,8 | 0 | A | 18 | A | 82 | A |
| Example 13 | A | 68,5 | 69,3 | 0,988 | B | 11,2 | 0 | A | 20 | A | 68 | A |
| Example 14 | A | 67,7 | 68,7 | 0,985 | B | 11,4 | 0 | A | 19 | A | 74 | A |
| Example 15 | A | 67,2 | 68,6 | 0,980 | B | 11,9 | 0 | A | 18 | A | 82 | A |
| Example 16 | A | 68,5 | 69,8 | 0,981 | B | 11,3 | 0 | A | 18 | A | 69 | A |

Evaluation

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A | Good | - | - | - | 0.96? | - | - | 0 | - | < 20 | - | 50% < |
| B | Small cavity | - | - | - | < 0.96 | - | - | < 5 | - | < 30 | - | 30% < |
| C | — | - | - | - | — | - | - | - | - | - | - | 10% < |
| D | Unusable | - | - | - | < 0.90 | - | - | 5? | - | ?30 | - | ?10% |

[0032]

[TABLE 2-2]

TABLE 2 - 2

| | Formability of balls | Ultrasonic bonding ball | | Ultrasonic bonding ball | | Shear strength | Chip damage | | Dispersion of neck | | Heat test | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | X | Y | X / Y | Judgement | | No. of cracks | Judgement | | | Bump area | Judgement |
| | | μm | μm | | | kg/mm$^2$ | | | μm | Judgement | % | |
| Example17 | A | 67,8 | 68,5 | 0,990 | B | 11,5 | 0 | A | 17 | A | 73 | A |
| Example18 | A | 67,4 | 68,3 | 0,987 | B | 11,9 | 0 | A | 18 | A | 81 | A |
| Example19 | A | 68,4 | 69,5 | 0,984 | B | 11,2 | 0 | A | 22 | B | 62 | A |
| Example20 | A | 67,6 | 68,5 | 0,987 | B | 11,4 | 0 | A | 19 | A | 77 | A |
| Example31 | A | 67,4 | 68,8 | 0,980 | B | 11,6 | 0 | A | 16 | A | 76 | A |
| Example32 | A | 67,4 | 68,4 | 0,985 | B | 11,9 | 0 | A | 17 | A | 82 | A |
| Example33 | A | 68,2 | 69,2 | 0,986 | B | 10,2 | 0 | A | 18 | A | 81 | A |
| Example34 | A | 67,5 | 68,1 | 0,991 | A | 10,3 | 0 | A | 17 | A | 77 | A |
| Example35 | A | 67,4 | 68,3 | 0,987 | B | 11,8 | 0 | A | 19 | A | 80 | A |
| Example39 | A | 67,5 | 68,3 | 0,988 | B | 11,5 | 0 | A | 19 | A | 67 | A |
| Example40 | A | 68,2 | 69,7 | 0,978 | B | 9,5 | 0 | A | 20 | A | 26 | C |
| Example41 | B | 67,9 | 68,9 | 0,986 | B | 10,3 | 0 | A | 20 | A | 75 | A |
| Example42 | A | 67,8 | 68,3 | 0,993 | A | 11,7 | 0 | A | 19 | A | 79 | A |
| Example43 | B | 68,7 | 70,1 | 0,980 | B | 9,3 | 0 | A | 19 | A | 28 | C |
| Example44 | A | 68,3 | 69,7 | 0,980 | B | 10,1 | 0 | A | 20 | A | 74 | A |
| Example45 | A | 67,6 | 68,2 | 0,991 | A | 11,3 | 0 | A | 18 | A | 81 | A |
| Example46 | A | 68,5 | 68,2 | 0,995 | A | 9,5 | 0 | A | 23 | B | 33 | B |
| Example47 | A | 68,1 | 69,3 | 0,982 | B | 10,3 | 0 | A | 20 | A | 76 | A |
| Example48 | A | 67,8 | 68,5 | 0,986 | B | 11,2 | 0 | A | 18 | A | 81 | A |
| Example49 | A | 68,7 | 69,3 | 0,991 | A | 9,5 | 0 | A | 20 | A | 27 | C |
| Example50 | A | 68,3 | 69,3 | 0,985 | B | 10,2 | 0 | A | 19 | A | 74 | A |
| Example51 | A | 68,4 | 69,2 | 0,988 | B | 11,2 | 0 | A | 20 | A | 80 | A |
| Example52 | A | 68,8 | 69,4 | 0,991 | A | 9,3 | 0 | A | 24 | B | 34 | B |
| Example53 | A | 68,2 | 69,2 | 0,986 | B | 10,1 | 0 | A | 19 | A | 77 | A |
| Example58 | A | 69,5 | 70,9 | 0,980 | B | 10,1 | 0 | A | 19 | B | 77 | A |
| Example59 | A | 68,8 | 70,6 | 0,975 | B | 9,6 | 0 | A | 21 | A | 32 | B |
| Example60 | A | 68,8 | 70,2 | 0,981 | B | 10,5 | 0 | A | 20 | A | 74 | A |

Evaluation

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A | Good | - | - | - | 0.96? | - | - | 0 | - | < 20 | - | 50% < |
| B | Small cavity | - | - | - | < 0.96 | - | - | < 5 | - | < 30 | - | 30% < |
| C | — | - | - | - | - | - | - | — | - | — | - | 10% < |
| D | Unusable | - | - | - | < 0.90 | - | - | 5? | - | ?30 | - | ?10% |

## CLAIMS

[CLAIM 1]

Wire bumping material comprising the content of:

Au-Ag alloy comprising Au-Ag matrix alloy and a particle of additive elements, said Au-Ag matrix alloy consisting of 1 to 25 mass % of Ag which purity is more than 99.99 mass %; said Au-Ag matrix alloy includes 5 to 50 mass ppm of Ca, 1 to 20 mass ppm of Be and/or 5 to 90 mass ppm of rare-earth elements as said additive elements; the residual of Au alloy is Au which purity is more than 99.99 mass %.

[CLAIM 2]

Wire bumping material according to claim 1, wherein said additive elements include 10 to 90 mass ppm of at least one element selected from a group consisting of Ge, Mg, Sr, Bi, Zn, Si, Ga, Sn, Sb, B and Li.

[CLAIM 3]

Wire bumping material according to claim 1, wherein said additive elements include 5 to 50 mass ppm of Ca, 1 to 20 mass ppm of Be and/or 5 to 90 mass ppm of at least one element of rare-earth elements further 10 to 90 mass ppm of at least one element selected from a group consisting of Ge, Mg, Sr, Bi, Zn, Si, Ga, Sn, B and Li, wherein in the case only B or Li is used, 0.5 to 40 mass ppm.

[CLAIM 4]

Wire bumping material according to one of claims 1 to 3, wherein said Au matrix of Au-Ag alloy includes 5 to 25 mass % of Ag.

[CLAIM 5]

Wire bumping material according to claim 1 or 3, wherein said additive rare-earth elements consist of Y, La, Ce, Eu, Nd, Gd and /or Sm.

[CLAIM 6]

Wire bumping material according to one of claims from 1 to 5, characterized by being bonded to Pb matrix solder or Sn matrix solder.

[CLAIM 7]

Wire bumping material according to one of claims from 1 to 5 characterized by being flip chip bonded to Pb-free Sn matrix solder.

[CLAIM 8]

Wire bumping material according to one of claims from 1 to 5 characterized by being flip chip bonded to Pb-free Sn matrix solder,

which has melting point of 170 ℃ to 260 ℃.