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(54) **ENHANCED DIE-UP BALL GRID ARRAY AND METHOD FOR MAKING THE SAME**

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(62) Division of application No. 10/942,031, filed on Sep. 16, 2004, which is a division of application No. 09/742,366, filed on Dec. 22, 2000, now abandoned.

Publication Classification

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H01L 21/60 (2006.01)

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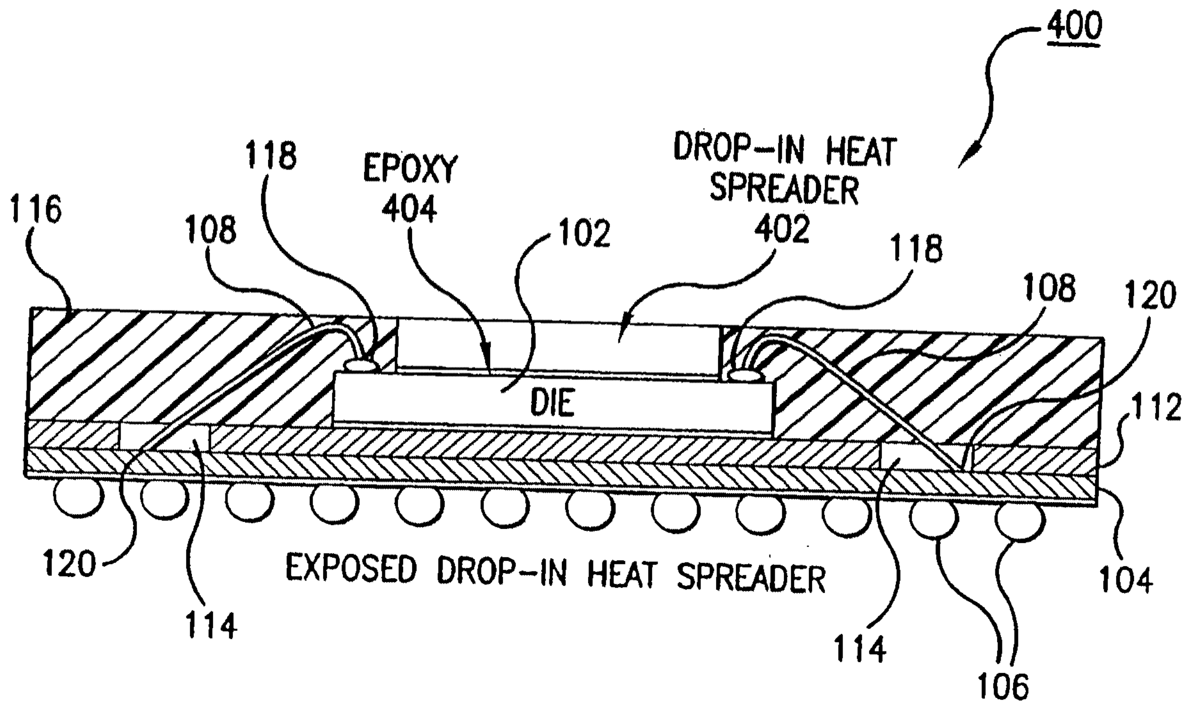
(57) **ABSTRACT**

Methods of assembling a ball grid array (BGA) package is provided. One method includes providing a tape substrate that has a first surface and a second surface, attaching a first surface of a stiffener to the first substrate surface, mounting an IC die to the second stiffener surface, mounting a heat spreader to the IC die, and attaching a plurality of solder balls to the second substrate surface.



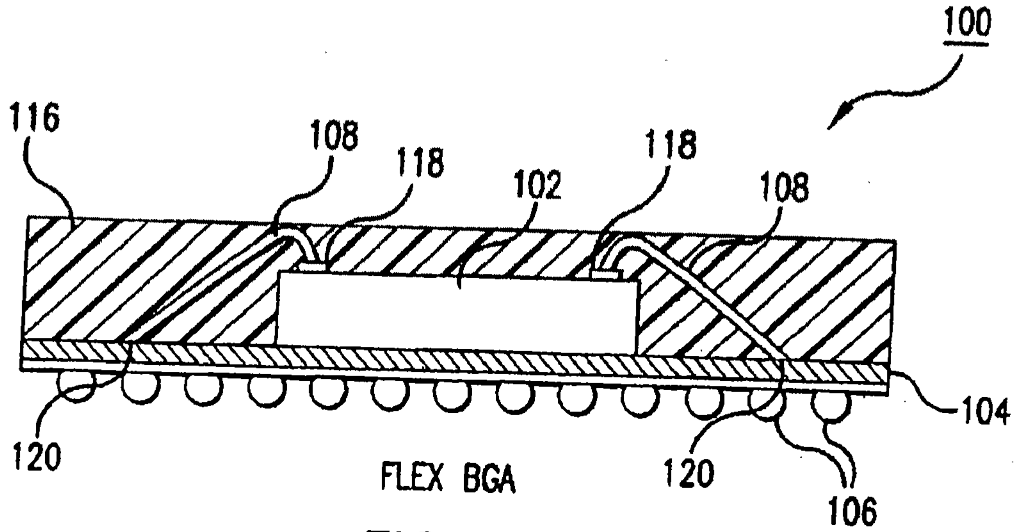


FIG.1A
(PRIOR ART)

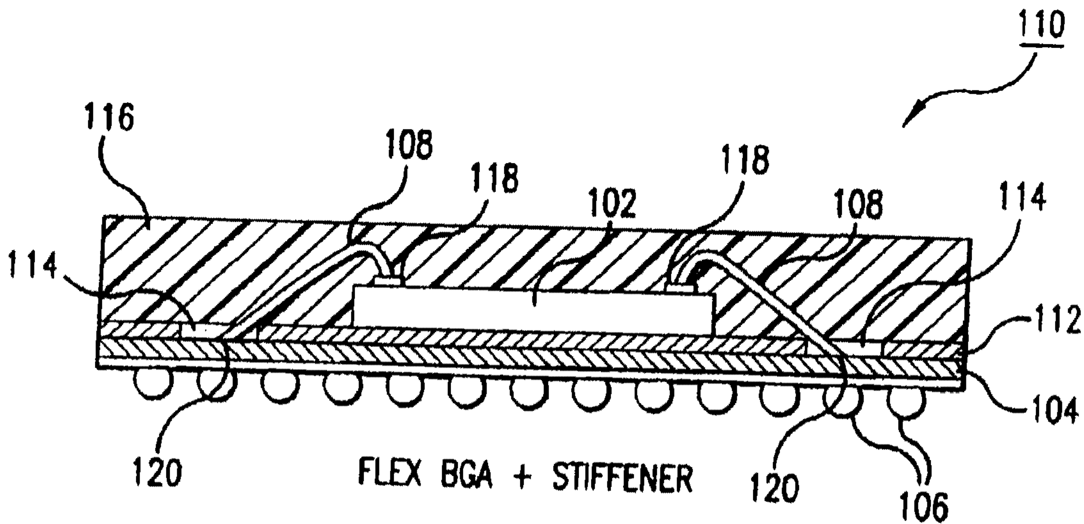


FIG.1B
(PRIOR ART)

