

SEMICONDUCTOR DEVICE

The present invention relates to semiconductor devices having a bonding site at which a wire is bonded to a bonding pad.

In semiconductor devices, it is usual to use gold (Au) or aluminium (Al) wire for forming electrical connections between the respective bonding pads of a semiconductor pellet and a lead part.

However, gold wire is expensive: wire is used in increasing amounts accompanying the trend toward high density semiconductor devices and the increasingly high degree of integration, and the manufacturing cost has inevitably increased. Aluminium is relatively inexpensive, but it corrodes readily, and is not suitable for resin moulded semiconductor devices. It is therefore desirable to find a suitable alternative wire material that is both inexpensive and corrosion resistant.

The inventors have therefore considered using copper (Cu) wire, because it is inexpensive and has good corrosion resistance. Therefore the present invention proposes in a first aspect, a semiconductor device comprising a semiconductor pellet, a passivation film formed on a first surface of the pellet, a metal bonding pad formed on the passivation film, a lead adjacent the pellet, a wire connecting the bonding pad and the lead, and resin encapsulating the pellet, the passivation film, the bonding pad, the wire and part of the lead, wherein the wire

contains at least 99.999% of copper by weight and has a ball portion at the bonding pad.

Also, in a second aspect, the present invention proposes a method of forming a semiconductor device comprising:

forming a passivation film on a first surface of a semiconductor pellet;

forming a metal bonding pad on the passivation film;

locating a lead adjacent the pellet,

connecting a wire between the lead and the bonding pad, the wire containing at least 99.999% of copper by weight and having a ball portion at the bonding pad; and

encapsulating the pellet, passivation film, bonding pad, wire, and part of the lead in resin.

An embodiment of the invention will now be described in detail, by way of example with reference to the accompanying drawings, in which:

Fig. 1 is a sectional view which shows schematically an embodiment of a semiconductor device

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according to the present invention;

Fig. 2 is a sectional view showing, on an enlarged scale, a wire bonding portion of the semiconductor device of Fig. 1;

5 Figs. 3 and 4 are diagrams respectively illustrating the formation of a ball on the copper wire and bonding using ultrasonic waves; and

Fig. 5 is a diagram showing the relationship between the purity of copper wire and the bonding

damage occurrence percentage.

Referring first to Fig. 1, a semiconductor device has a semiconductor pellet 3 attached to a tab 2 of a copper alloy lead frame by a junction layer 4 composed of an adhesive, for example an eutectic of gold-silicon or silver-epoxy paste. As shown in more detail in Fig. 2, a bonding pad 5 of the pellet 3 is composed of aluminium while a bonding wire 6 is composed of copper.

The pad 5 of pellet 3 is electrically connected via the bonding wire 6 to an aluminium film 14 formed on an inner lead portion 7 of a lead 1. The film 14 may be plated with gold, silver or copper.

After the wires are bonded to the pad, the pellet 3, bonding wires 6 and the like are moulded with a plastic resin 8. With reference to Figs. 3 and 4, to bond the wire 6 according to this embodiment, a ball portion 6a is formed at the end of the wire by an electric discharge that takes place between the end of the wire 6 held by a wire bonder (not shown) and an electrode 9 of the wire bonder. By selecting the material of the wire 6, as will be described later, the ball portion 6a assumes a hardness suitable for bonding.

Using an ultrasonic bonding tool 10 which is shown in Fig. 4, the ball portion 6a is pressed onto the aluminium pad 5 on the pellet 3, and is firmly bonded thereto by ultrasonic vibration.

The ball portion 6a which is pressed forms a bonding portion 6b. The bonding portion 6b covers the aluminium pad 5 that is exposed through a window in a final passivation film 13.

5 In this embodiment the wire 6 is refined to a purity of 99.999% by weight or higher by the zone refining method and/or by electrolysis, and the ball portion thereby consists of copper of which the microvickers hardness (MHv) is controlled to lie  
10 within the range of 35 to 65 (at 5g.f).

By forming copper wire having a hardness within the abovementioned range, it is possible to perform ball bonding without destroying the passivation film 12 on the pellet 3. Moreover, a wire and bond having  
15 a sufficiently large strength are obtained. If the ball portion 6a is too hard, bonding damage occurs, i.e., the silicon dioxide ( $\text{SiO}_2$ ) layer 12 under the aluminium pad 5 is destroyed by the force at the time of wire bonding. In other words, as the microvickers  
20 hardness at the ball portion 6a of wire 6 exceeds 65, the passivation film 12 is destroyed at the time of bonding.

