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Semiconductor package with heat spreader

The present invention relates to a structure of a semiconductor package.

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Fuelled by exponential increases in device clock speeds, the heat which must be dissipated in electronic devices has grown dramatically in recent years. Poor heat dissipation in packaged electronic devices limits device performance and the size of the module. In some cases, the need for an external heat sink to manage the thermal dissipation has limited the size of a small module or end-product which is not in tune with the key technology trend. Electronics gadgets are growing smaller in size so that ever smaller modules containing an ever increasing density of devices are desired.

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Heat dissipation is an increasing problem and improved thermal management is required. To date, this problem has not been satisfactorily solved to a extent particularly for simple low-cost heat dissipation.

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One solution is the cavity-down approach. However, the routing space for signals, powers and grounds traces is limited which results in lower I/Os. Also, the assembly processes are difficult with high material and packaging costs.

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US 6 339 254 B1 discloses a stacked multi-chip assemblage including a plurality of integrated circuit die directly attached to a substrate having pads corresponding to terminals on the die and interconnections between the die, and also external contacts.

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US 5,681,663 discloses a heat spreader carrier strip including a first strip of laminated material portioned into smaller heat spreader portions with a welded second strip. Thermal manufacturing cycles will not cause a bowing of the second
5 strip or of the heat spreader sections.

US 5,5156,923 discloses a heat transferring circuit substrate including layers of copper and Invar which has limited thermal expansion.

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US 5,358,795 discloses a heat-conductive material which receives and releases heat evenly, has excellent thermal conductivity and can have any desired thermal expansion coefficient.

15 US 5,736,785 discloses a structure, shown in Figure 5a, where a planar heat spreader is mounted on the top surface of a semiconductor die, which in turn is mounted on and electrically connected to a substrate. The planar heat spreader comprises a central recessed portion protruding from the bottom
20 surface of the heat spreader surrounded by a plurality of apertures at the edges. The die is coated with a layer of adhesive covering also the bonding wires attaching the die to the substrate. This structure has a limited thermal efficiency.

25 It is one object of the present invention to provide a packaging structure offering an enhanced thermal management solution. The above and other objects are solved by the independent patent claims. Further improvements are given in the dependent patent claims.

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The invention provides an interface between the die and the heat spreader which is bridged in part by adhesive or solder.

A fluid adhesive gives good physical connection between the die and heat spreader surfaces as a fluid compensates for surface imperfections. Even better thermal conductive properties are found in adhesives which are also at least partly electrically conductive as they contain metal particles. These cannot
5 be used in the structure of US 5,736,785 as the adhesive also covers the bonding wires and undesirable electrical shorts between the bonding wires and heat spreader will occur.

10 The present invention provides a semiconductor package comprising a device carrier having a plurality of contact areas, a semiconductor die having a plurality of die pads located at the edges of its active surface mounted to the device carrier, connection means to electrically connect the die pads on the
15 die to the contact areas on the device carrier, a device contact means such as a solder ball array on the bottom side of the device carrier, and a heat spreading means which includes an upper plate and a foot ring which protrudes from a bottom surface of the upper plate and which is positioned between the
20 die pads on the active surface such that a cavity is formed between the heat spreading means and the active surface, the cavity being filled with an adhering means interconnecting the heat spreading means and the active surface and methods of assembling such a package.

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It is advantageous to attach a heat spreading means to the upper surface of the die as heat is dissipated upwards away from the board so that neighbouring devices are not overheated. There is also easy routing of the wires making up the electrical
30 cal connections and there is no need for an external heat sink so that the size of the package is not increased. Conventional

adhesives and packaging technology can be used simplifying the processing route.

A heat spreading means of high thermal conductivity preferably
5 comprises a material selected from Cu, Al, Ag or an alloy of one of these, as these materials have good thermal conduction properties thus enabling efficient heat conduction away from the active surface. More preferably the heat spreading means comprises Cu as copper has good thermal conductivity, is read-
10 ily available and is the least costly material. The heat spreading means is attached to the active surface of the die. The heat spreading means includes an upper plate and an integral foot ring protruding from the bottom surface.

