

TITLE: METHOD AND APPARATUS FOR HEAT SINK

Field of the Invention

This invention relates generally to cooling of integrated circuit packages and more specifically applies to such cooling which includes use of a heat sink.

Cross Reference to Related Patent Applications

None.

Background of the Invention

Improvements in integrated circuit technology, such as lowering circuit voltages and selectively modifying circuit operation in response to heating, have tended to somewhat mitigate the increasing heat density which normally accompany ever increasing circuit density and operating frequency. Nevertheless, integrated circuit heating continues to be problematic. The art is replete with methods and devices for improving IC cooling, particularly involving the use of a heat sink.

There are numerous difficulties associated with using a heat sink for IC cooling. One of the difficulties involves how to attach a small, relatively fragile IC to a larger, relatively more sturdy heat sink. Heat treating is commonly used for attaching the IC to a relatively small carrier. To include a relatively large heat sink in a heat treating oven for attachment to the IC or

carrier would increase processing time and presents difficult problems of temperature control.

The prior art, therefore, includes improving the thermal conductivity of a mechanical attachment or contact between the heat sink and the IC or between the heat sink and the IC and carrier combination, where attachment or contact can be without thermal treatment. For example, U.S. patent 5,311,1300 to M.D. Rostoker, et al. describes a heat sink having a flat surface in close proximity above an IC die, with a silicon gel therebetween. The die is mounted on a substrate therebelow. One problem with this die/heat sink attachment is that the plane of the die which is proximate to the heat sink will inevitably be somewhat tilted with respect to the flat surface of the heat sink, resulting in reduced thermal conductivity.

U.S. patent 5,184,211 to L.R. Fox describes a heat sink mounted to a substrate, with the substrate supporting the die. The heat sink above the die is drawn down toward the substrate by mechanical attachment to achieve close contact with the die. A compliant cushion is disposed between the die and the substrate below. This somewhat accommodates dimensional variances, with the cushion acting like a spring to press the die to the heat sink. But the spring-like effect must necessarily be small because the die is also constrained by electrical leads connecting the IC to the substrate.

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As may be seen from these examples, a need exists for an improved method and apparatus for cooling an IC die.

Summary of the Invention

An objective of the invention is to improve heat dissipation for an IC die, using a heat sink having a mechanical attachment to an element for transferring heat from the die to the heat sink.

According to the present invention, the foregoing and other objects are attained by an assembly for dissipating heat includes a die containing an electronic circuit (a "chip") and a heat transfer element ("HTE") proximate to the chip and tending to be thermally conductive. The HTE has a face opposite the chip. The heat sink has a face tending to match the HTE face. The heat sink and HTE faces are held proximate to one another.

In another aspect of the invention, the heat sink face and HTE face entirely overlay the chip.

In a further aspect, the HTE and the heat sink faces are substantially flat so that gaps therebetween are reduced and heat transfer therebetween is improved.

Also, the assembly includes a thin layer of a first pliable, thermally conductive material between the HTE and heat sink faces, and a thin layer of a second pliable, thermally conductive material between the die and the HTE.

In one embodiment, a substrate supports the die and is attached to the HTE, holding the die proximate to the HTE. The



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substrate has substantially the same coefficient of thermal expansion as the HTE.

In the preferred method of assembling circuitry of the chip is connected to conductors of a wiring substrate. A first pliable, thermally conductive material is applied to a heat transfer element ("HTE"). The chip is abutted against the first pliable, thermally conductive material. The chip, first pliable, thermally conductive material, wiring substrate and HTE are heated. After the heating, the heat sink is secured proximate to the HTE.

In a further aspect of the method, a face is formed on the HTE and a face is formed on the heat sink which substantially matches the face on the HTE. In applying the first pliable, thermally conductive material to the HTE, it is applied opposite the HTE face. In abutting the chip, it is abutted to the first pliable, thermally conductive material opposite the HTE face.

In still a further aspect of the method, a second pliable, thermally conductive material may also be applied between the HTE and heat sink after the heating. Both the first and second pliable, thermally conductive material may tend to act as an adhesive. Alternatively, one of the first and second pliable, thermally conductive materials may tend to act as an adhesive. Or, neither the first nor the second pliable, thermally conductive materials may tend to act as an adhesive.

