This Sheet Has Been Replaced

9801429-3 IP05

REPLACED SHEETS SG
☑ Description : paged ...1... to paged ...24...
☑ Claim(s) : paged ...25... to paged ...27...
☐ Drawing(s) : paged ..... to paged .....
☑ Abstract : paged ...27... to paged .....
DATE OF RECEIPT .....

CARRIER, SEMICONDUCTOR DEVICE, AND THEIR MOUNTING METHOD

FIELD OF THE INVENTION

The present invention relates to the field of semiconductor devices for mounting semiconductor elements on circuit boards.

BACKGROUND OF THE INVENTION

A semiconductor device of the prior art is explained with reference to drawings.

In Fig. 8, a semiconductor device 1 consists of a semiconductor element 2 disposed on a carrier 3 made of insulating material. A plurality of electrodes 6 soldered or bonded with a gold bump 5 to electrodes 4 of the semiconductor element 2 are disposed on the top face of the carrier 3, and external electrode terminals 8 are aligned in a matrix on the bottom face of the carrier 3. The electrodes 6 are electrically coupled to external electrode terminals 8. The space between the semiconductor element 2 and carrier 3, and around the semiconductor element 2 are filled and covered with epoxy resin sealant 7. Solder bumps 9 may in some cases be formed on the surface of the external electrode terminals

This Sheet Has Been Replaced

8. In Fig. 8, the semiconductor device is mounted on a circuit board 12. Electrodes 11 are disposed in the matrix on the circuit board 12 in an area where the semiconductor device 1 will be mounted, corresponding to the external electrode terminals 8. Solder paste 13 is printed on the matrix electrodes 11. As shown in Fig. 9, the semiconductor device 1 is placed on the circuit board 12 so as to allow the external electrode terminals 8 of the semiconductor device 1 to make contact with the electrodes 11 of the circuit board 12. The external electrode terminals 8 and electrodes 11 are bonded with solder 10 by heating and melting the solder paste 13.

The design of the semiconductor device 1 as configured above makes it difficult to adjust the height H between the carrier 3 and circuit board 12, as shown in Fig. 9, when mounting the semiconductor device 1 onto the circuit board 12. If the height H is short, thermal stress generated by the difference in thermal expansion coefficient of the carrier 3 and circuit board 12 is concentrated on the soldered portion, causing cracks in soldered portions or peeling in some cases.

DISCLOSURE OF THE INVENTION

The present invention offers a semiconductor device which can be mounted on a printed circuit board with high

This Sheet Has Been Replaced

reliability, and a mounting method for such semiconductor devices.

In the semiconductor device of the present invention, output electrodes formed on the surface of semiconductor elements which forms an integrated circuit is connected to a conductive circuit formed on a carrier for semiconductor for enabling electrical coupling with an external material using external electrodes formed on the carrier for semiconductor. The external electrodes are disposed on the bottom of a concave portion provided on the carrier for semiconductor.

The carrier for semiconductor has a multi-layer structure from the upper part to the lower part protruding to the bottom face, in the thickness direction of the semiconductor device, for forming the concave portion with the upper part of the flat board. Materials used for forming the multi-layer structure has different thermal expansion coefficients which bridge the thermal expansion coefficient of the carrier for semiconductor of the semiconductor device to the circuit board on which the semiconductor device is mounted.

A method for mounting the semiconductor device comprises the dispensing of solder paste to the concave portion of the external electrode of the semiconductor device, flipping of the semiconductor device, mounting of the semiconductor device onto the circuit board, and soldering by

This Sheet Has Been Replaced

heating the circuit board. Another method comprises application of adhesive flux to the concave portion of the external electrode of the semiconductor device, supplying of solder balls on top of the adhesive flux applied, flipping of the semiconductor device, mounting of the semiconductor device onto the circuit board, and soldering by heating the circuit board. Still another method comprises application of adhesive to an area where electrical coupling is not required but the semiconductor device contacts the circuit board when the electrode provided on the concave portion of the semiconductor device and the electrode of the circuit board are electrically coupled, mounting of the semiconductor device onto the circuit board, and soldering by heating the circuit board.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1A is a perspective of a semiconductor device with a carrier in accordance with a first exemplary embodiment of the present invention.