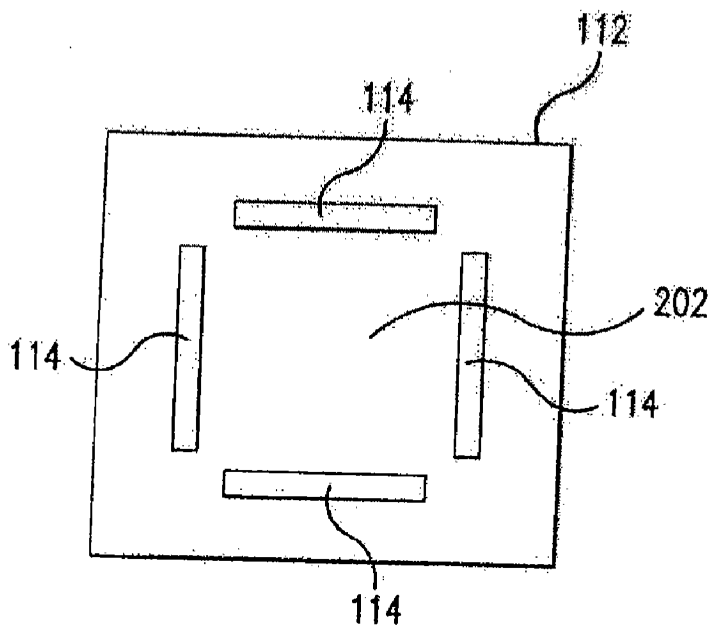


FIG. 2A
(Prior Art)

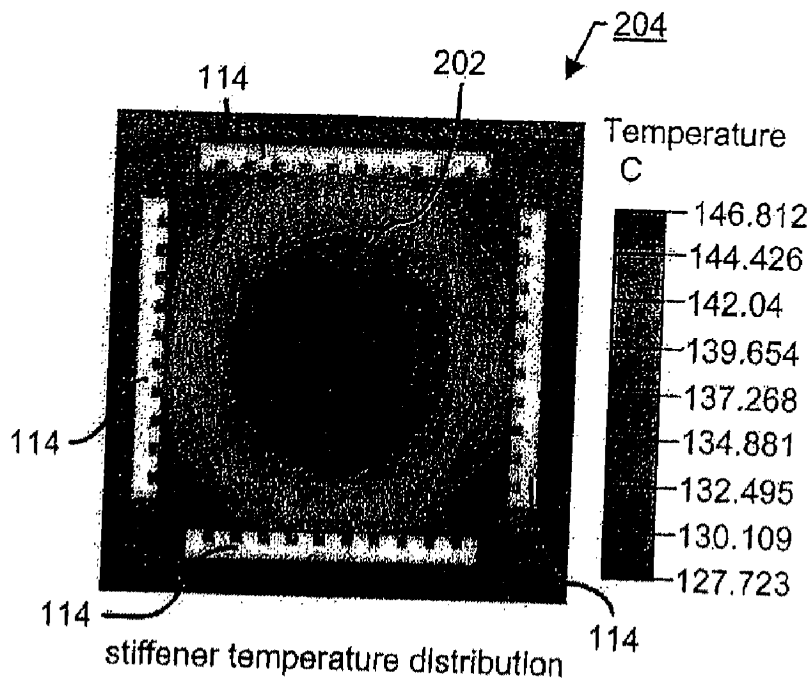


FIG. 2B
(Prior Art)