It is an advantage that the HTE, may be tightly secured in a close fit with the heat sink, due to the rugged construction of the

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HTE and heat sink, and yet the HTE may also be heat treated with the die, due to the relatively small size of the die and the HTE. Thus good heat transfer is achieved from the die to the HTE, and from the HTE to the heat sink.

It is another advantage of the present invention that heat may dissipate in a direct line from the chip to the HTE and the heat sink, and also outwardly therefrom.

Additional objects, advantages, and novel features are set forth in the following description, or will be apparent to those skilled in the art or those practicing the invention. Other embodiments are within the spirit and scope of the invention. These objects and embodiments may be achieved by the combinations pointed out in the appended claims. The invention is intended to be limited only as defined in the claims.

Brief Description of the Drawings

FIG. 1 illustrates the preferred embodiment of the invention for a wire bond package.

FIG. 2 illustrates the preferred embodiment of the invention for a flip chip package.

Detailed Description

To clearly point out novel features of the present invention, the following discussion omits or only briefly describes conventional features of chip packaging, such as wire bond and flip

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chip packaging; chip to carrier attachment, such as may include preparation for adhesive application and heat treatment; and machining, such as to achieve closely fitting, flat faces on metal parts, which are apparent to those skilled in the art.

Referring to FIG. 1, one preferred embodiment of the invention for a wire bond package is illustrated. A die 102 containing integrated circuitry is supported on a heat transfer element 104, held by an adhesive 106. A close fit and low thermal resistance between the die 102 and heat transfer element ("HTE") 104 is typically achieved, at least in part, by heat treating of the die, HTE and adhesive in an oven. Because the HTE is substantially smaller than the heat sink, this heat treating may be performed more quickly, controllably and reliably than would be required if the heat sink were included.

The heat transfer element 104 is preferably also of copper, which can be machined to obtain a substantially flat surface, such as within a deviation not exceeding 20 microns. Thus, face 108 of the heat transfer element 104, to which the die 102 is attached, and the face 110 of the HTE 104, which is held against heat sink 112, may be flat to within this tolerance.

Likewise, heat sink 112 is preferably of copper. Thus, heat sink 112 face 114, which is held against HTE 104 face 110, may be flat to within this tolerance, so that the heat sink 112 and heat transfer element 104 may be in substantially uniform contact throughout the entire area of the faces 110 and 114 to improve heat

transfer across the interface therebetween. Also, because the materials are the same, the coefficients of expansion for the HTE and the heat sink are the same. This further promotes the uniform contact despite heating by operation of the circuitry on the die.

Because the heat transfer element 104 and heat sink 112 are relatively sturdy, they may be tightly drawn together by screws 116a through 116e, which are inserted through the heat sink 112 and threaded into the heat transfer element. This further improves the uniformity of contact between the faces 110 and 114, thereby improving the thermal conduction of heat from the heat transfer element 104, across the interface, and into the heat sink 112. Also, it does not put any substantial stress on the wire bond connections 118 from the die 102 to metal conductors (not shown), preferably of copper, embedded in wiring laminate 120 connecting the circuitry to pins 124.

It should be understood that the heat sink 112 and heat transfer element 104 may also be attached and drawn together tightly by screws inserted through both the HTE 104 and heat sink 112 and held by nuts, or inserted through the HTE 104 and threaded into the heat sink 112, or by still other attachment means, such as clips, clamps etc.

The uniformity of contact between the faces 110 and 114 in the preferred embodiment may also be enhanced by a layer of compliant, thermally conductive material 122, such as mineral oil or thermal paste, therebetween.

The wiring laminate 120 is preferably of a material, such as a composite structure, which has a coefficient of expansion close to that of the copper HTE, and tends to be electrically nonconducting and thermally conducting. A typical pin 124, includes a pad for connection to conductors (not shown) embedded in the wiring laminate 120 such as by brazing. The pins 124 are preferably of copper or a gold plated nickel alloy, which is a good electrical conductor and also has a coefficient of expansion similar to the wiring laminate, embedded conductors and HTE, to reduce thermal stresses on the connections between the die and the wiring laminate, and between the pins and the wiring laminate.