Fig. 1B is a section view seen at A-A of Fig. 1A.

Fig. 1C is a bottom view of Fig. 1A.

Fig. 2A is a perspective of a semiconductor device with a carrier in accordance with a second exemplary embodiment of the present invention.

This Sheet Has Been Replaced



Fig. 2B is a section view seen at A-A of Fig. 2A.

Fig. 2C is a bottom view of Fig. 2A

Fig. 3A is a perspective of a semiconductor device with a carrier in accordance with a third exemplary embodiment of the present invention.

Fig. 3B is a section view seen at A-A of Fig. 3A.

Fig. 3C is a bottom view of Fig. 3A.

Figs. 4A to 4D are a process chart of a mounting method for a semiconductor device in accordance with the first exemplary embodiment of the present invention.

Figs. 5A to 5D are a process chart of a mounting method for a semiconductor device in accordance with the second exemplary embodiment of the present invention.

Figs. 6A to 6E are a process chart of a mounting method for a semiconductor device in accordance with the third exemplary embodiment of the present invention.

Fig. 7 is a table of thermal expansion coefficients of a material used in a semiconductor device of the exemplary embodiments of the present invention.

Fig. 8 is a side view of a configuration of a semiconductor device of the prior art.

Fig. 9 is a side view of a configuration of a conventional semiconductor device mounted onto a circuit board.

This Sheet Has Been Replaced

DESCRIPTION OF THE PREFERRED EMBODIMENTS

First exemplary embodiment

Figs. 1A to 1C show the configuration of a semiconductor device 1 employing a carrier in a first exemplary embodiment of the present invention. A specified circuit is formed in a semiconductor element 2 itself, and an electrode 4 is formed on a part of the semiconductor element 2. A carrier 3 is made of an insulating substrate 17, and the semiconductor element 2 is disposed on the carrier 3. A second electrode 6 is disposed on the top face (other face) of the carrier 3 which is electrically coupled to the electrode 4 on the semiconductor element 2. An external electrode terminal 8, which is the first electrode, is disposed in the matrix on the bottom face (one face) of the carrier 3 as shown in Fig. 1C. The external electrode terminal 8 is electrically coupled to the second electrode 6. A filling area 18 is formed on the bottom face of the carrier (or insulating material 17) in concave fashion. The filling area 18 will be filled with a bonding material such as solder in a later process. The external electrode terminal 8 is disposed at the bottom of the filling area 18. A sealant 7 fills and covers the space between the semiconductor element 2 and carrier 3, and around the semiconductor element 2. Here,

This Sheet Has Been Replaced

the depth of the filling area is determined based on the desirable height for bonding the semiconductor device 1 or carrier 3 to a board with a specified circuit (hereafter referred to as the "circuit board") in a later process. There is a range of methods for forming the concave filling area 18. For example, a concave portion may be formed by exposure and development using a photosensitive epoxy resin film. The depth of the filling area 18 is preferably 0.2 mm to 1.0 mm if the alignment pitch of the external electrode terminal (the distance between the center of adjacent external electrode terminals 8) is 1 mm and its diameter (the diameter of the external electrode terminal 8) is 0.5 mm. The carrier 3 is generally made of alumina and ceramic such as glass ceramic, but it may also be made of resin material such as epoxy resin.

When a semiconductor device as configured above is electrically bonded to a circuit board by means such as soldering, the height H of the bonded portion can be adjusted as required by changing the depth of the filling area 18. This allows the securing of a greater height H between the circuit board and the external electrode terminal 8, compared to the case of mounting a semiconductor device without the filling area onto the circuit board, thereby reducing the stress applied to the bonded face of the external electrode

This Sheet Has Been Replaced

terminal 8 and improving reliability and thermal heat cycle resistance.

The thermal heat cycle resistance here is checked by applying thermal stress to a test piece by repeatedly alternating the ambient temperature surrounding the test piece between high and low. No cracks have been noticed in the soldered portion of the semiconductor device of the present invention after repeating a cycle of +80°C for 30 minutes and -40°C for 30 minutes for 1,000 times.

