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ENHANCED BGA GROUNDED HEATSINK

BACKGROUND OF THE INVENTION

(1) Field of the Invention

The invention relates to the fabrication of integrated circuit devices, and more particularly, to a method for grounding an enhanced BGA package to an underlying heatsink.

(2) Description of the Prior Art

The semiconductor industry has for many years followed a path of product improvement by the electrically required approach of device miniaturization and by the therefrom following increase of the device packaging density. For many of the semiconductor devices, increased device density is implemented internally to the device by creating device features of smaller dimensions. Where these devices need to be assembled into complete device packages, the completed semiconductor devices are frequently assembled in multi-device packages. This has led to the field of high density interconnect technology, where multilayer structures are mounted on the surface of a substrate thereby connecting integrated circuits to one another. This approach results in high wiring and high packaging density, whereby many integrated circuit chips are physically and electrically interconnected and

connected to a single substrate commonly referred to as a Multi-Chip-Module (MCM). Electrical device isolation is provided by layers of dielectric such as polyimide that separate various functional planes (such as signal lines, power lines and ground planes) in the substrate. Metal interconnects can readily be provided by metal lines that are embedded in other layers of dielectric, thereby using vias (holes) to provide electrical connections between the various types of lines. Interconnect lines must thereby be connected in such a manner that optimum performance can be realized for the completed package. For instance, adjacent layers must be formed such that primary signal propagation directions are orthogonal to each other. This to avoid crosstalk between lines that are in close physical proximity, which can induce false signals and noise between adjacent lines. Good planarity must also be maintained between adjacent layers of interconnect lines because the metal interconnect lines are typically narrow in width and thick in a vertical direction (in the range of 5 to 10 microns thick) and must be patterned with microlithography. Patterned layers must therefore be substantially flat and smooth (i.e. have good planarity) so that these layers can serve as a base for the next layer.

One of the original approaches that has been used to create surface mounted, high pin count integrated circuit packages has been the use of Quad Flat Packs (QFP's) with various pin configurations. For QFP's, closely spaced leads along the four edges of the flat package are used for making electrical connections from where the electrical connections are distributed to the surrounding circuitry. The input/output (I/O) connections that can be made to QFP's are therefore confined to the edges of the flat package, which limits the number of I/O connections that can be made to the QFP even in applications where the pin to pin spacing is small. QFP's have found to be cost effective for semiconductor devices where the device I/O pin count does not exceed 200. To circumvent this limitation, a new package, a Ball Grid Array (BGA) package has been introduced. For the BGA package, the electrical contact points are distributed over the entire bottom surface of the package thereby eliminating the restriction of having I/O connects only around the periphery of the package. More contact points with greater spacing between the contact points can therefore be allocated across the BGA package than was the case with the QFP's. The contact points that are used for the BGA package are typically solder balls that have the added advantage of facilitating flow soldering of the package onto a printed circuit board.

A Ball Grid Array (BGA) is an array of solderable balls placed on a chip carrier, such as a Printed Circuit Board (PCB). The balls contact a printed circuit board in an array configuration where, after reheat, the balls connect the chip to the printed circuit board. BGA's are known with 40, 50 and 60 mils spacings in regular or staggered array patterns. The BGA package is part of a larger packaging approach that is often referred to as Chip Scale Packages (CSP), which is a packaging approach that is considered to be different from the previously highlighted approach of MCM's.

Flip Chip packages have in general been used to accommodate increased I/O count combined with increased high requirements for high performance IC's. Flip chip technology fabricates bumps (typically Pb/Sn solder) on Al pads and interconnects the bumps directly to the package media, which are usually ceramic or plastic based. The flip-chip is bonded face down to the package through the shortest paths. This approach can be applied to single-chip packaging and to higher integrated levels of packaging (in which the packages are larger) and to more sophisticated packaging media that accommodate several chips to form larger functional units.