15 The heat spreading means preferably includes an aperture located in the upper plate, the aperture extending between the cavity and the upper surface of the upper plate. This enables the cavity to be filled with adhesive material or other adhering means from above after the heat spreader has been placed
20 onto the die.

The upper plate of the heat spreading means is preferably laterally square so as to be compatible with the existing assembly line and is preferably laterally larger than the width of
25 the die in order to increase heat dissipation.

Preferably the foot ring is laterally square, so as to have the greatest contact area with the die has a height greater than the height of the connecting means above the upper surface of the die so that the upper plate section of the heat
30 spreading means is not in contact with the connecting means and electrical shorting does not occur. The width of the foot

ring smaller than the distance between the die pads on opposing sides of the die again so that undesirable electrical contact is not made between the heat spreader and connecting means.

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The at least partial direct contact between the heat spreading means and the active surface of the die facilitates the dissipation of heat through a small number of layers thereby enhancing heat dissipation.

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Preferably the adhering means is a thermally conductive adhesive such as epoxy glue, sealant resin, thermal grease or liquid encapsulant in order to improve heat dissipation from the die to the heat spreading means. Preferably the adhesive material includes at least in part electrically conductive material as such adhesive has a high thermal conductivity.

The structure of a heat spreading means allows control of the adhesive means as the adhesive means is contained within the cavity and does not spread into surrounding area, in particular onto the connecting means. This enables the use of electrically conductive adhesive which has superior thermal conduction properties, thereby enabling improved heat dissipation.

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The present invention also relates to methods of mounting a semiconductor package.

A method comprises the steps of attaching a semiconductor die, which has a plurality of die pads on its active surface, to a device carrier such as BT or lead frame having contact areas by, for example, a die attach process. Electrical connections

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between the die and the substrate are made by, for example, attaching bond wires between the die pads and conductive traces on the substrate. Next, a heat spreading means, which includes an upper plate and foot ring which protrudes from a bottom surface of the upper plate, is positioned between the die pads on the active surface of the die such that a cavity is formed between the heat spreading means and the active surface. The cavity is then filled with adhering means such that the adhering means interconnects the heat spreading means and the active surface and curing the adhering means.

Preferably the cavity is filled with an adhering means by dispensing adhesive through an aperture located in the heat spreading means as this enables the adhesive to enter the cavity from above. The spread of the adhesive to be contained largely within the cavity.

A further method comprises the steps of attaching a semiconductor die, which has a plurality of die pads on its active surface and special contact areas for the solder adhering means, to a device carrier having a plurality of contact areas. Electrical connections are then made between the die and the substrate. Next, a heat spreading means, which includes an upper plate and foot ring which protrudes from a bottom surface of the upper plate, is positioned between the die pads on the active surface such that a cavity is formed between the heat spreading means and the active surface. The cavity is then filled with solder means and the semiconductor package heated such that the solder means interconnects the heat spreading means and the active surface.

If a solder means is used for adhering the heat spreader to the active surface of the die, the semiconductor die may be provided with special contact areas for the solder on its active surface. Solder means has good thermal conductivity and
5 the foot ring stops the solder from spreading onto the die pads and bond wires so that shorting between the device and heat spreader is prevented.

There are two methods for mounting the embodiment which includes solder adhering means. The solder means may be spread
10 onto the surface of the die within the die pads before the heat spreader is positioned on the surface of the die. The solder and heat spreader are so positioned that the solder is contained within the foot ring of the heat spreading means. In
15 this embodiment it is not necessary for the heat spreader to contain an aperture in the upper plate. The package is then heated so that the solder interconnects the foot ring and therefore the heat spreader with the active surface of the die.

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Alternatively, the heat spreader is positioned on the die and the solder means dispensed through the aperture in the upper plate. The semiconductor package is then heated so that the solder means interconnects the heat spreading means and the
25 active surface.

One further advantage of the present invention is that it offers a simple low-cost solution for enhanced thermal management whereby the current conventional assembly packaging technology of a laminate package can still be used. The invention
30 can be used for all existing semiconductor devices. It eliminates the need for an external heat sink which doubles or tri-

ples the size (in terms of thickness) of the package or component. This affects the overall dimension of the modules or application boards. The present invention also enables improved trace routability over the existing cavity-down thermal management solutions.