In addition, when the semiconductor device 1 without the filling area 18 is mounted on the circuit board, the solder used for electrical coupling forms a convex drum shape as shown in Fig. 9. With the carrier 3 or the semiconductor device 1 of the present invention, soldering takes place after solder paste or solder balls are provided to the filling area 18, thus enabling the solder to form an hourglass shape with the concave central section in the height direction of bonding. This transfers the stress conventionally focused on the bonded surface to the center part of the bonded portion, allowing improvement of bonding strength and preventing destruction of the bonded surface.

Second exemplary embodiment

Figs. 2A to 2C show a configuration of the semiconductor device 1 with a carrier in a second exemplary

This Sheet Has Been Replaced

embodiment of the present invention. Parts configured identically to the first exemplary embodiment are given the same numeral codes, and thus their explanation is omitted.

The carrier 3 comprises a control material 52 from the bottom face (an insulating material 51 which is a substrate) of the semiconductor device 1 where the filling area 18 (control material 52) is provided (one face) to the bottom surface in the thickness direction of the semiconductor device 1, and a flat insulating material 51 without any concave portion. The external electrode terminal 8, the first electrode, is disposed on the insulating material 51 at the side where the control material 52 is provided. The second electrode 6 is disposed on the insulating material 51 at the side where the control material 52 is not provided (other face). The external electrode terminal 8 and electrode 6 are electrically coupled. The control material 52 is disposed around the external electrode terminal 8, and comprises the external electrode terminal 8 as its bottom, thus forming the filling area 18. The filling area 18 controls the bonding material when applying a bonding material such as solder to the external electrode terminal 8.

The insulting material 51 and the control material 52 in this exemplary embodiment are made of different materials. A material of thermal expansion coefficient closer to that of the semiconductor element 2 than that of the resin is used

This Sheet Has Been Replaced

for the insulating material 51 of the carrier 3. For example, if the semiconductor element 2 employs a silicone substrate, the insulating material 51 may be made of ceramic such as glass ceramic or a mixture of alumina and glass. Alumina may be used for the insulating material 51 and control material 52.

A material of thermal expansion coefficient midway between that of the circuit board on which the semiconductor device 1 is mounted and that of the insulating material 51 is used for the control material 52 of the carrier 3. This will ease the thermal stress between the semiconductor element 2, insulating material 51, control material 52, and circuit board, and improve the reliability of the portion involved after applying a bonding material such as solder to the external electrode terminal 8 in a later process. If, for example, the insulating material 51 is made of glass ceramic, a heat-resistant engineering plastic such as polyphenylene sulfide may be used for the control material 52.

The above configuration further reduces the stress applied to the bonded portion in addition to the effect of the first exemplary embodiment.

Third exemplary embodiment

Figs. 3A to 3C show a configuration of a semiconductor device 1 with a carrier in a third exemplary embodiment of

This Sheet Has Been Replaced

the present invention. Parts configured the same as the first exemplary embodiment are given the same numeral codes, and thus their explanation is omitted.

The carrier 3 comprises the control material 52 and insulating material 51 in the same way as in the second exemplary embodiment. The control material 52 consists of several layers 53 to 55 in the thickness direction, made of several materials. The layers in the control material 52 are configured so that their thermal expansion coefficients form a stepwise, positively correlated gradient between the thermal expansion coefficient of the insulating material 51 and that of the circuit board on which the semiconductor device 1 will be mounted in a later process.

Materials comprising the control material 52 are made of polyphenylene sulfide mixed with filler (glass fiber), and their thermal expansion coefficient is adjusted by changing the type and volume of the filler. In this exemplary embodiment, the filler consists about 60% of the entire material in the first layer 53 of the control material 52, about 50% in the second layer 54, and about 40 % in the third layer 55. The thermal expansion coefficient increases as the percentage of the filler to the entire volume is reduced. The layers 53, 54, and 55 are bonded with adhesive.

The above configuration enables further reduction of the stress applied to the bonded portion in addition to the

This Sheet Has Been Replaced

effect of the first exemplary embodiment. The thermal expansion coefficients of the materials used in this exemplary embodiment are shown in Fig. 7.