Prior Art substrate packaging uses ceramic and plastic BGA packaging. Ceramic substrate packaging is expensive and has proven to limit the performance of the overall package. Recent years have seen the emergence of plastic BGA packaging; this packaging has become the main stream design and is frequently used in high volume BGA package fabrication. The plastic substrate BGA package performs satisfactorily when used for low-density flip-chip IC's. If the number of pins emanating from the IC is high, that is in excess of 350 pins, or if the number of pins coming from the IC is less than 350 but the required overall package size is small, or if the chip power dissipation is high (in excess of 4 Watts per chip), the plastic structure becomes complicated and expensive.

It is therefore the objective of providing a package for flip chips that has a direct ground connect between the flip chip and a heatsink on the surface of which the flip chip is mounted. In a typical flip chip packaging arrangement, a substrate layer that contains three layers is used to connect the flip chip to surrounding circuitry, using wire bond connections between the flip chip and the substrate layer. The contact points of the BGA/flip chip make contact with contact points in the top surface of the substrate layer, the substrate layer re-distributes (fan-out) the BGA/flip-chip contact points. An opening is provided in

each of the three layers that are contained in the substrate layer, this opening is filled with a low-resistivity material thus establishing electrical contact between one selected copper pad of the copper traces (in the upper layer of the substrate layer) and the heatsink. Connecting the ground point of the IC die to the selected copper pad of the copper traces completes the ground path between the ground of the IC die and the heatsink. A molding is encased between the lower surface of the BGA/flip-chip device and the upper surface of the substrate. This molding is referred to as underfill since it is filled in under the original BGA/flip-chip device. A heat sink is typically attached to the lower surface of the flip-chip.

Fig. 1 shows a Prior Art method of packaging a BGA/flip chip whereby a major part of the package contains a heatsink 10. The semiconductor chip or die 12 takes up the center of the package; the contact points of die 10 are closely spaced around the periphery of the die 10. Cavity 16 is provided in the heatsink 10 for the mounting of the Integrated Circuit (IC) chip 12. Heatsink 10 has a surface that is electrically conductive. The top of the IC chip 12 is in close physical contact with the heatsink 10 via a thin adhesive layer 18 of thermally conductive epoxy that is deposited over the top surface of cavity 16, the IC die 12 is attached to the heatsink 10 by means of this layer 18. The

adhesive layer 18 is cured after the IC die 12 has been inserted into cavity 16. The contact points of the die 12 are conductively bonded, using wire-bonding techniques, to the substrate layer 20.

The bond wires 28 and 30 are shown here as applied for the connection of the IC die 12 to layer 26 of the substrate 20. The substrate 20 has been shown as containing three layers, that is layers 22, 24 and 26. Layer 22 is typically an adhesive layer that directly connects the substrate 20 to the heatsink 10. This establishes the necessary mechanical support for the wire bonding operation. Layer 24 can contain a stiffener that provides rigidity to the substrate 20, while layer 26 contains copper traces and/or circuitry that further interconnects the solder balls 32 to the surrounding circuitry or functional elements. Wires 28 and 30 provide a wire bonded connection between a contact points on the IC die 12 and the copper traces contained in layer 26 of the substrate layer 20.

The substrate 20 contains, as has previously been indicated, the adhesive layer 22, the layer 24 of stiffener for the substrate and the copper traces 26 for interconnect of the IC die 12. In addition, the solder mask layer 27 with openings is deposited over the surface of the substrate 20. Solder mask 27 has been provided with openings that are aligned with the copper

traces 26 to provide solder connections between the copper traces 26 and the contact balls 32.

Fig. 1 also shows how the IC die 12 is encapsulated using an encapsulation material that is syringe dispensed to surround the die 12 forming the encapsulation layer 34. It must be noted that this layer not only surrounds the IC die 12 but also covers the bond wires 28 and 30. The encapsulation layer 34 is cured after injection.

For extremely fine pitch packages, where the distance between the contact points of the IC die is very small, an inner lead bonding packages is better suited. Wire bonding requires better access to the bonding contact points and is therefore not suited to extremely fine pitch connections. Wire bonding is typically used for packages with larger pitch interconnects, these packages tend to be more expensive to produce. The wire used during the wire bonding operation also introduces larger parasitic elements into the circuit configuration, resulting in limiting the high end frequency range over which wire bonded packages can be used.

