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HEAT SINK FOR BALL GRID ARRAY PACKAGES

BACKGROUND OF THE INVENTION

(1) FIELD OF THE INVENTION

This invention relates to the inclusion of heat sinks in a molded circuit package.

(2) DESCRIPTION OF THE RELATED ART

Molded circuit packages using high performance circuit dies, which generate large amounts of heat energy, must have a means of spreading the heat energy. Usually the carrier board to which the circuit die is attached must perform this heat spreading function.

U.S. Pat. No. 5,635,671 to Freyman et al. describes a degating region having a material formed thereon chosen such that the material in the degating region forms a weak bond with the encapsulant used. Freyman et al. describe the used of degating material such as gold so that wiring traces must be routed away from the degating region.

U.S. Pat. No. 5,241,133 to Mullen, III et al. describes a leadless pad array chip carrier package using an array of solder pads for the ball grid array.

SUMMARY OF THE INVENTION

As circuit performance and density increases, circuit packages require higher thermal performance in order to properly dissipate the heat generated by the circuits. In conventional packages this improved thermal performance requires carrier boards having extra layers to act as heat spreaders resulting in added cost and loss of standardization.

A cross section of a conventional molded circuit ball grid array package is shown in Fig. 1. A circuit die 12 is bonded to the first surface of a carrier board 10 using an epoxy bond 14. Wire bonds 16 connect the circuit die input/output pads to pads 18 on the carrier board. Interconnection balls 22 are joined to pads 20 on the second surface of the carrier board. The circuit die is enclosed in a molded encapsulant 17 to complete the package. In order to properly dissipate the heat generated by the circuit die 12 the carrier board 10 must have sufficient performance, which usually means extra layers in the carrier board 10 will be required.

It is a principle objective of this invention to provide a method of forming a circuit package which does not require any thermal enhancement of the carrier boards.

It is another principle objective of this invention to provide a circuit package which does not require any thermal enhancement of the carrier boards.

These objectives are achieved by using a heat sink in the circuit package. The heat sink is placed over the circuit die, but not in physical contact with the circuit die, and held in place by the encapsulation material used to encapsulate the circuit die. In some embodiments standoff members are used to provide separation between the heat sink and the circuit die. In other embodiments the heat sink is temporarily held in place as the encapsulation material is cured and subsequently held in placed by the cured encapsulation material. The heat sinks may be exposed to the environment or may be covered by a thin layer of the cured encapsulation material.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 shows a cross section view of a conventional molded circuit package.

Fig. 2 shows a cross section view of a molded circuit package of this invention showing a heat sink covered by a thin layer of cured encapsulant and standoff members holding the heat sink away from the circuit die.

Fig. 3 shows a cross section view of a molded circuit package of this invention showing a heat sink exposed to the environment and standoff members holding the heat sink away from the circuit die.

Fig. 4 shows a cross section view of a molded circuit package of this invention showing a heat sink covered by a thin layer of cured encapsulant and cured encapsulation material holding the heat sink away from the circuit die.

Fig. 5 shows a cross section view of a molded circuit package of this invention showing a heat sink exposed to the environment and cured encapsulation material holding the heat sink away from the circuit die.

Fig. 6 shows a cross section of a two piece mold used to form a molded circuit package of this invention having a heat sink covered by a thin layer of encapsulant and standoff members holding the heat sink away from the circuit die.

Fig. 7 shows a cross section of a two piece mold used to form a molded circuit package of this invention having a heat sink exposed to the environment and standoff members holding the heat sink away from the circuit die.

Fig. 8 shows a cross section view of a two piece mold used to form a molded circuit package of this invention having a heat sink covered by a thin layer of cured encapsulant and a vacuum chuck used to temporarily hold the heat sink in place during the molding process.

Fig. 9 shows a cross section view of a two piece mold used to form a molded circuit package of this invention having a heat sink exposed to the environment and a vacuum chuck used to temporarily hold the heat sink in place during the molding process.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Refer now to Figs. 2-5 for a description of the embodiments of the molded circuit package, having a heat sink formed therein, of this invention.

