Description

The present invention relates to a semiconductor device in which copper wire is used as a bonding wire and, more particularly, to improvements in the structure of electrode pads of a semiconductor device.

Heretofore, in a semiconductor device, copper or copper alloy is used as a bonding wire, and aluminum or aluminum alloy is used as an electrode pad, which is also known as bonding electrode. Fig. 1 is a sectional view of such a conventional semiconductor device which has yet to be wire-bonded. Fig. 2 is a sectional view of the semiconductor device which has been wire-bonded. In these figures, reference numeral 11 denotes a lead frame. Semiconductor element 13 is bonded to the lead frame by means of conductive paste 12, for example, silver paste, on the lead frame. Insulating films 14 are formed at predetermined positions on semiconductor element 13. Electrode pad 15, formed of a layer of aluminum or aluminum alloy, is formed on those portions of the semiconductor element which are not covered by the insulating films. As is shown in Fig. 2, copper bonding wire 16 is bonded to electrode pad 15. The electrode pad is deformed by the pressure of bonding the hard bonding wire to the electrode pad so that the bonding wire may contact semiconductor element 13 through the electrode pad as shown in Fig. 2. The direct contact of the wire with the element will alter the electric characteristics of the bonding portion, and mortally vary to malfunction the electric characteristics of the semiconductor device exposed at high temperature. Since the hard wire is pressed directly on semiconductor element 13, element 13 is distorted. Temperature changes, i.e., temperature cycles, cause the semiconductor element to have cracks, due to the difference in thermal expansion coefficients between the semiconductor element and the wire. The electrode pad is more easily corroded than other portions during patterning process, thus exposing the semiconductor element. Thus, the semiconductor device is liable to malfunction during use.

JP-A-6054462 describes an electrode structure for a semiconductor device consisting of three layers. An aluminium layer is formed on the surface of a semiconductor substrate. A TiN, TiC, W, Mo or Ta film is deposited on the aluminium film as a barrier layer. The final layer is formed of gold and a gold wire is bonded thereto.

JP-A-61125065 describes ball-bonding a copper wire to a bonding pad comprising aluminium.

FR-A-2170846 describes an electrode structure consisting of layers of aluminium, vanadium and aluminium. This structure is not used for bonding lead wires.

Accordingly, an object of the present invention is to provide a semiconductor device which prevents a wire from directly contacting a semiconductor device during wire bonding process.

Another object of the present invention is to provide a semiconductor device in which a wire is not pressed directly on a semiconductor element during wire bonding process, not producing strain in the semiconductor element.

Still another object of the invention is to provide a semiconductor device in which the electrode pad is not corroded to adversely influence a semiconductor element.

In order to achieve the above and other objects, there is provided according to the present invention a semiconductor device comprising a semiconductor element, an electrode pad formed on the element and a wire bonded on the electrode pad and connecting the electrode pad to an external lead,

said electrode pad being substantially formed of:

a first metal layer formed on the semiconductor element, ohmically contacting the semiconductor element; said first metal layer being made of aluminium or an aluminium alloy, thus imposing no adverse influence on the functions of the semiconductor element,

a second metal layer formed on the first metal layer; and

a third metal layer formed on the second metal layer;

characterized by

said second metal layer being made of vanadium or a vanadium alloy, thus being hard enough to resist pressing force applied at wire bonding step;

said third metal layer being made of aluminium or an aluminium alloy and thus having a composition suitable for bonding a copper wire; and

said wire being made of copper.

According to the present invention as described above, a three-layered electrode pad is used, and the second metal layer of the pad is formed of hard metal and can hardly be deformed. Thus, even if the third metal layer of the electrode pad is deformed at wire bonding step, the second metal layer remains undeformed. The electrode pad therefore does not directly contact the semiconductor element. Thus, the electric characteristics of the bonding portion do not change. Nor do the electric characteristics of the semiconductor element alter even at high temperature. Since the second metal layer is not deformed, the semiconductor element is not deformed to have strain, which results to have cracks during temperature changes. Further, even if the third metal layer of the electrode pad is corroded, the second metal

layer is not; the corrosion does not advance to the surface of the semiconductor element. Therefore, the semiconductor element does not malfunction during use.