Fig. 5 is a diagram showing the relationship between the percentage of bonding damage occurrence  
25 and the purity of the wire, wherein the ordinate represents the bonding damage rate, i.e., represents the percentage of samples in which cracks develop in

the insulating film 12 when bonding is effected using a bonding tool 10 with a force of 80 grams.

The abscissa represents the purity of copper wire, in this case the percentage by weight of copper in the wire. For example, the term "3N" (three nines) indicates that the wire contains at least 99.9% by weight of copper; the microvickers (MHv) of the ball portion is then about 120. Copper wire of 4N (four nines) contains at least 99.99% by weight of copper and has a microvickers hardness (MHv) of about 90 in the ball portion. At 5N (copper content is 99.999% by weight or higher), the microvickers hardness (MHv) is about 65, and at 6N (copper content is 99.9999% by weight or more), the microvickers hardness is about 45. Wire which lies between 6N and 7N (copper content is 99.99999% by weight or more) wire has a microvickers hardness (MHv) of about 30. The hardness of copper wire depends mainly upon its purity.

To confine the bonding damage rate within a permissible range of about 10% or less, the copper wire 6 should have a purity of higher than 99.999% by weight (five nines) or should have a microvickers hardness (MHv) of less than 65 in the ball portion 6a. The bonding damage rate is very slight, particularly when the copper wire has a microvickers hardness (MHv) of less than 50 in the ball portion 6a.

The present invention includes the use of copper

wires with a purity substantially higher than 99.999% by weight and copper wires of which the microvickers hardness in the ball portion can be regarded as substantially less than 65.

5           Copper wires produced by different refining methods may contain different impurities in different ratios. Therefore, even copper wires having the same percentage by weight of copper may exhibit different degrees of hardness.

10           Further, even when copper wires of the same hardness are used, the bonding damage rate may vary depending upon the bonding condition.

Variance due to these factors appears in the form of variance in the bonding damage rate in Fig. 5.

15           Moreover, the microvickers hardness varies depending upon the measuring method. The method of measuring the microvickers hardness has been specified under Z2244 of Japanese Industrial Standard, according to which a sharp end of a small diamond crystal is  
20 pressed onto a material to be measured under the application of a predetermined force, and microvickers hardness is determined by measuring the depth to which the diamond tip is driven. However, the depth to which the diamond tip is driven may vary depending upon  
25 whether the diamond tip hits a grain of copper or a grain boundary. Therefore, the microvickers hardness may appear to vary.

In this embodiment, the microvickers hardness is measured in accordance with the aforementioned method under the application of a force of 5 grams, and is expressed as 5 g.f.

5        The easiest means for obtaining a microvickers hardness (MHv) of 35 to 65 in the ball portion 6a of the copper wire 6 is to increase the purity of the copper to 99.999% or more by weight.

Desirable methods of obtaining copper wires having  
10 a purity of higher than 99.999% by weight include zone refining and electrolysis.

Table 1

|    |                     | Impurities |    |    |    |    |      |    |    |    |    | Total |     |
|----|---------------------|------------|----|----|----|----|------|----|----|----|----|-------|-----|
|    |                     | Ag         | Fe | Bi | As | Sb | P    | Zn | Pb | Ni | Sn |       | Si  |
| 15 | Cu plate            | 7          | 6  | 1  | 1  | <1 | <0.5 | <1 | 1  | 1  | 1  | 1     | <21 |
|    | After Electrolysis  | 4          | 3  | 1  | <1 | <1 | <0.5 | <1 | 1  | 1  | 1  | 1     | <15 |
|    | After Zone Refining | 3          | 2  | <1 | <1 | <1 | <0.5 | <1 | <1 | <1 | <1 | 1     | <10 |

Table 1 shows the methods which the inventors have employed to increase the purity of copper wires, and  
20 the results. Numerals in Table represent the concentrations of impurities in ppm (parts per million), so that <1 represents a concentration of impurity less than 1 ppm.

First, a copper plate is prepared. The copper  
25 plate contained various impurities shown in Table 1 in

amounts of about 20 - 21 ppm.

Copper is refined by electrolysis using sulphuric acid. Electrolysis may be carried out once or several times. It is necessary to increase the purity of the sulphuric acid solution which is the electrolyte. After electrolysis, impurities in the copper, particularly, iron (Fe) are approximately halved.