Figs. 2 and 3 show the embodiment of the molded circuit package using a heat sink having standoff members. Figs. 2 and 3 show a cross section of a molded circuit package showing a circuit die 12 bonded to the first surface 31 of a carrier board 30, having a first surface 31 and a second surface 33. The circuit die 12 is bonded using, for example, an epoxy bond 14 or the like. Wire bonds 16 form electrical connections between the circuit die and pads 18 on the first surface 31 of the carrier board 30. Interconnection balls 22 are joined to pads 20 on the second surface 33 of the carrier board 30. In this invention the carrier board 30 is not relied upon to spread the heat energy generated by the circuit die 12 and can be a very simple board of, for example, one or two layers.

The first ends of each of a number of standoff members 36, each standoff member 36 having a first end and a second end, are attached to the second surface 37 of a heat sink 34, having a first surface 35 and a second surface 37. The heat sink is then placed directly over the circuit

die 12 with the second ends of each of the standoff members 36 contacting the first surface 31 of the carrier board 30. The standoff members 36 fix the position of the heat sink 34 above the circuit die 12 and provide separation between the circuit die 12 and the heat sink 34. The heat sink 34 has a high thermal conductivity and is usually formed of a metal, such as copper or aluminum, or other thermally conductive material. The heat sink 34 provides the function of spreading the heat generated in the circuit die 12 so that the heat can be more easily removed from the circuit package. The standoff members 36 can be a metal, such as copper or aluminum, or other thermally conductive material.

The circuit package is encapsulated in an encapsulation material 32 such as epoxy molding compound. Fig. 2 shows the case where the encapsulation material 32 covers the first surface 35 of the heat sink. Fig. 3 shows the case where the encapsulation material 32 does not cover the first surface 35 of the heat sink 34 and the first surface 35 of the heat sink 34 is exposed to the environment.

Figs. 4 and 5 show the embodiment of the molded circuit package using a heat sink without standoff members. Figs. 4 and 5 show a cross section of a molded circuit package showing a circuit die 12 is bonded to the first

surface 31 of a carrier board 30, having a first surface 31 and a second surface 33. The circuit die 12 is bonded using, for example, an epoxy bond 14 or the like. Wire bonds 16 form electrical connections between the circuit die and pads 18 on the first surface 31 of the carrier board 30. Interconnection balls 22 are joined to pads 20 on the second surface 33 of the carrier board 30. In this invention the carrier board 30 is not relied upon to spread the heat energy generated by the circuit die 12 and can be a very simple board of, for example, one or two layers.

A heat sink is positioned directly over the circuit die 12 and held in place by cured encapsulation material 32. The cured encapsulation material 32 fixes the position of the heat sink 34 above the circuit die 12 and provides separation between the circuit die 12 and the heat sink 34. The encapsulation material 32 is a material such as epoxy molding compound. The heat sink 34 has a high thermal conductivity and is usually formed of a metal, such as copper or aluminum, or other thermally conductive material. The heat sink 34 provides the function of spreading the heat generated in the circuit die 12 so that the heat can be more easily removed from the circuit package. Fig. 4 shows the case where the encapsulation material 32 covers the first surface 35 of the heat sink 34. Fig. 5 shows the case where the encapsulation material 32

does not cover the first surface 35 of the heat sink 34 and the first surface 35 of the heat sink 34 is exposed to the environment.

Refer now to Figs. 6-9 for a description of the embodiments of the method of forming the molded circuit package, having a heat sink formed therein, of this invention.