FIG.1 provides only an orthographic view in a single plane (hereinafter referred to as the vertical plane). As can be only partially seen in the FIG. 1, in the horizontal plane the heat sink 112 face 114 entirely overlays heat transfer element 104 face 110, and heat transfer element 104 face 108 entirely overlays die 102. That is, as viewed from a horizontal plane above the heat sink 112, heat transfer element 104 and die 102, the perimeter of the heat transfer element face 110 extends beyond the perimeter of the die 102. (Of course, it may not be required in all instances for the HTE to completely overlay the die, or the heat sink to completely overlay the HTE. It is within the spirit of the invention for these elements to merely overlay one another to a substantial degree.)

Thus, heat from die 102 is more efficiently conducted from the die 102 to heat transfer element 104 to heat sink 112, since the heat may dissipate through the conductive materials of the heat transfer element and heat sink straight upward from the die, and also tangentially outward in all directions from the path straight upward.

Referring now to FIG. 2, a preferred embodiment of the invention is illustrated for a flip chip package. In this embodiment, die 102 containing integrated circuitry is supported on a substrate 126. Conductors (not shown) are embedded or on the surface of the substrate 126 to connect the circuitry of the die 102 to the pins 104. The substrate 126 is preferably an alumina ceramic material, which tends to be electrically nonconducting, and a good thermal conductor. The die 102 is attached to the substrate 126 by controllably collapsible chip connections 128 bonded to pads (not shown) on the substrate, as is known in the art. The substrate is attached to HTE 104, such as by solder 130, which may provide a hermetic seal. The HTE 104 is preferably of copper tungsten, which may also be machined to obtain a substantially flat surface, such as to within a deviation of no greater than 20 microns. Thus, faces 108 and 110 of the HTE 104 may be flat to within this tolerance.

Due to the selection of materials as set forth above, the coefficient of expansion of the HTE and substrate are substantially similar to reduce stress on the seal 130 caused by heating from

operation of the circuitry on the die.

Note that in this flip chip embodiment, the surface of the die 102 opposite the surface with the connections 128 is held by substrate 126 in close proximity to the face 108 of the HTE 104, with a thermally conductive paste 132, such as a silicon gel, therebetween.

Again, as in the embodiment of FIG. 1 for the wire bond package, heat sink 112 is preferably of copper. Thus, heat sink 112 face 114, which is held against HTE 104 face 110, may be flat to within the previously mentioned tolerance, so that the heat sink 112 and HTE 104 may be in substantially uniform contact throughout the entire area of the faces 110 and 114 to improve heat transfer across the interface therebetween.

Because the HTE 104 and heat sink 112 are relatively sturdy, they may be tightly drawn together by screws 116a and 116b, which, as shown in FIG. 2, are inserted through both heat sink 112 and HTE 104 and held by threaded collars, i.e., nuts, 134 the collars and screws being preferably of aluminum. This further improves the uniformity of contact between the faces 110 and 114, thereby improving the thermal conduction of heat from the HTE 104, across the interface, and into the heat sink 112.

Note that in this package, it is preferred that the screws 116 pass through both the heat sink and the HTE and are held by nuts 134, rather than engaging threads within the HTE or heat sink. Furthermore, it is preferable that the apertures in the HTE and

heat sink, through which the screws are inserted, have a somewhat larger diameter than the screws so that there is some freedom of lateral movement between the heat sink face 114 and HTE face 110 to accommodate differential expansion of the heat sink 112 and HTE 104. The uniformity of contact between the faces 110 and 114 in the preferred embodiment may also be enhanced by a layer of compliant, thermally conductive material 122, such as mineral oil or thermal paste, therebetween. The lateral movement is further enabled by including the mineral oil or thin thermal paste 122.

It should be recognized that because the lateral freedom, as described above, accommodates the differential thermal expansion of the heat transfer element with respect to the heat sink, so that although differential heating and expansion of the heat sink 112 and HTE 104 may occur, stress is substantially reduced on the connections (not shown) from the die 102 to metal conductors (not shown) embedded in, or on the surface of, substrate 126 connecting the circuitry to pins 122. On the other hand, it should be understood that this freedom of lateral movement is somewhat limited by the faces 114 and 110 being pressed tightly together held by the screws 116 and nuts 134. The screws and nuts must be properly tightened to achieve a balance between the objectives of 1) holding the faces 114 and 110 tightly together, and 2) allowing a certain amount of lateral movement as permitted by the diameter of the apertures relative to screws 116.