Solder flux is applied to the balls 32 that need to be attached to the package, the solder balls 32 are then inserted

into the solder mask 27. The solder balls 32 are re-flowed by applying heat to the package, excess flux is cleaned from the conductive pads 26 by applying an appropriate cleaning agent. As a final step, the IC package is dry baked, which completes the process of assembling the wire bond package.

For the flip chip/BGA package that has been described, it is important that a solid and dependable ground connection is provided for the ID die 12 of Fig. 1. This common ground is of importance for instance in applications where electrical measurements must be performed on the mounted IC chip 12 after the chip 12 has been mounted on the heatsink 10. Commonality of ground between the IC die 12 and the test system is required for such an application. Not only must there be commonality in the grounding of the test system and the ground point of the chip 12, the commonality must be provided without introducing contact resistance of any significant ohmic value between the ground plane of the IC chip 12 and the surrounding ground plane, in the case of the test example that is the ground plane of the tester. This latter requirement is significant where ohmic resistance of relatively small values is tested, a relatively high value of resistance that is introduced between the ground point of the IC chip 12 and the tester takes on a relatively high value as compared with the (relatively low) value of the resistance that

is being evaluated thereby reducing the sensitivity of the test. As an example of such testing can be cited the testing that is performed to evaluate the contact resistance between the connected bond wires (28 and 30 in Fig. 1 as an example) and the copper traces of layer 26 to which these wires are connected. A high resistivity path between the various ground planes (of the IC die 12 and the ground point of the wire traces 26) is unacceptable and must therefore be avoided. In short: the method of assuring commonality between the ground point of the IC chip 12 and the ground point of surrounding electrical circuitry or equipment must provide a low resistivity connection between these two points of ground.

US 6,011,299 (Brench) shows a package using conductive epoxy that has a ground and heatsinks isolated from shields. The Prior art section states that heatsinks are grounded, see column 2.

US 5,376,909 (Nelson et al.) shows a package where the ground plane is the heatsink. Conductive epoxy is also used.

US 5,739,581 (Chillara et al.) shows a package with heat sinks and traces.

SUMMARY OF THE INVENTION

A principle objective of the invention is to provide a low-resistivity connection between a BGA/flip chip that is mounted on a heatsink and the heatsink.

In accordance with the objectives of the invention a new method is provided for the establishment of a low resistivity connection between a wire bonded IC chip that is mounted on a heatsink and the heatsink of the package. A copper trace connection is allocated for this purpose on the surface of the substrate layer to which the IC chip is connected. An opening is provided in the substrate layer of the package, this opening aligns with the copper trace that has been allocated for establishing a ground connection and penetrates the substrate layer down to the surface of the underlying heatsink. The opening is filled with a conductive epoxy or an equivalent low-resistivity material, establishing a direct electrical connection or short between the allocated copper trace and the underlying heatsink. By connecting the ground point of the IC chip to the allocated copper trace, a low resistivity electrical connection is made between the ground point of the IC chip and the heatsink into which the IC chip is mounted thereby providing a common

ground point between the flip chip die, the electrical traces to which the flip chip die is connected and the underlying heatsink.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 shows a cross section of packaging a BGA/flip chip using a heatsink and a Prior Art substrate.

Fig. 2a shows a cross section in an X-direction of a package of a BGA/flip chip using a heatsink and the substrate of the invention.

Fig. 2b shows a cross section in an Y-direction of a package of a BGA/flip chip using a heatsink and the substrate of the invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Fig. 2a shows a cross section in an X-direction of the package of the invention wherein a IC chip 12 has been mounted within a cavity 16 that has been provided for this purpose in a heatsink 10.