Figs. 6 and 7 show the embodiment of the method of forming the molded circuit package using a heat sink with standoff members. Figs. 6 and 7 show an upper mold section 42, having a first cavity 46 and a lower mold section 40 having a second cavity. A carrier board 30 is placed in the second cavity of the lower mold section 40 with the second surface 33 of the carrier board 30 contacting the lower mold section 40. A circuit die 12 is bonded to the first surface of a carrier board 30, having a first surface 31 and a second surface 33. The circuit die 12 is bonded using, for example, an epoxy bond 14 or the like. Wire bonds 16 form electrical connections between the circuit die 12 and pads 18 on the first surface 31 of the carrier board 30. Interconnection balls will be formed on the second surface 33 of the carrier board after the encapsulation has been completed. In this invention the carrier board 30 is not relied upon to spread the heat energy generated by the

circuit die 12 and can be a very simple board of, for example, one or two layers.

The first ends of each of a number of standoff members 36, each standoff member 36 having a first end and a second end, are attached to the second surface 37 of a heat sink 34, having a first surface 35 and a second surface 37. The heat sink is then placed directly over the circuit die 12 with the second ends of each of the standoff members 36 contacting the first surface 31 of the carrier board 30. The standoff members 36 fix the position of the heat sink 34 above the circuit die 12 and provide separation between the circuit die 12 and the heat sink 34. The heat sink 34 has a high thermal conductivity and is usually formed of a metal, such as copper or aluminum, or other thermally conductive material. The heat sink 34 provides the function of spreading the heat generated in the circuit die 12. The standoff members can be a metal, such as copper or aluminum, or other thermally conductive material.

As shown in Figs. 6 and 7 the upper mold section 42 is placed over the lower mold section 40 such that circuit die 12, wire bonds 16, pads 18, heat sink 34, and standoff members 36 fit into the first cavity 46 of the upper mold section 42. Uncured encapsulation material, such as epoxy molding compound, is then injected into the first

cavity 46 of the upper section 42 of the mold through the mold runner 44 until the first cavity 46 is filled with encapsulation material.

Fig. 6 shows the case where there is a space between the first surface 35 of the heat sink 34 and the top of the first cavity 46 of the upper mold section 42. This will form a circuit package with cured encapsulation material covering the first surface 35 of the heat sink 34. Fig. 7 shows the case where there is no space between the first surface 35 of the heat sink 34 and the top of the first cavity 46 of the upper mold section 42. This will form a circuit package with no cured encapsulation material covering the first surface 35 of the heat sink 34 and the first surface 35 of the heat sink will be exposed to the environment. The encapsulation material is then cured and the circuit package is removed from the mold. Cured encapsulation material 32 holds the heat sink 34 and standoff members 36 in place.

Figs. 8 and 9 show the embodiment of the method of forming the molded circuit package using a heat sink without standoff members. Figs. 8 and 9 show an upper mold section 42, having a first cavity 46 and a lower mold section 40 having a second cavity. A carrier board 30 is placed in the second cavity of the lower mold section 40 with the second

surface 33 of the carrier board 30 contacting the lower mold section 40. A circuit die 12 is bonded to the first surface of a carrier board 30, having a first surface 31 and a second surface 33. The circuit die 12 is bonded using, for example, an epoxy bond 14 or the like. Wire bonds 16 form electrical connections between the circuit die and pads 18 on the first surface 31 of the carrier board 30. Interconnection balls will be formed on the second surface 33 of the carrier board after the encapsulation has been completed. In this invention the carrier board 30 is not relied upon to spread the heat energy generated by the circuit die 12 and can be a very simple board of, for example, one or two layers.

A heat sink 34 is placed in the first cavity 46 of the upper mold section 42. The heat sink 34 must be temporarily held in place and in this example a vacuum chuck 48 is used for that purpose. The tip of the vacuum chuck 48 is placed against the first surface 35 of the heat sink 34 and the interior of the vacuum chuck 48 is evacuated thereby holding the heat sink 34 in place. When the vacuum in the vacuum chuck is released the vacuum chuck releases the heat sink and can be removed. Alternatively the mold could be turned upside down and gravity used to hold the heat sink in place.