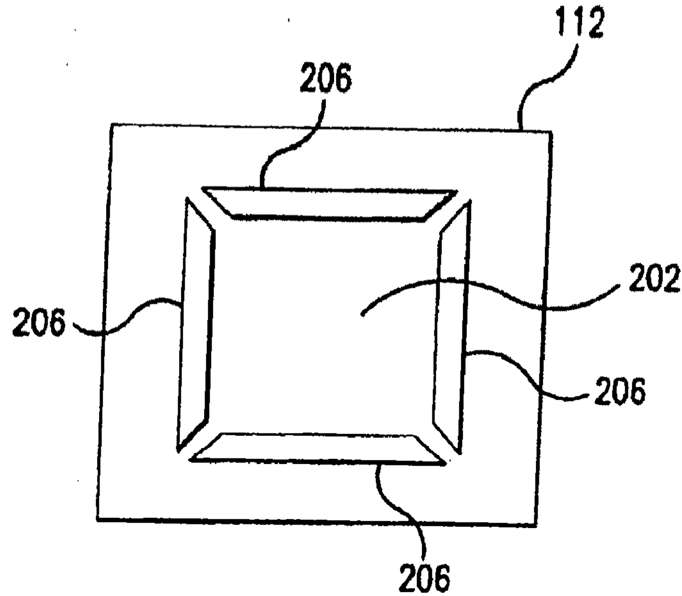


FIG.2C

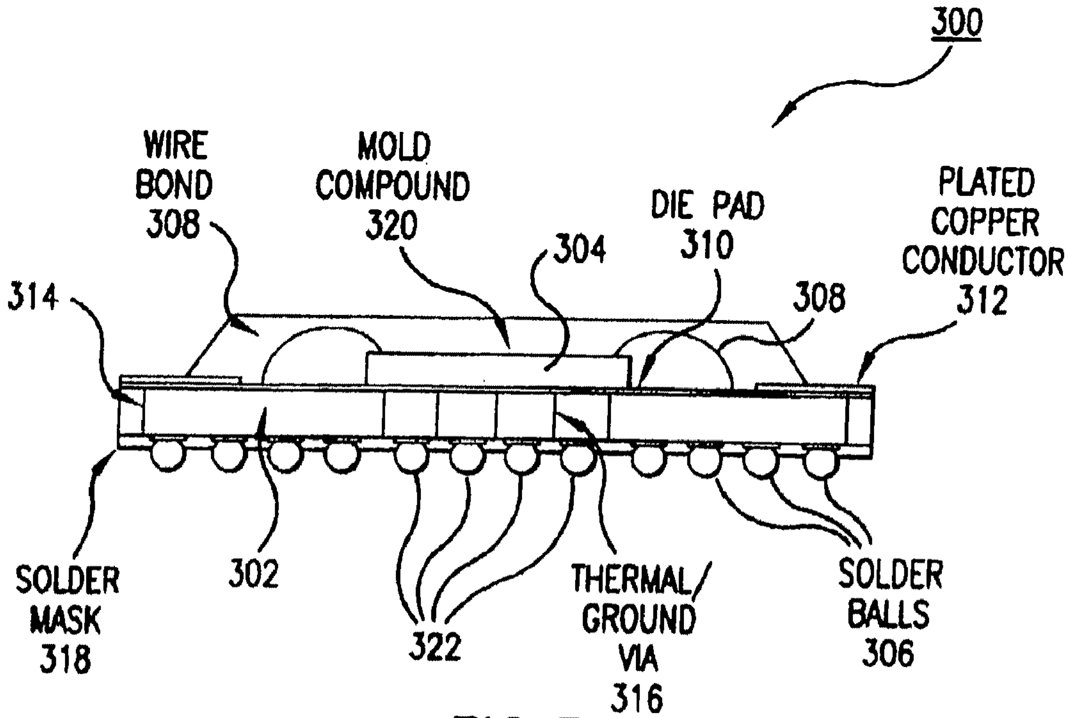


FIG.3
(PRIOR ART)