This invention can be more fully understood from the following detailed description when taken in conjunction with the accompanying drawings, in which:

Fig. 1 is a sectional view of a conventional semiconductor device which has yet to be wire-bonded;

Fig. 2 is a sectional view of the semiconductor device which has been wire-bonded;

Fig. 3 is a sectional view of a semiconductor device according to the present invention, which has yet to be wire-bonded; and

Fig. 4 is a sectional view of the semiconductor device of this invention, which has been wire-bonded.

Preferred embodiments of the present invention will be described in detail with reference to the accompanying drawings. The same reference numerals as in the semiconductor device in Figs. 1 and 2 denote the same parts in the embodiment of the present invention. In the semiconductor device shown in Figs. 3 and 4, semiconductor element 13 is bonded by conductive paste 12 on lead frame 11. Insulating films 14 are formed at predetermined portions on the semiconductor element. Electrode pad 21 according to the present invention is formed on the portion on which the insulating films are not provided on the semiconductor element and the insulating films. Electrode pad 21 is fundamentally formed of three-layered structure metal layer. The first metal layer is formed on the semiconductor element to ohmically contact semiconductor element and to affect no adverse influence to the functions of the semiconductor element. The no adverse influence to the functions of the semiconductor element means no deterioration of the electric functions due to invasion of alloy element or impurities in the metal layer into the semiconductor element. First metal layer 18 is adapted for one metal selected from a group consisting of aluminum, aluminum alloys or, not claimed, gold and gold alloys. The aluminum alloys preferably contain at least 60 wt.% aluminum. Gold alloys preferably contain at least 60 wt.% gold. The preferable thickness of the first metal layer made of aluminum or aluminum alloys is 0.1 to 2.0 micrometer. The preferable thickness of the first metal layer made of gold or gold alloys is 0.2 to 2.0 micrometer. The reason why the preferably thickness of the first alloy layer is determined as described above is because, if excessively thin, the second metal diffuses to the semiconductor element to induce a damage of ohmic contact and, if excessively thick, second metal layer on the first metal layer easily deforms.

The second metal layer 19 is formed on the first metal layer, and the second metal layer has a hardness in which the layer is not deformed by the pressing force at wire bonding step. The hardness of the second metal is ordinarily lower than that of aluminum and aluminum alloys. The preferable metals of the second metal layer contain one metal selected from a group consisting of vanadium, vanadium alloys or, not claimed, nickel, nickel alloys, titanium, titanium alloys, tantalum and tantalum alloys. The vanadium and tantalum alloys preferably contain at least 60 wt.% vanadium or tantalum. The preferable thickness of the second metal layer made of the vanadium, vanadium alloys, tantalum or tantalum alloys is 0.05 to 1 micrometer. The nickel alloys preferably contain at least 60 wt.% nickel and one or two metals selected from a group consisting of at least 40 wt.% chronium and at least 40 wt.% cobalt. The preferable thickness of the second metal layer made of the nickel or nickel alloys is 30 to 1000 nm (300 - 10.000 Ångstroms). The titanium alloys preferably contain at least 60 wt.% titanium. The preferable thickness of the second alloy layer made of the titanium or titanium alloys is 30 to 1000 nm (300 - 10.000 Ångstroms) The reason why the preferable thickness of the second alloy layer is determined as described above is because, if excessively thin, desired hardness cannot be obtained, and if excessively thick, etching step is hardly achieved.

Third metal layer 20 is formed on the second metal layer, and the third metal layer has a composition for bonding a copper wire. The preferable metal of the third metal layer is selected from a group consisting of aluminum, aluminum alloys or, not claimed, gold and gold alloys. Aluminum alloys preferably contain at least 60 wt.% aluminum and gold alloys preferably contain at least 60 wt.% gold. The preferable thickness of the metal layer made of the aluminum or aluminum alloys is 0.1 to 5.0 micrometer. The preferable thickness of the gold or gold alloys is 0.2 to 2.5 micrometer. The reason why the preferable thickness of the third alloy layer is determined as described above is because, if excessively thin, oxidation of the second metal layer is induced, and if excessively thick, the second layer is hardly worked.

In the preferred embodiments, the first metal layer is made of aluminum or aluminum alloy of 0.1 to 2.5 micrometer of thickness and preferably 0.5 to 2.5 micrometer, the second metal layer is made of vanadium or vanadium alloy of 0.05 to 1 micrometer and preferably 0.1 to 0.8 micrometer of thickness and the third metal layer is made of aluminum or aluminum alloy of 0.1 to 5.0 micrometer of thickness and preferably 0.5 to 5.0 micrometer.