The thermal expansion coefficient in this exemplary embodiment varies stepwise in the thickness direction from the insulating material 51. However, the same effect can be achieved by linearly varying the thermal expansion coefficient.

Fourth exemplary embodiment

A method for mounting the semiconductor device 1 of the present invention onto the circuit board is explained with reference to Figs. 4A to 4D.

First, the semiconductor device 1 is flipped to face the opening 19 in the filling area 18 of the carrier 3 upwards for injecting solder paste 13 (a pasty mixture of solder powder and flux) into the filling area 18 as shown in Fig. 4A. The solder paste 13 is supplied by using a mask with openings corresponding to the opening 19 of the filling area 18. The mask is placed on the semiconductor device 1 with its openings positioned onto the opening 19, and solder paste 13 is supplied by printing it using a squeegee (a rubber spatula used for solder printing). The semiconductor device 1 filled with the solder paste 13 is then flipped again to face the

This Sheet Has Been Replaced

filling area 18 of the carrier 3 filled with the solder paste 13 downwards.

As shown in Fig. 4B, the solder paste 13 is also printed on a circuit board 12 on which the semiconductor device 1 will be mounted, using a mask.

Next, the semiconductor device 1 is mounted on the circuit board 12 after being positioned as shown in Fig. 4C. During the reflow process (a soldering method carried out by melting the solder using hot air or heat), the circuit board 12 after mounting is heated above the melting point of the solder paste for soldering the external electrode terminal 8 and electrode 11 of the circuit board 12 by melting the solder paste. In general, for eutectic solder, the temperature is increased to 220°C. The volume of solder paste drops approximately by half due to evaporation of the flux in the solder paste during melting. When the semiconductor device 1 and circuit board 12 after soldering are cooled to room temperature, the soldered portion shows an hourglass shape with a concave central section in the bonding height direction as shown in Fig. 4D. Metals also lose about 10% of their volume during solidification.

The solder paste 13 can be supplied into the filling area 18 without using a mask as explained in this exemplary embodiment. For example, the solder paste 13 can be supplied

This Sheet Has Been Replaced

by applying the solder paste 13 directly to the carrier 3 and using the squeegee to remove the excess.

This exemplary embodiment also employs a mask for printing the solder paste 13 on the circuit board 12 because electronic components other than the semiconductor device 1 of the present invention, such as resistors and capacitors, are generally mounted together with the semiconductor device 1. However, since the solder paste 13 is already supplied to the filling area 18 of the carrier 3, printing of the solder paste 13 onto the circuit board 12 may not always be necessary for mounting the semiconductor device 1. Whether to print the solder paste 13 on the circuit board 12 for the semiconductor device 1 depends on whether an opening is provided on the mask or not, and therefore the mounting process itself is always the same.

The mounting method of this exemplary embodiment can be employed for mounting the semiconductor device with carrier in any of the first, second, and third exemplary embodiments.

With the use of this mounting method, the effect described in the first to third exemplary embodiments can be achieved.

Fifth exemplary embodiment

Another method for mounting a semiconductor device of the present invention is explained with reference to Fig. 5.

This Sheet Has Been Replaced

First, the semiconductor device is flipped to face the opening 19 on the filling area 18 disposed on the carrier 3 face upwards, adhesive flux 15 is applied to the external electrode terminal 8, and solder balls 16 are supplied over the adhesive flux 15.

In this exemplary embodiment isopropyl alcohol is used as adhesive flux and solvent, abietic acid as rosin, and ethyl amine hydrochloride as activator. Other substances, however, are applicable.

The adhesive flux 15 is dispensed, and the solder balls 16 are supplied by a mounter placing electronic components. However, other methods are also applicable. Here, dispensing means the supply of adhesive flux 15 to a syringe-like container, after which adhesive flux 15 from a needle tip is extruded to one side by applying pressure to the adhesive flux 15 from the other side.

The semiconductor device 1 supplied with the solder balls 16 is then flipped again to face the filling area of the carrier 3 supplied with the solder balls 16 downwards.