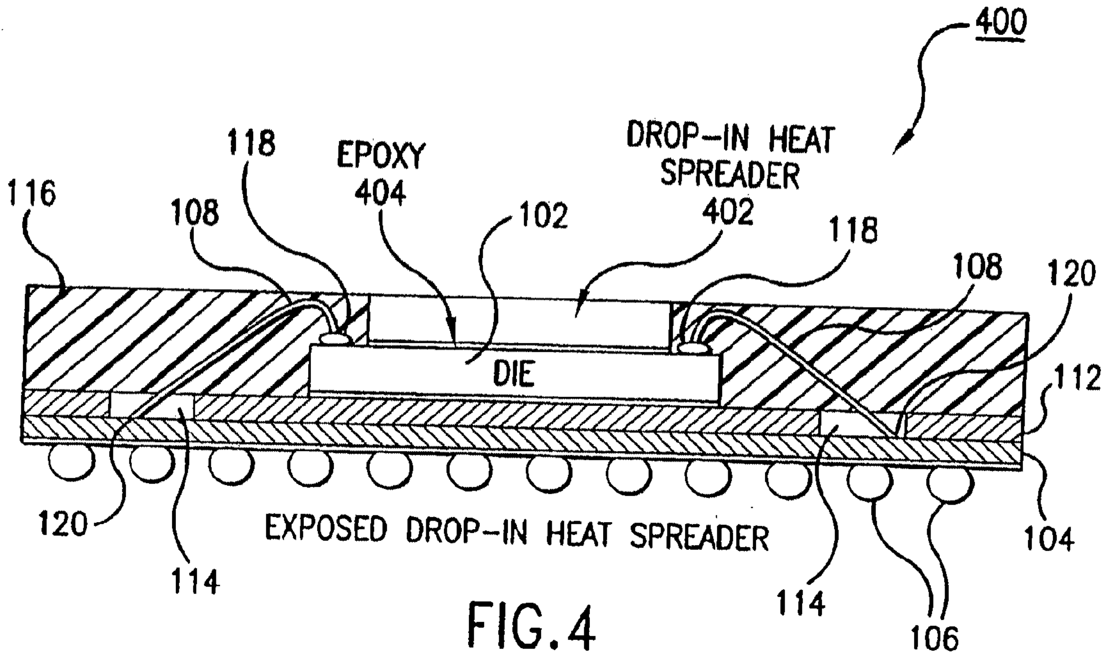


FIG.4

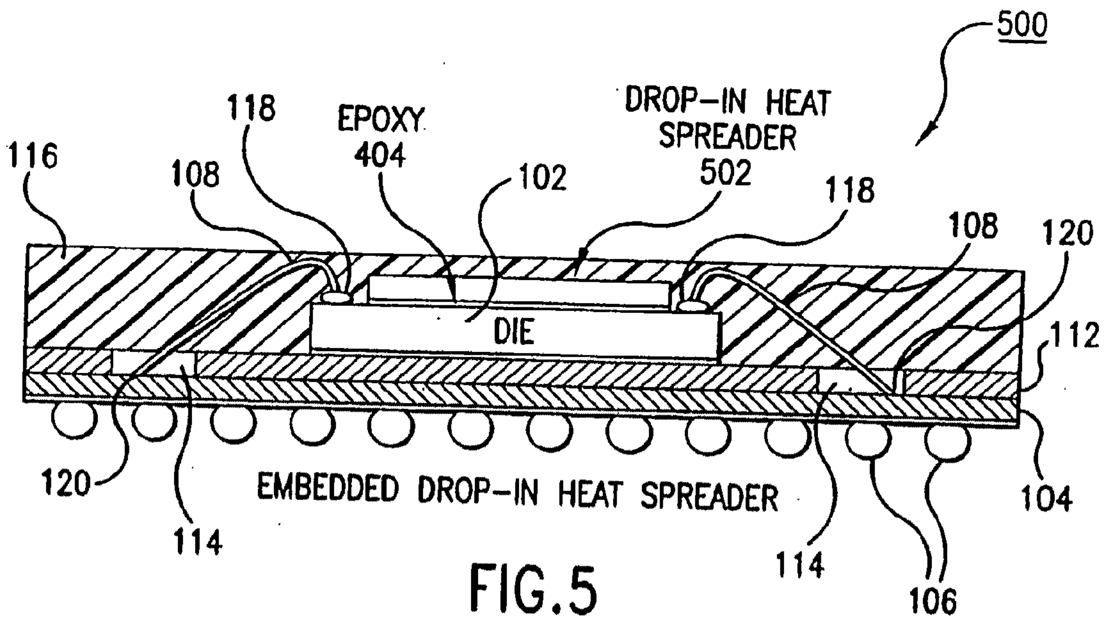


FIG.5

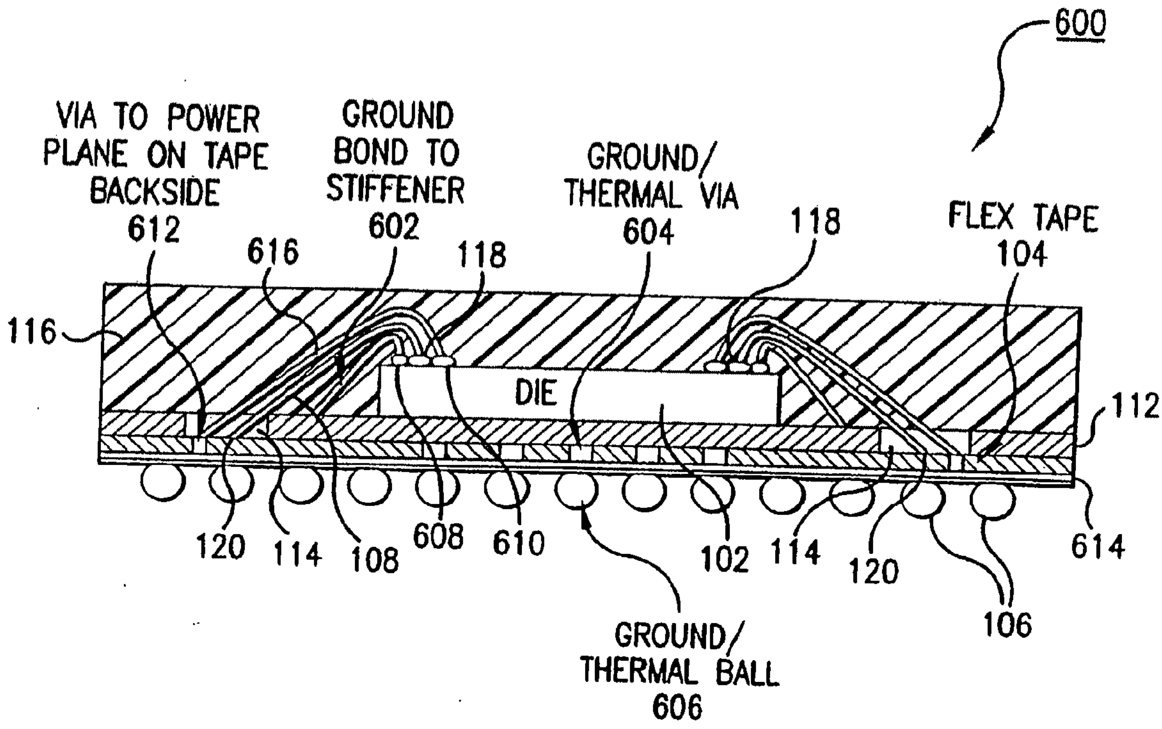


FIG.6