Electrode pad 21 is formed by the steps of sequentially evaporating the first to third metal layers on the surface of the semiconductor element and the insulating films, and then patterning by etching the metal layers. In the wire bonding step, lead frame 11 is heated to 200 to 450 °C, and copper bonding wire 16 is bonded on third metal layer 20 by means of vibration by thermally press-bonding or ultrasonic wave.

According to the construction as described above, soft third metal layer 20 is deformed by the pressing force of wire 16 at wire bonding step, but hard second metal layer 19 is not deformed, and the deformation does not reach first metal layer 18. Thus, the wire is not contacted with semiconductor element 13, and no stress is applied to the semiconductor element. Therefore, the electric characteristics of the semiconductor device are not varied, nor the semiconductor element is cracked. Since the second metal layer prevents the corrosion from advancing to the first metal layer at the step of patterning electrode pad 21, the element 13 is hardly corroded to cause no electric malfunction to occur, and the electric characteristics do not alter even in a test exposing at high temperature. Four or more layered electrode pad may be constructed as a metal layer on the three-layered metal above described or a metal layer among the three-layered metal above described.

The semiconductor device as shown in Figs. 3 and 4 according to the present invention was actually manufactured, and the malfunction occurring ratio was compared with that of the semiconductor device as shown in Figs. 1 and 2. In this case, in the electrode pad of the present invention, the first metal layer was made of aluminum of 0.5 micrometer of thickness, the second metal layer was made of vanadium of 0.3 micrometer of thickness, and the third metal layer is made of aluminum of 2.5 micrometer of thickness . The electrode pad of the conventional semiconductor device was formed of a single layer made of aluminum of 2.5 micrometer of thickness. These semiconductor devices were tested by a heat cycle test of periodically repeating high temperature of 150 °C and low temperature of -45 °C, and both were compared. Then, the conventional semiconductor device became improper in 25 % in 400 cycles, and in 80 % in 600 cycles. Conversely, the semiconductor device according to the present invention did not become improper in not only 400 cycles but 600 cycles. The semiconductor device was manufactured by bonding by increasing the load to 300 gram as high as twice at the normal bonding wire bonding step, and the malfunction occurring ratio was observed. Then, the ratio of the conventional structure was 30 to 50 %, while that of the device according to the present invention was less than 0.1 %.

Claims

1. A semiconductor device comprising a semiconductor element (13), an electrode pad (21) formed on the element and a wire (16) bonded on the electrode pad and connecting the electrode pad to an external lead,
   said electrode pad being substantially formed of:
   a first metal layer (18) formed on the semiconductor element, ohmically contacting the semiconductor element; said first metal layer (18) being made of aluminium or an aluminium alloy, thus imposing no adverse influence on the functions of the semiconductor element,
   a second metal layer (19) formed on the first metal layer; and
   a third metal layer (20) formed on the second metal layer;
   characterized by
   said second metal layer (19) being made of vanadium or a vanadium alloy, thus being hard enough to resist pressing force applied at wire bonding step;
   said third metal layer (20) being made of aluminium or an aluminium alloy and thus having a composition suitable for bonding a copper wire; and
   said wire (16) being made of copper.

2. A semiconductor device according to claim 1,
   characterized in that
   the thickness of said first metal layer (18) is 0.1 to 2.5 micrometer.

3. A semiconductor device according to claim 1 or 2,
   characterized in that
   the thickness of said second metal layer (19) is 0.05 to 1 micrometer.

4. A semiconductor device according to claim 1, 2 or 3,
   characterized in that
   the thickness of said third metal layer (20) is 0.1 to 5.0 micrometer.

5. A semiconductor device according to claim 1,
   characterized in that
   the first metal layer (18) has a thickness of 0.5 to 2.5 micrometer, the second metal layer (19) has a thickness of 0.1 to 0.8 micrometer and the third metal layer (20) has a thickness of 0.5 to 5.0 micrometer.