The invention favours heat dissipation upwards from the active surface which means that heat is dissipated away from the board. This is highly desirable as heat dissipation path along the device carrier could overheat the adjacent components when mounted onto the application board.

One concept of this invention includes an integrated circuit device whereby the heat spreader, which can be a composite of either Cu, Cu alloys, Al, Al alloys, Ag and Ag alloys is mounted onto this device using thermally conductive adhesives such as epoxy glue, sealant resins, thermal grease or even liquid encapsulant. Some of these adhesives can also be used to attach devices to a carrier such as a BT substrate or lead frame in the die attach process. Packaging of stack-die has also used such adhesives when attaching two devices together stacking them one on top of the other. One embodiment of the invention would be the use of selected material i.e. pure copper (Cu) for the heat spreader and an epoxy glue formulated with high adhesive and low viscosity properties as the thermally conductive adhesives to attach the heat spreader onto the die.

A concept introduced in the present invention can also be seen in the design of the aperture in the heat spreading means. This acts as a funnel so that the adhesive can be filled-in through this funnel to make the attachment of the heat

spreader onto the die top. The funnel-like design allows the adhesives to be contained within the boundary of the heat spreader inner-walls which controls creeping of adhesive preventing it from smudging the surface of the dies. Under such
5 well-defined process control, the contact area between the heat spreader base and the die top surface could also be enlarged to have optimum adhesion between the heat spreader and the die top and in addition creates also an avenue for another heat transfer path. This approach of having a direct attachment
10 ment of heat spreader onto die top surface by means of dispensing adhesives improves its thermal properties.

The concept can be applied differently, e.g. by exposing the copper heat spreader or by burying the heat spreader by encapsulating it within the package. Both deliver the desired thermal
15 dissipation except that the exposed heat spreader would have a better thermal dissipation performance. The design can be chosen to suit the kind of assembly process that has been established in the conventional platform of the process / production
20 line.

The invention can be easily seen by X-Ray on the package or assembled component. Conventional packaging technology can be used without having to change or introduce an entirely new assembly
25 process line.

An embodiment of the invention will now be described by way of example with reference to the drawings.

30 Fig. 1 shows a cross-sectional view of the structure of a semiconductor package according to the invention and

Fig. 2 shows a perspective and exploded view of the semiconductor package of Fig. 1.

The semiconductor package 1 comprises a device carrier 2, a semiconductor die 3 which is electrically connected to the device carrier 2 by bond wires 4 and a heat spreader 5 which is mounted on the upper active surface of the die 3.

The device carrier 2 comprises an insulation carrier 6, multi-layer copper distribution traces 20, a plurality of contact areas 7 on its upper surface, a plurality of via contacts 18, and a plurality of device contacts 8 on its bottom surface. Solder balls 9 are attached to the device contacts 8. The inner structure of the device carrier 2 is illustrated in Fig. 1 by way of two via contacts 18 which connect a contact area 7 with a device contact 8.

The die 3 is mounted on the device carrier 2 and it has a plurality of die pads 10 located at the edges of its upper surface. Bond wires 4 between die pads 10 and the contact areas 7 electrically connect the die 3 to the device carrier 2.

A copper heat spreader 5 is mounted on the upper active surface of the die 3. The heat spreader 5 includes an upper plate 11 and a foot ring 12 which protrudes from the bottom surface of the upper plate 11. The foot ring 12 is integral with the upper plate 11. The upper plate 11 is laterally larger than the width of the die 3 and includes an aperture 13 located in the centre of its lateral plane. The foot ring 12 is located centrally around the longitudinal axis of the upper plate 11. The height of the foot ring 12 is greater than the height of the bond wires 4 above the upper active surface of the die 3

and its width is smaller than the distance between the die pads 10 on opposing sides of the die 3.

5 The heat spreader 5 is positioned so that the foot ring 12 is mounted centrally on the upper surface of die 3 within the die pads 10. The bottom surface of the foot ring 12 is in partial contact with the upper surface of the die 3.

10 The cavity 14 formed by the aperture 13, by the foot ring 12 and by the upper surface of the die 3 is filled with adhesive material 15. The adhesive material 15 is highly adhesive, has a low viscosity, is thermally conductive and includes at least in part electrically conductive material.