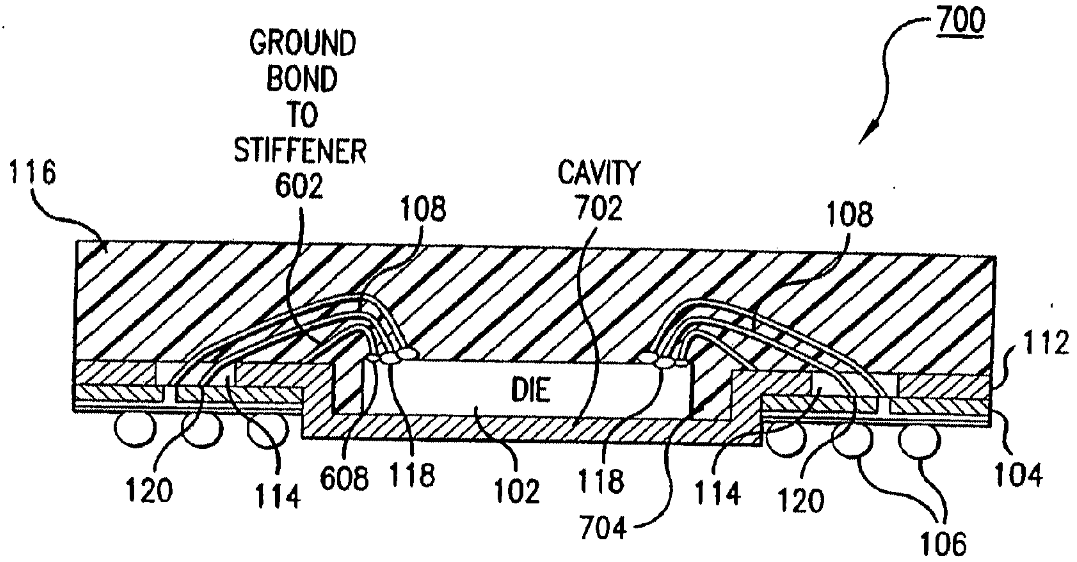


FIG.7

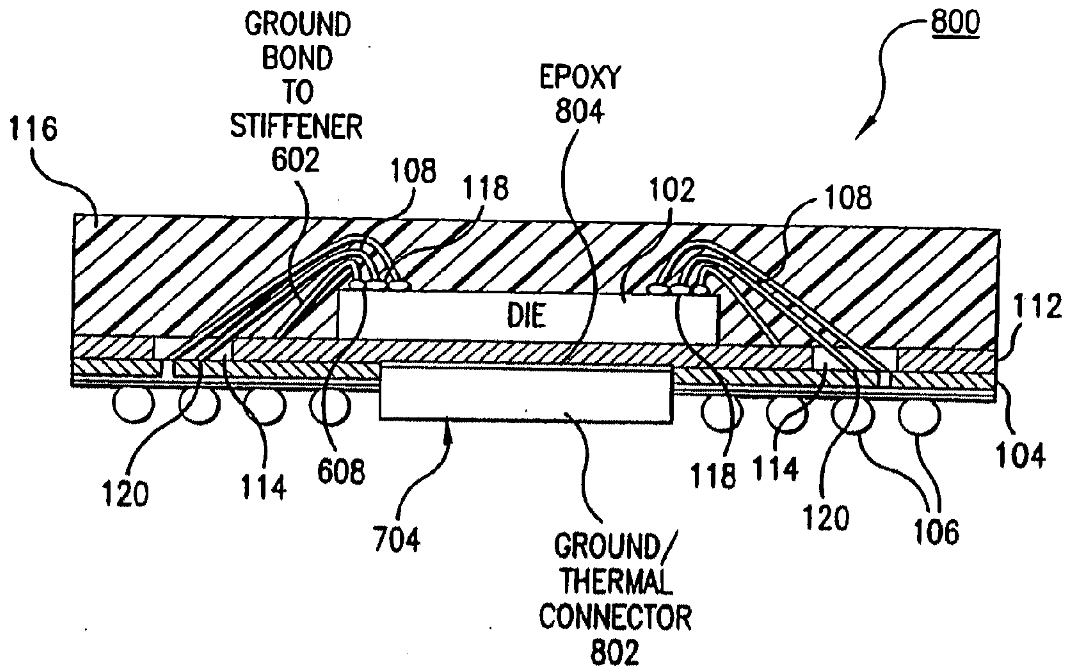


FIG.8

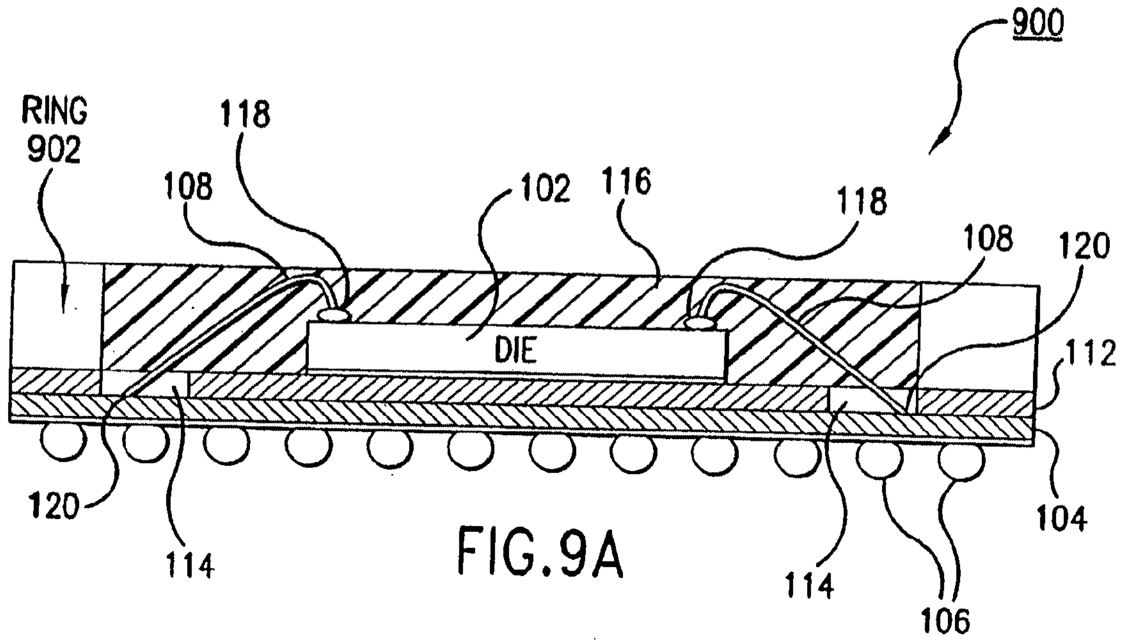


FIG.9A

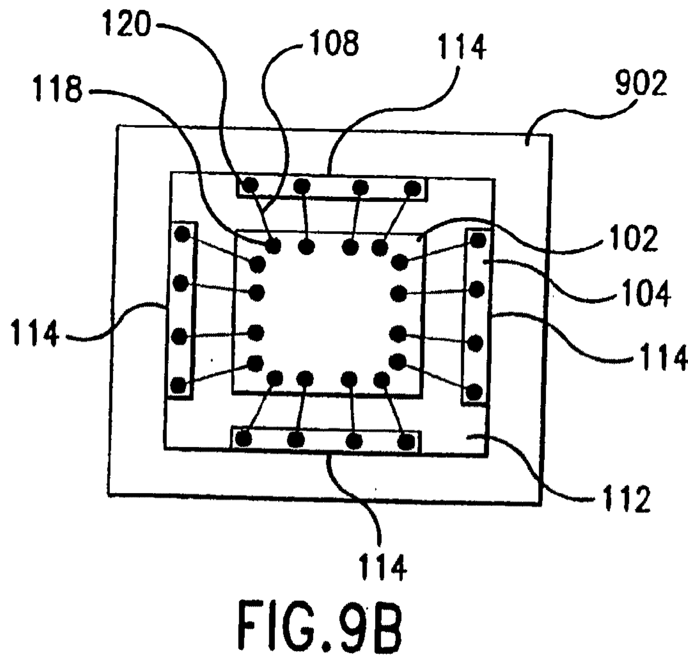