The package of the invention contains the following components:

1) a heatsink 10, heatsink 10 has a surface that is electrically conductive

2) a semiconductor chip or die 12 that takes up the center of the package; the contact points of the die 12 (not shown) are closely spaced around the periphery of the die 12

3) a cavity 16 that is provided in the heatsink 10 for the mounting of the Integrated Circuit (IC) chip 12

4) a thin adhesive layer 18 of thermally conductive epoxy that is deposited over the top surface of cavity 16; the IC die 12 is attached to the heatsink 10 by means of this layer 18. The top of the IC chip 12 is in close physical contact with the heatsink 10 via the adhesive layer 18, layer 18 is cured after the IC die 12 has been inserted into cavity 16

5) a substrate 20 containing three layers, that is layers 22, 24 and 26; the contact points (not shown) of the die 12 are conductively bonded, using wire bonding techniques, to the substrate layer 20

6) layer 22 is typically an adhesive layer that directly connects the substrate layer 20 to the heatsink 10, this establishes the necessary mechanical support for the wire bonding operation

7) layer 24 can contain a stiffener that provides rigidity to the substrate layer 20

8) layer 26 contains copper traces and/or circuitry that interconnect the solder balls of the flip chip package of Fig. 2a to surrounding circuitry or functional elements

9) the solder mask layer 27 with openings that is deposited over the surface of the substrate layer 20; solder mask 27 has been provided with openings that align with the copper traces 26 to provide solder connections between the copper traces 26 and the contact balls 40 of the flip chip package of Fig. 2a

10) wires 28 and 30 that provide a wire-bonded connection between a contact points on the IC die 12 (not shown) and the copper traces contained in layer 26 of the substrate layer 20

11) an encapsulation material 34 that is syringe dispensed to surround the die 12, surrounding the IC die 12 and the bond wires 28 and 30. The encapsulation layer 34 is cured after injection, and

12) BGA contact balls 40.

The design feature of the invention that has been added to the substrate 20 is the via 36 that has been created in the substrate 20. It must be noted that the via 36 is located in the immediate vicinity of the opening 16 in the heatsink 10, thus enabling a short wire bond connection 28 between a ground point on the IC die 12 (not shown) and the heatsink 10.

It must further been noted that the copper trace 38 is dedicated to the establishing of a ground connection between the IC chip 12 and the heatsink 10 of the package of the invention. Via 36 is filled with a low resistivity, high conductivity material such as conductive epoxy or any other suitable material that establishes a low resistivity path between the ground of the IC chip 12 and the heatsink 10.

It must further be emphasized that, where Fig. 2a shows only one via 36, the process of the invention is not limited to one via. A plurality of vias can be provided where this is required thereby establishing a plurality of electrical ground paths between the top surface of substrate 20 and the heatsink 10.

Fig. 2b contains component elements within its cross-section that are identical to the component elements of the package that have previously been highlighted under Fig. 2a. The cross section that is shown in Fig. 2b is a cross section that is taken under an angle that is perpendicular with the cross section that is shown in Fig. 2a. The purpose of the cross section that is shown in Fig. 2b is to indicate that the copper trace 38, which is provided for the establishment of a ground connection between the chip 12 and the heatsink 10, extends perpendicularly from the opening 16 that has been created in the heatsink 10. This

perpendicular extension of the copper trace ground connection 38 can therefore be further used to interconnect with contact balls via the solder mask 27 thus further providing a method for connecting a ground of the surrounding circuitry, which is typically connected to the solder balls, to also connect to the heatsink. This latter connection therefore makes a direct interconnect between the ground point of the IC die 12, the surrounding circuitry (not shown) to which the contact balls 40 are connected and the heatsink 10 of the flip chip package. To connect these three separate ground points to one common ground point of reference is important and required for many of the uses and applications for which the flip chip will be applied. The previously cited example of product testing is one of these applications. It is clear that the ultimate circuit functionality will in some cases be dependent on and will therefore benefit from having such a common ground connect point available since this provides one common ground between flip chip 12 and the surrounding circuitry.

Although the invention has been described and illustrated with reference to specific illustrative embodiments thereof, it is not intended that the invention be limited to those illustrative embodiments. Those skilled in the art will recognize that variations and modifications can be made without departing

from the spirit of the invention. It is therefore intended to include within the invention all such variations and modifications which fall within the scope of the appended claims and equivalents thereof.