As shown in Figs. 8 and 9 the first mold section 42 is then placed directly over the lower mold section 40 and positioned such that the heat sink is positioned directly over the circuit die 12 and the circuit die 12, wire bonds 16, bond pads 18, and heat sink 34 fit into the first cavity 46 of the upper mold section 42. The heat sink 34 has a high thermal conductivity and is usually formed of a metal, such as copper or aluminum, or other thermally conductive material. The heat sink 34 provides the function of spreading the heat generated in the circuit die 12. Uncured encapsulation material, such as epoxy molding compound, is then injected into the first cavity 46 of the upper section 42 of the mold through the mold runner 44 until the first cavity 46 is filled with encapsulation material.

Fig. 8 shows the case where there is a space between the first surface 35 of the heat sink 34 and the top of the first cavity 46 of the upper mold section 42. This will form a circuit package with cured encapsulation material covering the first surface 35 of the heat sink 34. Fig. 9 shows the case where there is no space between the first surface 35 of the heat sink 34 and the top of the first cavity 46 of the upper mold section 42. This will form a circuit package with no cured encapsulation material covering the first surface 35 of the heat sink 34 and the

first surface 35 of the heat sink will be exposed to the environment. The encapsulation material is then cured, the vacuum chuck removed, and the circuit package is removed from the mold. The cured encapsulation material 32 holds the heat sink in place.

Injection molding is described in U.S. Pat. No. 5,635,671 to Freyman et al. and is incorporated herein by reference. U.S. Pat. No. 5,241,133 to Mullen, III et al. describes the formation of solder pads as part of a ball grid array an is incorporated herein by reference.

While the invention has been particularly shown and described with reference to the preferred embodiments thereof, it will be understood by those skilled in the art that various changes in form and details may be made without departing from the spirit and scope of the invention.



CLAIMS

1. A method of forming a circuit package, comprising:

providing a carrier board having a first surface, a second surface, and a circuit die attached to said first surface of said carrier board;

providing a heat sink having a first surface, a second surface, and edges;

providing a number of standoff members wherein each said standoff member has a first end and a second end and said first end of each said standoff member is attached to said second surface of said heat sink;

placing said heat sink directly over said circuit die so that said second end of each said standoff member contacts said first surface of said carrier board, wherein said standoff members do not physically contact said circuit die and said standoff members prevent physical contact between said heat sink and said circuit die; and

placing encapsulation material over said circuit die, over said standoff members, between said circuit die and said second surface of said heat sink, and over said edges of said heat sink.

2. The method of claim 1 wherein said encapsulation material is also placed over said first surface of said heat sink.

3. The method of claim 1 wherein said first surface of said heat sink is free of said encapsulation material.

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4. The method of claim 1 wherein said placing said encapsulation material over said circuit die, over said standoff members, between said circuit die and said second surface of said heat sink, and over said edges of said heat sink further comprises:

providing an upper mold section having a first cavity;

providing a lower mold section having a second cavity;

placing said carrier board into said second cavity of said lower mold section after placing said heat sink directly over said circuit die so that said second surface of said carrier board contacts said lower mold section;

placing said upper mold section over said lower mold section so that said first cavity is directly over said circuit die and said heat sink;

injecting uncured encapsulation material into said first cavity of said upper mold section;

curing said encapsulation material; and

removing said upper mold section and said lower mold section from said carrier board, said circuit die, said heat sink, and said cured encapsulation material.

5. The method of claim 1 wherein said encapsulation material is epoxy molding compound.

6. The method of claim 1 wherein said heat sink is copper.

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7. The method of claim 1 wherein said heat sink is aluminum.