FIG.9B

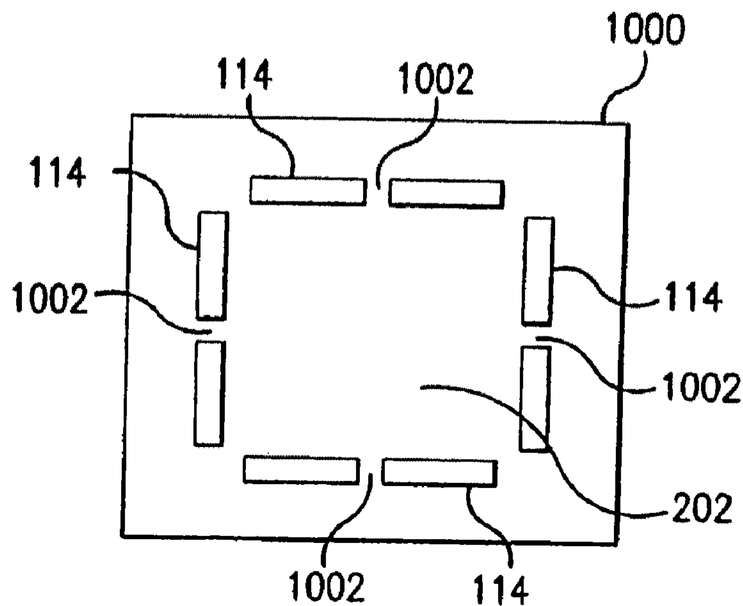


FIG.10A

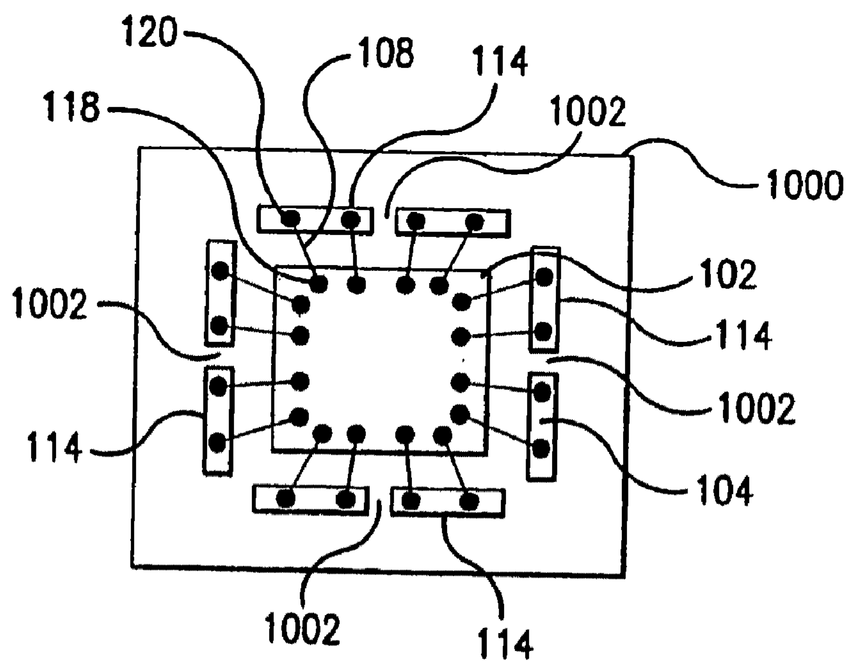


FIG.10B

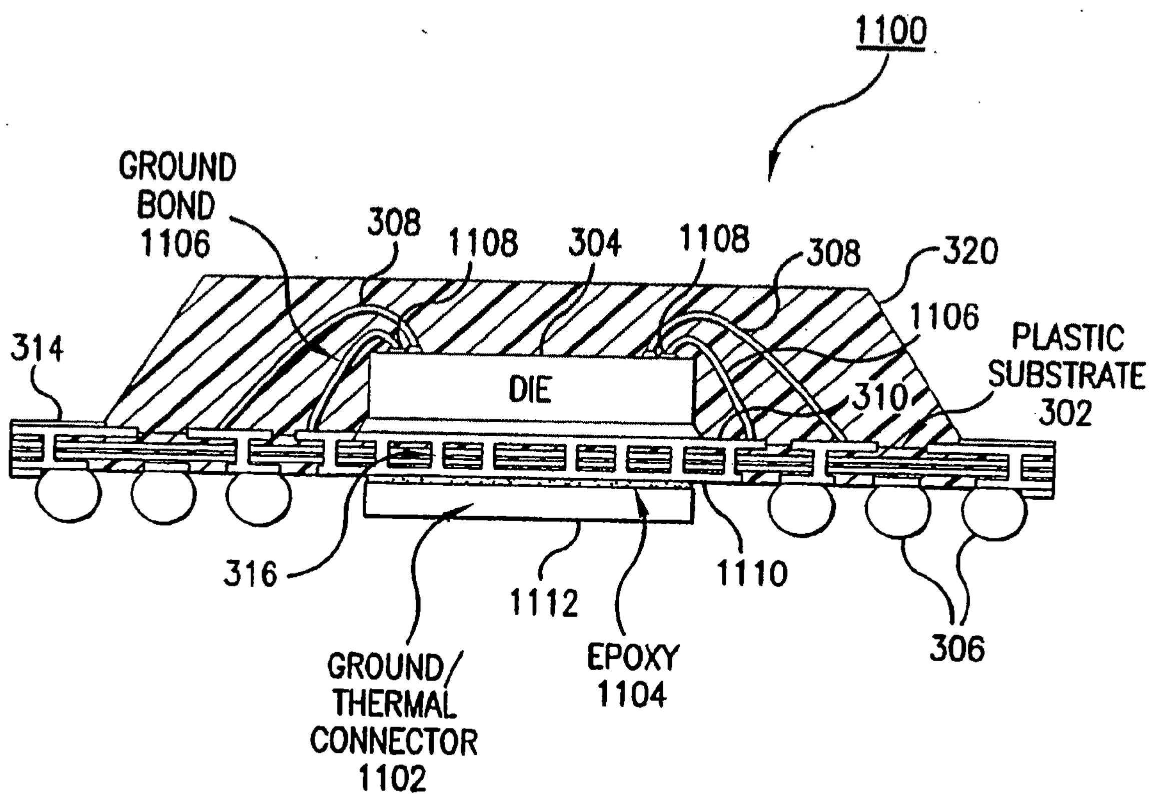