Although the embodiment shown is the preferred embodiment, it should be understood that the heat sink 112 and HTE 104 may also be attached and drawn together tightly by screws inserted through the HTE and threaded into the heat sink 112, screws which are inserted through the heat sink 112 and threaded into the HTE 104, or by still other attachment means, such as clips, clamps etc. However, some of these alternative methods of attachment may present difficulties. For example, copper tungsten is not well suited for threading. Also, some modest lateral expansion due to heating should be accommodated by whatever fastening means is used.

Overlay among the die, HTE and heat sink is substantially as in the embodiment of FIG. 1. Again, the extent of overlay can be only partially seen in FIG. 2, because FIG. 2 provides only an orthographic view in the vertical plane. It should be understood that for the embodiment illustrated in FIG. 2, the heat sink 112 face 114 entirely overlays HTE 104 face 110 in the horizontal plane, and HTE 104 face 108 entirely overlays die 102 in the horizontal plane. That is, as viewed from a horizontal plane above the heat sink 112, HTE 104 and die 102, the perimeter of the HTE face 110 extends beyond the perimeter of the die 102. Thus, heat from die 102 is more efficiently conducted from the die 102 to HTE 104 to heat sink 112, since the heat may dissipate through the conductive materials of the HTE and heat sink straight upward from the die, and also tangentially outward in all directions from the path straight upward. In general terms, calculations indicate that

the package of FIG. 2 will accommodate a 100 watt chip operating at a temperature rise of about 50 degrees centigrade.

Although the present invention and its advantages have been described in detail, it should be understood that various changes, substitutions and alterations can be made without departing from the spirit and scope of the invention as defined by the following claims. For example, as mentioned previously, it may not be required in all instances for the HTE to completely overlay the die, or the heat sink to completely overlay the HTE. It is within the spirit of the invention for these elements to merely overlay one another to a substantial degree. Also, for example, the materials described herein may be altered, provided that they are similarly well matched in properties such as degree of thermal expansion, thermal conductivity and electrical conductivity.



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CLAIMS

What is claimed is:

1. An assembly for dissipating heat, comprising:
a die containing an electronic circuit (a "chip");
a heat transfer element ("HTE") proximate to the chip and
tending to be thermally conductive;
a heat sink;
wherein the HTE has a face opposite the chip, the heat sink
has a face tending to match the HTE face, and the heat sink and HTE
faces are held proximate to one another.
2. The assembly of claim 1, comprising attachment means, for
securing the heat sink and the HTE such that the heat sink face is
held proximate to the HTE face.
3. The assembly of claim 2, wherein the heat sink face and
HTE face entirely overlay the chip so that heat may dissipate in a
direct line from the chip to the HTE and the heat sink, and also
outwardly therefrom.
4. The assembly of claim 3, wherein the HTE and the heat
sink faces are substantially flat so that gaps therebetween are
reduced and heat transfer therebetween is improved.

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5. The assembly of claim 4, wherein the heat sink and HTE are held together by a number of screws.

6. The assembly of claim 4, comprising a thin layer of a first pliable, thermally conductive material between the HTE and heat sink faces, and a thin layer of a second pliable, thermally conductive material between the die and the HTE.

7. The assembly of claim 6, comprising:
a substrate supporting the die, and attached to the HTE so that the die is held proximate to the HTE.

8. A method for dissipating heat from a die containing an electronic circuit (a "chip"), comprising the steps of:

- a) connecting circuitry of a chip to conductors of a wiring substrate;
- b) applying a first pliable, thermally conductive material to a heat transfer element ("HTE");
- c) abutting the chip to the first pliable, thermally conductive material;
- d) heating the chip, first pliable, thermally conductive material, wiring substrate and HTE;
- e) securing, after step d), a heat sink proximate to the HTE.

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9. The method of claim 8, comprising the step of:

f) applying, before step e) a second pliable, thermally conductive material between the HTE and heat sink.

10. The method of claim 9, wherein both the first and second pliable, thermally conductive material tend to act as an adhesive.

11. The method of claim 10, wherein one of the first and second pliable, thermally conductive materials tends to act as an adhesive.

12. The method of claim 11, wherein neither the first and second pliable, thermally conductive materials tend to act as an adhesive.

13. The method of claim 9, comprising the steps of:

g) forming a face on the HTE; and

h) forming a face on the heat sink which substantially matches the face on the HTE;

wherein, in c) the first pliable, thermally conductive material is applied opposite the HTE face and, in d) the chip is abutted to the first pliable, thermally conductive material opposite the HTE face.

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