Electrode pad 21 is formed by the steps of sequentially evaporating the first to third metal layers on the surface of the semiconductor element and the insulating films, and then patterning by etching the metal layers. In the wire bonding step, lead frame 11 is heated to 200 to 450 °C, and copper bonding wire 16 is bonded on third metal layer 20 by means of vibration by thermally press-bonding or ultrasonic wave.

According to the construction as described above, soft third metal layer 20 is deformed by the pressing force of wire 16 at wire bonding step, but hard second metal layer 19 is not deformed, and the deformation does not reach first metal layer 18. Thus, the wire is not contacted with semiconductor element 13, and no stress is applied to the semiconductor element. Therefore, the electric characteristics of the semiconductor device are not varied, nor the semiconductor element is cracked. Since the second metal layer prevents the corrosion from advancing to the first metal layer at the step of patterning electrode pad 21, the element 13 is hardly corroded to cause no electric malfunction to occur, and the electric characteristics do not alter even in a test exposing at high temperature. Four or more layered electrode pad may be constructed as a metal layer on the three-layered metal above described or a metal layer among the three-layered metal above described.

The semiconductor device as shown in Figs. 3 and 4 according to the present invention was actually manufactured, and the malfunction occurring ratio was compared with that of the semiconductor device as shown in Figs. 1 and 2. In this case, in the electrode pad of the present invention, the first metal layer was made of aluminum of 0.5 micrometer of thickness, the second metal layer was made of vanadium of 0.3 micrometer of thickness, and the third metal layer is made of aluminum of 2.5 micrometer of thickness . The electrode pad of the conventional semiconductor device was formed of a single layer made of aluminum of 2.5 micrometer of thickness. These semiconductor devices were tested by a heat cycle test of periodically repeating high temperature of 150 °C and low temperature of -45 °C, and both were compared. Then, the conventional semiconductor device became improper in 25 % in 400 cycles, and in 80 % in 600 cycles. Conversely, the semiconductor device according to the present invention did not become improper in not only 400 cycles but 600 cycles. The semiconductor device was manufactured by bonding by increasing the load to 300 gram as high as twice at the normal bonding wire bonding step, and the malfunction occurring ratio was observed. Then, the ratio of the conventional structure was 30 to 50 %, while that of the device according to the present invention was less than 0.1 %.

Claims

1. A semiconductor device comprising a semiconductor element (13), an electrode pad (21) formed on the element and a wire (16) bonded on the electrode pad and connecting the electrode pad to an external lead,
   said electrode pad being substantially formed of:
   a first metal layer (18) formed on the semiconductor element, ohmically contacting the semiconductor element; said first metal layer (18) being made of aluminium or an aluminium alloy, thus imposing no adverse influence on the functions of the semiconductor element,
   a second metal layer (19) formed on the first metal layer; and
   a third metal layer (20) formed on the second metal layer;
   characterized by
   said second metal layer (19) being made of vanadium or a vanadium alloy, thus being hard enough to resist pressing force applied at wire bonding step;
   said third metal layer (20) being made of aluminium or an aluminium alloy and thus having a composition suitable for bonding a copper wire; and
   said wire (16) being made of copper.

2. A semiconductor device according to claim 1,
   characterized in that
   the thickness of said first metal layer (18) is 0.1 to 2.5 micrometer.

3. A semiconductor device according to claim 1 or 2,
   characterized in that
   the thickness of said second metal layer (19) is 0.05 to 1 micrometer.

4. A semiconductor device according to claim 1, 2 or 3,
   characterized in that
   the thickness of said third metal layer (20) is 0.1 to 5.0 micrometer.

5. A semiconductor device according to claim 1,
   characterized in that
   the first metal layer (18) has a thickness of 0.5 to 2.5 micrometer, the second metal layer (19) has a thickness of 0.1 to 0.8 micrometer and the third metal layer (20) has a thickness of 0.5 to 5.0 micrometer.