FIG.11

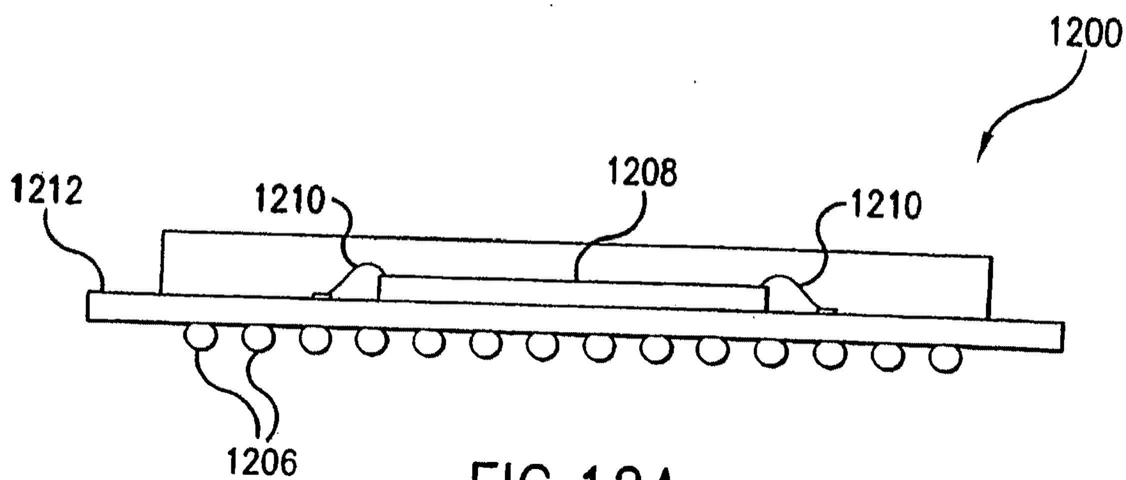


FIG.12A

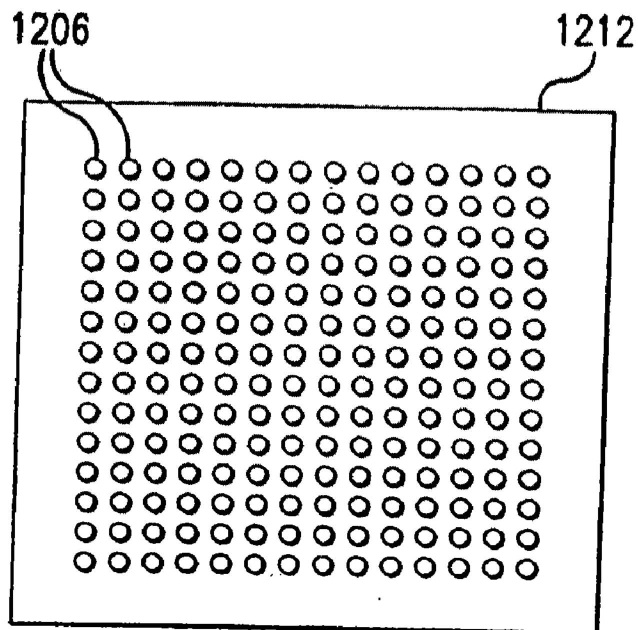


FIG.12B

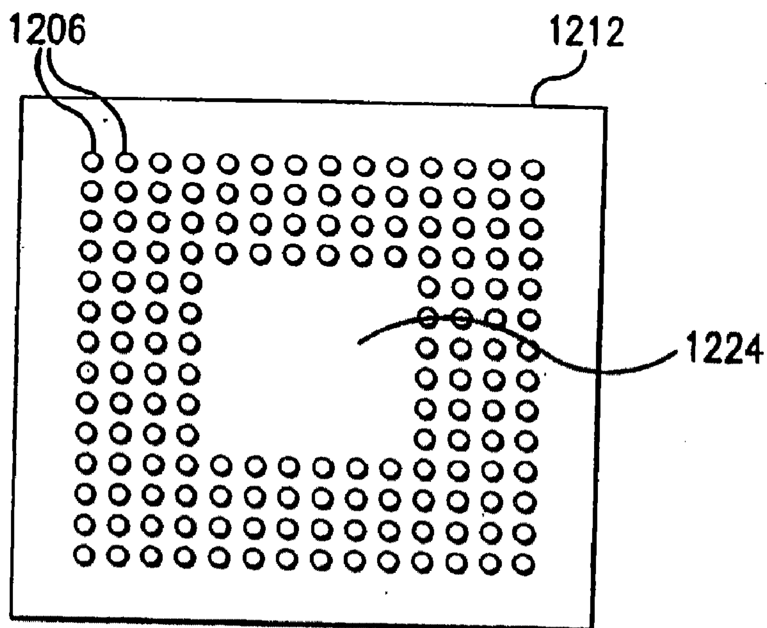