15 As can be seen in Fig 1, but not Fig. 2, incomplete contact between the bottom surface of the foot ring 12 and upper surface of the die 3 results in discrete gaps 19 in the interface. These gaps are filled with the adhesive material 15.

20 The die 3, bond wires 4 and heat spreader 5 are encapsulated by a plastic cover 16.

25 As can be best seen in Fig. 2, the plate 11, foot ring 12 and aperture 13 which comprise the heat spreader 5 are in this embodiment of the invention laterally square.

There are many possible alternatives to the embodiment shown in the figures. In an embodiment not shown in the figures, the device carrier 2 is replaced by a substrate which is known in
30 the state of the art such as BT or leadframe. The die may be any semiconductor device or plurality of devices but the invention is particularly advantageous for power devices which

generate a lot of heat. The solder balls 9 may be replaced by any suitable device contacting means, such as pins.

The heatspreader 5 may be made from any thermally conductive material such as Ag, Al or one of their alloys, a Cu-alloy. A metal/Invar type composite is also possible which also has the advantage in reducing the difference in thermal expansion properties between the die 3 and the heatspreader 5. The form of the upper plate 11 of the heatspreader 5 is not important but may be a round disc, hexagonal disc etc and can be as large as necessary to dissipate the heat from a given die 3. The form of the foot ring 12 can be chosen so that the contact area between the foot ring 12 and the heat producing areas of the die 3 is maximised. It is therefore clear that any lateral form of the heat spreader 5 and therefore cavity 14 is possible. The wires 4 making up the electrical connection between the die 3 and the device carrier 2 may be replaced by other connecting means. The package may or may not be encapsulated and the top surface of the heatspreader may or may not be encapsulated.

The steps in the method to assemble semiconductor package are as follows:

- 25 After the attachment of a die 3 to a device carrier 2 using die attach material 17, bond wires 4 are attached between the die pads 10 and the contact areas 7 to electrically connect the die 3 with the device carrier 2.
- 30 The heat spreader 5 is then positioned on the upper active surface of the die 3 and the cavity 14 formed by the aperture 13, foot ring 12 and upper surface of the die 3 is filled with

adhesive material 15. The gap 20 between the foot ring 12 and upper active surface of the die 3 is filled with the adhesive material 15 which flows from the cavity 14. After the adhesive material is dispensed into the cavity 14, it is given an appropriate curing treatment to attach the heatpreader 5 to the die 3.

The structure of the heatspreader 5 assures that the adhesive material 15 is contained largely within the cavity 14 and does not spread onto the die pads 10 and wires 4. This enables the use of thermally conductive adhesive material which is also electrically conductive. Such adhesive material enables the more efficient dissipation of the heat generated by the active upper surface of the die 3.

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The package is then encapsulated by a molding process and solder balls 9 are attached to the device contacts 8 on the bottom surface of the device carrier 2. The solder balls 9 enable the package to be mounted onto a circuit board (not shown) and the transfer of signals from external devices (also not shown).

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In an alternative embodiment of the invention the encapsulation step is omitted.

The heat generated by the die 3 is dissipated by conduction into the foot ring 12, into the adhesive material 15 and into the upper plate 11 of the heatspreader 5. The heatspreader 5 provides an improved upward thermal conductive path as, firstly, there is a physical contact between the heatspreader 5 and the upper active surface of the die 3. Secondly, any gaps or imperfections in this interface are filled by the ad-

hesive material 15. Thirdly, the adhesive material 15 contains at least in part metal particles providing the adhesive material with improved thermal conduction properties. The heat is then finally dissipated into the air by radiation from the
5 heatspreader 5 and/or plastic cover.