An ingot made of copper after electrolysis is then put into the zone refining process which is effected once or several times. After zone refining, the concentration of impurities in the copper decreases to less than 10 ppm. In particular, the content of nickel (Ni) decreases to less than 1 ppm.

According to a study conducted by the inventors, the hardness of copper is particularly affected by iron and nickel impurities. The contents of iron and nickel can be reduced through electrolysis and zone refining.

By performing electrolysis and zone refining several times respectively, the purity of the copper can be increased so that the microvickers hardness in a formed ball portion may be 35.

However, if the degree of hardness is too low, the wire tends to be deformed, which is not desirable.

When the microvickers hardness ranges from 40 to 50, the number of times that electrolysis and zone refining need be performed is fewer, enabling the manufacturing cost to be reduced. To obtain a copper

wire having a microvickers hardness of less than 35, electrolysis and zone refining must be performed many times; therefore such copper wire is very expensive.

To bond the copper wire 6 to the bonding pad 5 of the pellet 3, a ball may be formed at the end of the wire using a hydrogen torch, electrical discharge, or the like.

Bonding of the copper wire may be achieved by thermocompression bonding only, or by use of ultrasonic vibration in addition to the thermocompression bonding. In bonding the copper wire to the lead 1, a ball need not necessarily be formed, but a ball may be formed as a matter of course without presenting any problem.

The use of a copper wire having a microvickers hardness (MHv) of 35 to 65 (at 5 f.g) in the ball portion also provides good corrosion resistance.

Corrosion of a copper wire is triggered by impurities contained therein: the greater the degree of purity of copper, the greater the corrosion resistance. Copper wire resists corrosion more than aluminium wire does.

Refining of the wire by zone refining or electrolysis permits a very pure copper wire to be fabricated which, for the reasons above, has greatly improved corrosion resistance.

Moreover, the hardness of the copper wire is such as to produce a good shape of loop between the pellet

3 and lead 7.

For the abovementioned reasons, the invention may permit the fabrication of a highly reliable semiconductor device at reduced cost.

UK Patent Application No. 87.20643 (published under No. 2193672) was divided from the present application, and describes subject-matter also described in the present application. Attention is therefore drawn to application 87.20643.



CLAIMS:

1. A semiconductor device comprising a semiconductor pellet, a passivation film formed on a first surface of the pellet, a metal bonding pad formed on the passivation film, a lead adjacent the pellet, a wire connecting the bonding pad and the lead, and resin encapsulating the pellet, the passivation film, the bonding pad, the wire and part of the lead, wherein the wire contains at least 99.999% of copper by weight and has a ball portion at the bonding pad.
2. A device according to claim 1, wherein the pellet is secured to a tab with a silver-epoxy paste adhesive.
3. A device according to claim 1, wherein the pellet is secured to a tab with a gold-silicon paste adhesive.
4. A device according to any one of claims 1 to 3, wherein the passivation film is of silicon dioxide.
5. A device according to any of the preceding claims, wherein the leads are of a copper alloy.
6. A device according to any of the preceding claims, wherein the semiconductor pellet is of silicon.
7. A semiconductor device according to any one of the preceding claims, wherein the wire contains less than 2 ppm of iron.
8. A semiconductor device according to any one of the preceding claims, wherein the wire contains less than 1 ppm of nickel.
9. A semiconductor device according to any one of the preceding claims, wherein said wire is refined by



electrolysis and zone refining.

10. A semiconductor device according to any one of the preceding claims, wherein the wires are bonded to the pads with a capillary type bonding tool.

11. A semiconductor device according to any one of the preceding claims, wherein the ball is formed by electric discharge between the wire and an electrode.

12. A semiconductor device substantially as herein described with reference to and as illustrated in the accompanying drawings.

13. A method of forming a semiconductor device comprising:  
forming a passivation film on a first surface of a semiconductor pellet;

forming a metal bonding pad on the passivation film;

locating a lead adjacent the pellet,

connecting a wire between the lead and the bonding pad, the wire containing at least 99.999% of copper by weight and having a ball portion at the bonding pad; and

encapsulating the pellet, passivation film, bonding pad, wire, and part of the lead in resin.

14. A method according to claim 13, wherein the wire is refined by electrolysis and zone refining.

15. A method according to any one of claim 13 or claim 14, wherein the ball portion is bonded to the bonding pad using a capillary type bonding tool.

16. A method according to any one of claims 13 to 15, wherein the ball is formed by electric discharge between



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the wire and an electrode.

17. A method of forming a semiconductor device substantially as herein described with reference to the accompanying drawings.

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