Meanwhile, the solder paste 13 is printed using a mask on the circuit board 12 on which the semiconductor device 1 will be mounted.

Next, the semiconductor device 1 is positioned on the circuit board 12, and mounted. In the reflow process, the solder paste 13 is then melted to solder the external

This Sheet Has Been Replaced

electrode terminal 8 and the electrode 11 of the circuit board 12 by heating it to a temperature above the melting point of the solder paste 13. In general, for eutectic solder, the temperature is increased to 220° C. Since solder paste loses volume when fused, the soldered portion forms an hourglass shape with a concave central section in the height direction when it is cooled down to room temperature after soldering as shown in Fig. 5D.

This exemplary embodiment is applicable for mounting the carrier and semiconductor device described in the first, second, and third exemplary embodiments.

In this exemplary embodiment, the solder paste 13 is printed on the circuit board 12 using the mask, but a process for printing the solder paste 13 on the circuit board 12 is not always necessary for mounting the semiconductor device 1 as in the fourth exemplary embodiment.

With the use of this mounting method, the effect described in the first to third exemplary embodiments can be achieved.

Sixth exemplary embodiment

Still another method for mounting the semiconductor device 1 of the present invention is explained with reference to Fig. 6.

This Sheet Has Been Replaced

First, the semiconductor device 1 is flipped to face the opening 19 on the filling area 18 of the carrier 3 upwards, and the filling area 18 is filled with the solder paste 13 as shown in Fig. 6A.

Adhesive 14 is applied to a contacting area 20 on the circuit board 12 where electrical coupling is not required when the semiconductor 1 contacts the circuit board 12. The adhesive 14 may be applied to the carrier 3 side.

The solder paste 13 is supplied by using a mask with openings corresponding to the opening 19 of the filling area 18. The mask is placed on the semiconductor device 1 with its openings positioned onto the opening 19, and solder paste 13 is supplied by printing it using a squeegee. The semiconductor device 1 filled with the solder paste 13 is then flipped again to face the filling area 18 of the carrier 3 filled with the solder paste 13 downwards. The solder paste 13 is printed on the circuit board 12 on which the semiconductor device 1 will be mounted using a mask as shown in Fig. 6B.

Next, the semiconductor device 1 is positioned on the circuit board 12, and mounted. In the reflow process (a soldering method carried out by melting the solder using hot air or heat), the solder paste 13 is melted to solder the external electrode terminal 8 and the electrode 11 of the circuit board 12 by heating it to a temperature above the

This Sheet Has Been Replaced

melting point of the solder paste 13. In general, for eutectic solder, the temperature is increased to 220° C. Since solder paste loses volume when fused, the soldered portion forms an hourglass shape with a concave central section in the height direction when it is cooled down to room temperature after soldering as shown in Fig. 6E.

Accordingly, the semiconductor device 1 contacts the circuit board 12, and the area not requiring electrical coupling is bonded to the circuit board 12 with adhesive. Adhered area absorbs the stress at heating for soldering, and thus reduces the stress applied to the electrically bonded portion.

The solder paste 13 can be supplied into the filling area 18 without using a mask which is used as explained in this exemplary embodiment. For example, the solder paste 13 can be supplied by applying the solder paste 13 directly to the carrier 3, and using the squeegee to remove the excess.

This exemplary embodiment also employs a mask for printing the solder paste 13 on the circuit board 12, but a process of printing the solder paste 13 on the circuit board 12 may not always be necessary for mounting the semiconductor device 1, same as in the fourth exemplary embodiment.

With the use of this mounting method, the effect described in the first to third exemplary embodiments can be achieved.

This Sheet Has Been Replaced

INDUSTRIAL APPLICABILITY

A carrier or semiconductor device of the present invention allows the control of the height H of a bonded portion by adjusting the depth of the concave portion when electrically coupling, including soldering, to a circuit board. The height H of the bonded portion can be made greater than that when mounting a semiconductor device without the concave portion, thereby reducing the stress applied to the bonded surface and improving reliability and thermal heat cycle resistance.