Reference numbers

- 1 semiconductor package
- 5 2 device carrier
- 3 semiconductor die
- 4 bond wire
- 5 heat spreader
- 6 insulation carrier
- 10 7 contact area
- 8 device contact
- 9 solder ball
- 10 die pad
- 11 upper plate
- 15 12 foot ring
- 13 aperture
- 14 cavity
- 15 adhesive material
- 16 plastic cover
- 20 17 die attach material
- 18 via contact
- 19 gap
- 20 distribution trace

Patent Claims

1. A semiconductor package (1) comprising the following features:

- 5 - a device carrier (2) having a plurality of contact areas (7),
- a semiconductor die (3) having a plurality of die pads (10) of an active surface, the semiconductor die (3) being mounted on the device carrier (2),
- 10 - connection means (4) to electrically connect the die pads (10) to the contact areas (7),
- a heat spreading means (5) mounted on the active surface of the die (3),

wherein the heat spreading means includes an upper plate
15 (11) and a foot ring (12) which protrudes from a bottom surface of the upper plate (11) and which is positioned between the die pads (10) on the active surface such that a cavity (14) is formed between the heat spreading means (5) and the active surface, the cavity being filled with
20 an adhering means (15) interconnecting the heat spreading means (5) and the active surface.

2. A semiconductor package (1) according to claim 1, characterized in that

25 the adhering means comprises an adhesive (15) and/or a solder.

3. A semiconductor package (1) according to claim 1 or claim 2,

30 characterized in that

the heat spreading means (5) includes an aperture (13) located in the upper plate (11), the aperture (13) extending

between the cavity (14) and the upper surface of the upper plate (11).

4. A semiconductor package (1) according to one of the afore-
5 mentioned claims,
characterized in that
the upper plate (11) of the heat spreading means (5)
and/or the foot ring (12) are laterally square.
- 10 5. A semiconductor package (1) according to one of the afore-
mentioned claims,
characterized in that
the upper plate (11) of the heat spreading means (5) is
laterally larger than the width of the die (3).
- 15 6. A semiconductor package (1) according to one of the afore-
mentioned claims,
characterized in that
the height of the foot ring (12) is greater than the
20 height of the connection means (4) above the upper surface
of the die (3).
7. A semiconductor package (1) according to one of the afore-
mentioned claims,
25 characterized in that
the adhesive material is a thermally conductive adhesive
such as epoxy glue, sealant resin, thermal grease or liq-
uid encapsulant.
- 30 8. A semiconductor package (1) according to claim 8,
characterized in that

the adhesive material (15) comprises electrically conductive material.

9.A method to mount a semiconductor package (1) comprising the following steps:

- providing a device carrier (2) having a plurality of contact areas (7),
- attaching a semiconductor die (3) on the device carrier (2), the semiconductor die (3) having a plurality of die pads (10) on an active surface,
- making electrical connections between the die pads (10) and the contact areas (7) using connection means (4),
- placing a heat spreading means (5) on the active surface of the die (3), the heat spreading means including an upper plate (11) and a foot ring (12) which protrudes from a bottom surface of the upper plate (11) and which is positioned between the die pads (10) on the active surface such that a cavity (14) is formed between the heat spreading means (5) and the active surface,
- filling the cavity with an adhering means (15) such that the adhering means (15) interconnects the heat spreading means (5) and the active surface,
- curing the adhering means (15).

10.A method to mount a semiconductor package (1) according to claim 10,

characterized in that

the step of filling the cavity with an adhering means (15) comprises the step of dispensing adhesive means through an aperture located in the heat spreading means.

11. A method to mount a semiconductor package comprising the following steps:

- 5 - providing a device carrier having a plurality of contact areas,
- attaching a semiconductor die on the device carrier, the semiconductor die having a plurality of die pads on an active surface,
- 10 - making electrical connections between the die pads and the contact areas using connection means,
- placing a heat spreading means on the active surface of the die, the heat spreading means including an upper plate and a foot ring which protrudes from a bottom surface of the upper plate and which is positioned between the die pads on the active surface such that a cavity is formed between the heat spreading means and the active surface, the cavity containing a solder means,
- 15 - heating the semiconductor package such that the solder means interconnects the heat spreading means and the active surface.
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12. A method to mount a semiconductor package (1) according to claim 10,

25 characterized in that the cavity is filled with solder means before the heat spreading means is positioned on the die.

13. A method to mount a semiconductor package (1) according to claim 10,

30 characterized in that

the solder is positioned on the active surface of the die so that the solder is contained within the cavity of the heat spreader when the heat spreading means is subsequently positioned on the die.