* C L M S *

Patentansprüche

1. Halbleitervorrichtung, umfassend
ein Halbleiterelement (13), ein auf dem Element gebildeter Elektrodenanschlußfleck (21) und ein Draht (16), der auf den Elektrodenanschlußfleck gebondet ist und den Elektrodenanschlußfleck mit einer externen Zuleitung verbindet,
wobei der Elektrodenanschlußfleck im wesentlichen gebildet ist aus:
einer ersten Metallschicht (18), die auf dem Halbleiterelement gebildet ist und mit dem Halbleiterelement einen ohm'schen Kontakt eingeht; wobei die erste Metallschicht (18) aus Aluminium oder einer Aluminiumlegierung hergestellt ist, wodurch kein ungünstiger Einfluß auf die Funktionen des Halbleiterelements ausgeübt wird,
einer zweiten Metallschicht (19), die auf der ersten Metallschicht gebildet ist; und
eine dritte Metallschicht (20), die auf der zweiten Metallschicht gebildet ist;
dadurch **gekennzeichnet,** daß
die zweite Metallschicht (19) aus Vanadin oder einer Vanadinlegierung hergestellt ist, wodurch sie hart genug ist, um gegenüber der in dem Drahtbondungsschritt angewendeten Druckkraft widerstandsfähig zu sein;
die dritte Metallschicht (20) aus Aluminium oder einer Aluminiumlegierung hergestellt ist und somit eine Zusammensetzung aufweist, die sich zum Bonden eines Kupferdrahtes eignet; und
der Draht (16) aus Kupfer hergestellt ist.

2. Halbleitervorrichtung nach Anspruch 1,
dadurch **gekennzeichnet,** daß die Dicke der ersten Metallschicht (18) 0,1 bis 2,5 Mikrometer beträgt.

3. Halbleitervorrichtung nach Anspruch 1 oder 2,
dadurch **gekennzeichnet,** daß die Dicke der zweiten Metallschicht (19) 0,05 bis 1 Mikrometer beträgt.

4. Halbleitervorrichtung nach Anspruch 1, 2 oder 3,
dadurch **gekennzeichnet,** daß die Dicke der dritten Metallschicht (20) 0,1 bis 5,0 Mikrometer beträgt.

5. Halbleitervorrichtung nach Anspruch 1,
dadurch **gekennzeichnet,** daß die erste Metallschicht (18) eine Dicke von 0,5 bis 2,5 Mikrometer aufweist, die zweite Metallschicht (19) eine Dicke von 0,1 bis 0,8 Mikrometer aufweist und die dritte Metallschicht (20) eine Dicke von 0,5 bis 5,0 Mikrometer aufweist.

Revendications

1. Dispositif à semi-conducteur, comprenant un élément à semi-conducteur (13), une plage d'électrode (21) formée sur l'élément et un fil (16) lié à la plage d'électrode et connectant la plage d'électrode à un fil d'alimentation externe,
la plage d'électrode étant pratiquement formée par
une première couche métallique (18) formée sur l'élément semi-conducteur, en contact ohmique avec l'élément semi-conducteur, la première couche métallique (18) étant formée d'aluminium ou d'un alliage d'aluminium et n'ayant ainsi pas d'influence nuisible sur le fonctionnement de l'élément semi-conducteur,
une seconde couche métallique (19) formée sur la première couche métallique, et
une troisième couche métallique (20) formée sur la seconde couche métallique,
caractérisé en ce que
la seconde couche métallique (19) est formée de vanadium ou d'un alliage de vanadium, si bien qu'elle est suffisamment dure pour résister à une force de pression appliquée dans une étape de liaison d'un fil,
la troisième couche métallique (20) est formée d'aluminium ou d'un alliage d'aluminium et a ainsi une composition convenant à la liaison d'un fil de cuivre, et
le fil (16) est formé de cuivre.

2. Dispositif à semi-conducteur selon la revendication 1, caractérisé en ce que l'épaisseur de la première couche métallique (18) est comprise entre 0,1 et 2,5 µm.

3. Dispositif à semi-conducteur selon la revendication 1 ou 2, caractérisé en ce que l'épaisseur de la seconde couche métallique (19) est comprise entre 0,05 et 1 µm.

4. Dispositif à semi-conducteur selon la revendication 1, 2 ou 3, caractérisé en ce que l'épaisseur de la troisième couche métallique (20) est comprise entre 0,1 et 5,0 µm.

5. Dispositif à semi-conducteur selon la revendication 1, caractérisé en ce que la première couche métallique (18) a une épaisseur comprise entre 0,5 et 2,5 µm, la seconde couche métallique (19) a une épaisseur comprise entre 0,1 et 0,8 µm, et la troisième couche métallique (20) a une épaisseur comprise entre 0,5 et 5,0 µm.