In addition, the present invention enables the formation of an hourglass shape with a concave central section in the thickness direction at the soldered portion by filling the filling area with solder paste or solder balls before soldering. In the prior art, a semiconductor device without the filling area forms a convex drum shape at the soldered portion. The soldered portion in the present invention forms an hourglass shape because the volume of solder shrinks when the solder paste melts. The hourglass shape transfers the stress concentrated on the bonded surface to its central section, improving the bonding strength and preventing destruction of the bonded surface.

This Sheet Has Been Replaced

In the case of electrically coupling the concave portion provided on a carrier for semiconductor and the electrode on the circuit board, an adhered portion absorbs the stress, reducing the stress applied to the electrically coupled portion, by attaching an area where the semiconductor device and the circuit board contact but electrical coupling is not required with adhesive, and heating and soldering the semiconductor device onto the circuit board.

The present invention also enables the reduction of the stress applied to the adhered portion and thus reduces the stress applied to the electrically coupled portion by forming a part from the electrode at the bottom of the concave portion provided on the carrier for semiconductor of the semiconductor device to the surface of the side where there is no semiconductor element using layers comprising materials with different thermal expansion coefficients which bridge, in a stepwise fashion, the thermal expansion coefficient of the carrier for semiconductor of the semiconductor device to the circuit board on which the semiconductor device is mounted.

This Sheet Has Been Replaced

What is Claimed is:

1 A carrier comprising:

a substrate provided with a concave filling area on one face;

a first electrode provided at the bottom of said filling area of said substrate; and

a second electrode provided on the other face of said substrate;

said first electrode and said second electrode being electrically coupled.

2. A carrier comprising:

a first electrode provided at one face of a substrate;

a second electrode provided on the other face of said substrate and electrically coupled to said first electrode provided;

a filling area provided around said first electrode using said first electrode as the bottom, and said filling area being made of a control material for controlling a contact material which is bonded onto said first electrode.

3. A carrier as defined in Claim 2, wherein said substrate and said filling area are made of materials having different thermal expansion coefficients.

* C L M S *

This Sheet Has Been Replaced

4. A carrier as defined in Claim 2, wherein a thermal expansion coefficient of said control material of said filling area at the side of said substrate is close to the thermal expansion coefficient of said substrate, and is gradated, in the thickness direction, toward close to the thermal expansion coefficient of said circuit board on which to be mounted.

5. A semiconductor device having electrical coupling among a semiconductor element having a specified circuit and an electrode therein, said electrode of the semiconductor element, and a first electrode of a carrier as defined in one of Claims 1 to 4.

6. A method for mounting a semiconductor device as defined in Claim 5 comprising steps of:

supplying a bonding material to the filling area formed on the carrier of said semiconductor device;

flipping said semiconductor device;

mounting said semiconductor device onto the circuit board; and

heating said semiconductor device and said circuit board.

* C L M S *

This Sheet Has Been Replaced

7. A method for mounting a semiconductor device as defined in Claim 5 comprising steps of:

supplying a solder ball to the filling area formed on the carrier of said semiconductor device;

flipping said semiconductor device;

mounting said semiconductor device onto the circuit board; and

heating said semiconductor device and said circuit board.

8. A method for mounting a semiconductor device as defined in Claims one of Claims 1 and 2 comprising steps of:

applying adhesive to an area which does not require electrical coupling but the semiconductor device and circuit board contact at electrically coupling of the electrode provided in the concave portion of the carrier for semiconductor and the electrode of the circuit board;

mounting the semiconductor device onto the circuit board; and

heating for soldering the semiconductor device and circuit board.

9. A method for mounting by forming a bonding material, which bonds an electrode provided on a circuit board having a specified circuit and an electrode of the

* C L M S *

This Sheet Has Been Replaced

circuit board on which a component is mounted, into an hourglass shape with a concave central section for bonding the electrode provided on said circuit board and the electrode of the component to be mounted on said circuit board.

10. A mounted package made by forming a bonding material, which bonds an electrode provided on a circuit board having a specified circuit and an electrode of the circuit board on which a component is mounted, into an hourglass shape with a concave central section for bonding the electrode provided on said circuit board and the electrode of the component to be mounted on said circuit board.

* C L M S *