What is claimed is:

1. A method for packaging an Integrated Circuit die in a cavity provided in a heatsink comprising:

providing an Integrated Circuit die having a ground point, the Integrated Circuit die being a flip chip device;

providing a substrate comprising

(i) three layers; and

(ii) an opening there-through for establishment of a ground connection between the Integrated Circuit die and a heatsink;

providing a heatsink, the heat sink having a cavity having a bottom surface and sidewalls;

providing a first adhesive layer over the bottom surface of the cavity for attaching the IC die to the heatsink;

attaching the IC die to the heatsink by positioning the IC die over the first adhesive layer;

providing a plurality of wire bond connections between the IC die and the substrate;

providing a conductive material through the opening provided through the substrate;

providing a wire bond connection between the ground point of said IC die and the conductive material provided through the opening through the substrate;

providing an encapsulation layer within and adjacent to the cavity for attaching the IC die to the heatsink; and

providing and attaching a plurality of solder balls.

2. The method of claim 1, said substrate comprising a lower layer in addition to a center layer in addition to an upper layer.

3. The method of claim 2, said lower layer comprising:

a first opening, said first opening aligning with said bottom surface of said cavity in said heatsink;

an adhesive layer, said adhesive layer forming an interface between said substrate and said heatsink, attaching said substrate to said heatsink; and

a second opening being aligned with matching second openings in said center and upper layers.

4. The method of claim 2, said center layer being a stiffener comprising a first opening, said first opening aligning with said bottom surface of said cavity in said heatsink, said stiffener further comprising a second opening, said second opening aligning with a second opening in said upper and lower layers.

5. The method of claim 2, said upper layer comprising:

a first opening, said first opening aligning with said bottom surface of said cavity in said heatsink;

a second opening being aligned with matching second openings in said center and lower layers;

copper traces with an array of conductive pads, said copper traces forming metal interconnect lines;

a solder mask layer having openings having a diameter, providing interconnect points between said copper traces and said plurality of solder balls; and

a conductive pad in said array of conductive pads being aligned with said second opening in said upper layer of said substrate, said conductive pad being located immediately adjacent to sidewalls of said cavity in said heatsink.

6. The method of claim 2, said providing a conductive material through the opening provided through the substrate, comprising providing a conductive material through a second opening in said lower layer of said substrate in addition to a second opening in said center layer of said substrate in addition to a second opening in said upper layer of said substrate, establishing electrical contact between an electrically conductive pad in an array of conductive pads in said upper layer of said substrate and said heatsink.

7. The method of claim 1, said heatsink having an electrically conductive surface.

8. The method of claim 1, a solder ball of said plurality of solder balls having a diameter approximating a diameter of openings in a solder mask, said solder balls being inserted through said solder mask, furthermore said solder balls attaching to electrically conductive traces in an upper layer of said substrate.

9. The method of claim 1, said first adhesive layer for attaching said IC die to said heatsink attaching a bottom surface of said Integrated Circuit die to the bottom surface of the cavity in the heatsink, the adhesive layer being a thermally conductive layer.

10. The method of claim 1, said encapsulation layer being injected between sidewalls of said IC die and said heatsink, including said upper surface of said IC die and further including wire bond interconnects being provided between said IC die and said substrate, said encapsulation layer comprising a thermally conductive epoxy.

11. A method for packaging an Integrated Circuit die in a cavity provided in a heatsink, comprising:

providing a flip chip semiconductor device having a ground point;

providing a heatsink having a cavity having a bottom surface and sidewalls;

providing a substrate, the substrate comprising:

(i) at least one layer of interconnect metal;

(ii) a first opening for insertion of the flip chip there-through;

(iii) a solder mask over a surface thereof, exposing points of contact provided over a surface of the substrate; and

(iv) a second opening for establishment of a ground connection between the ground point of the flip chip device and the heatsink, the opening being surrounded by a conductive pad over a surface of the substrate;

providing a first adhesive layer over the bottom surface of the cavity for attaching the IC die to the heatsink;

attaching the IC die to the heatsink by positioning the IC die over the first adhesive layer;

providing at least one wire bond connection between the flip chip and the substrate;

providing a conductive material through the second opening provided through the substrate, contacting the conductive pad surrounding the opening;

providing a wire bond connection between the ground point of said IC die and the conductive material provided through the opening through the substrate;

providing an encapsulation layer within and adjacent to the cavity for attaching the IC die to the heatsink;

inserting at least one solder ball in the solder mask of the substrate; and

applying reflow to the at least one solder ball.