8. The method of claim 1 wherein said standoff members are copper.

9. The method of claim 1 wherein said standoff members are aluminum.

10. A method of forming a circuit package, comprising:

providing a carrier board having a first surface, a second surface, and a circuit die attached to said first surface of said carrier board;

providing a heat sink having a first surface, a second surface, and edges;

providing an upper mold section having a first cavity;

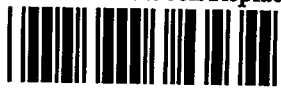
providing a lower mold section having a second cavity;

placing said carrier board into said second cavity of said lower mold section so that said second surface of said carrier board contacts said lower mold section;

providing means to temporarily hold said heat sink in said first cavity of said upper mold section;

placing said heat sink in said first cavity of said upper mold section using said means to temporarily hold said heat sink in said first cavity of said upper mold section;

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placing said upper mold section over said lower mold section so that said first cavity is directly over said circuit die, said heat sink is directly over said heat die, and said means to temporarily hold said heat sink in said first cavity of said upper mold section prevents said heat sink from physically contacting said circuit die;

injecting uncured encapsulation material into said first cavity of said upper mold section;

curing said encapsulation material; and

removing said upper mold section and said lower mold section from said carrier board, said circuit die, said heat sink, and said cured encapsulation material whereby said cured encapsulation material holds said heat sink directly over said circuit die.

11. The method of claim 10 wherein said cured encapsulation material covers said first surface of said heat sink.

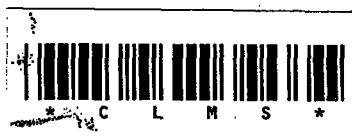
12. The method of claim 10 wherein said first surface of said heat sink is free of said cured encapsulation material.

13. The method of claim 10 wherein said encapsulation material is epoxy molding compound.

14. The method of claim 10 wherein said heat sink is copper.

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15. The method of claim 10 wherein said heat sink is aluminum.



16. The method of claim 10 wherein said means to temporarily hold said heat sink in said first cavity of said upper mold section comprises a vacuum chuck.

17. A circuit package, comprising:

a carrier board having a first surface, a second surface, and a circuit die attached to said first surface of said carrier board;

a number of standoff members wherein each said standoff member has a first end and a second end;

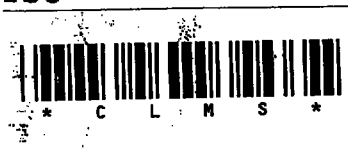
a heat sink having a first surface, a second surface, and edges placed directly over said circuit die, wherein said first end of each said standoff member is attached to said second surface of said heat sink and said second end of said standoff member contacts said carrier board thereby preventing physical contact between said heat sink and said circuit die; and

cured encapsulation material formed over said circuit die, over said standoff members, between said circuit die and said second surface of said heat sink, and over said edges of said heat sink.

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18. The circuit package of claim 17 wherein said cured encapsulation material is also formed over said first surface of said heat sink.



19. The circuit package of claim 17 wherein said first surface of said heat sink is free of said cured encapsulation material.

20. The circuit package of claim 17 wherein said encapsulation material is epoxy molding compound.

21. The circuit package of claim 17 wherein said heat sink is copper.

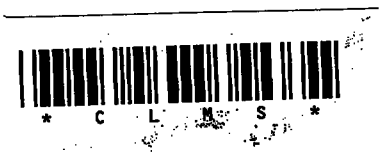
22. The circuit package of claim 17 wherein said heat sink is aluminum.

23. The circuit package of claim 17 wherein said standoff members are copper.

24. The circuit package of claim 17 wherein said standoff members are aluminum.

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25. A circuit package, comprising:

a carrier board having a first surface, a second surface, and a circuit die attached to said first surface of said carrier board;

a heat sink having a first surface, a second surface, and edges placed directly over said circuit die; and

cured encapsulation material formed over said circuit die, over said standoff members, between said circuit die and said second surface of said heat sink, and over said edges of said heat sink wherein said cured encapsulation material prevents physical contact between said heat sink and said circuit die.

26. The circuit package of claim 25 wherein said cured encapsulation material is also formed over said first surface of said heat sink.

27. The circuit package of claim 25 wherein said first surface of said heat sink is free of said cured encapsulation material.

28. The circuit package of claim 25 wherein said encapsulation material is epoxy molding compound.

29. The circuit package of claim 25 wherein said heat sink is copper.

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30. The circuit package of claim 25 wherein said heat sink is aluminum.

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