FIG.12C

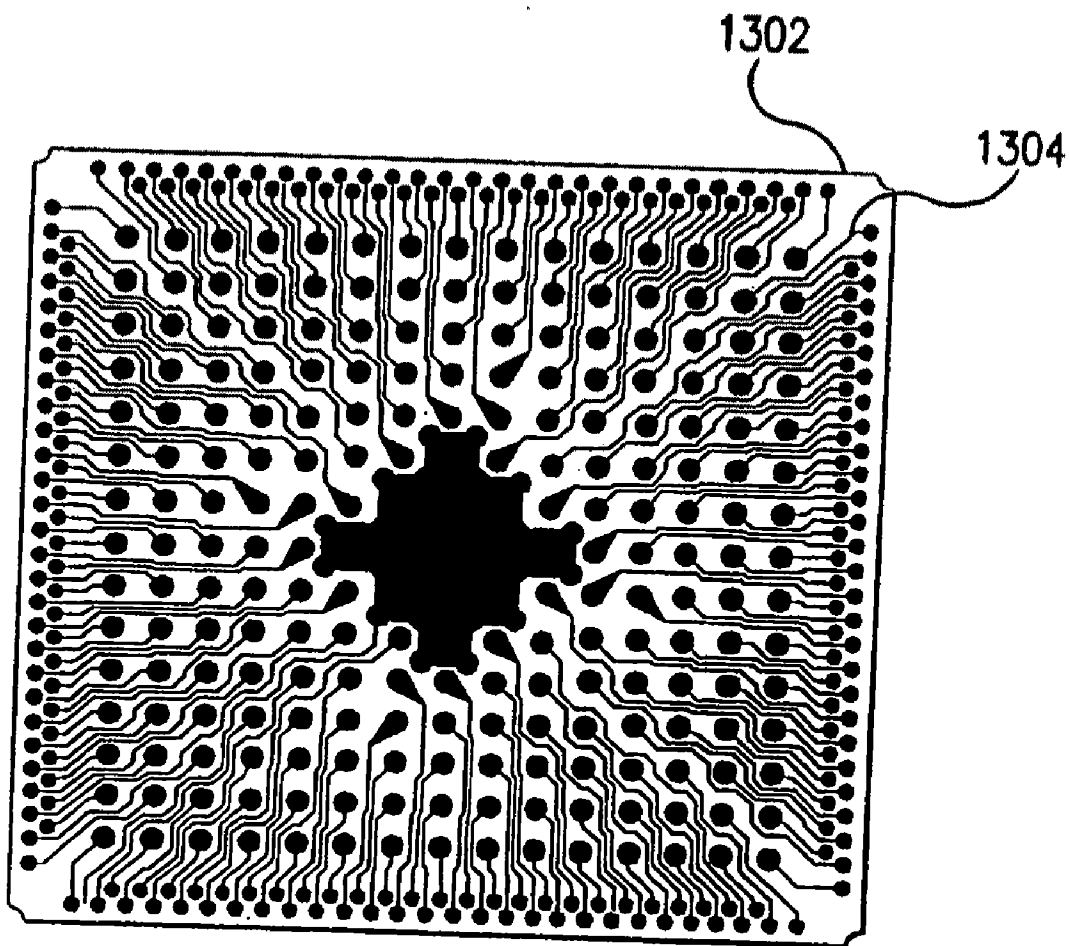


FIG.13

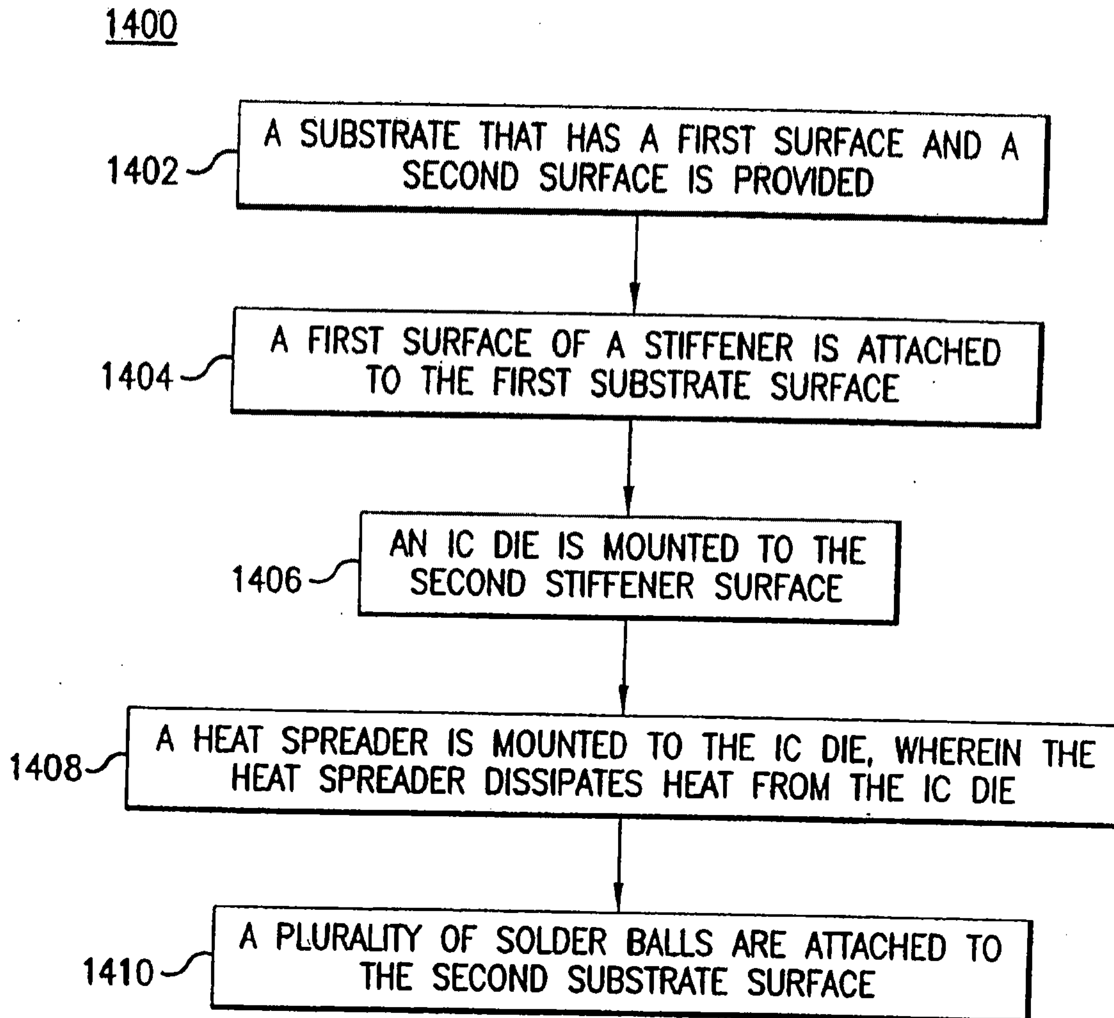


FIG.14

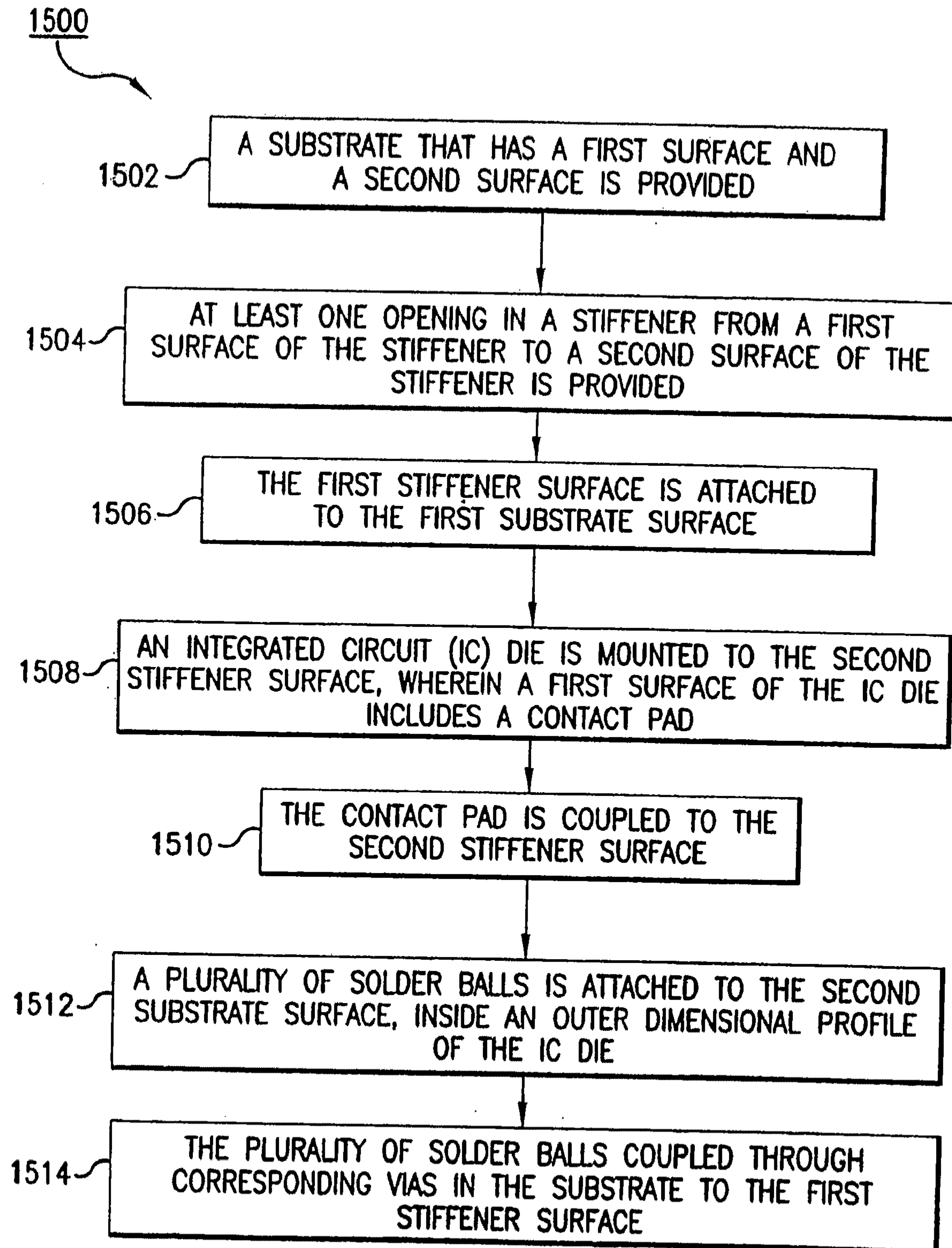


FIG.15

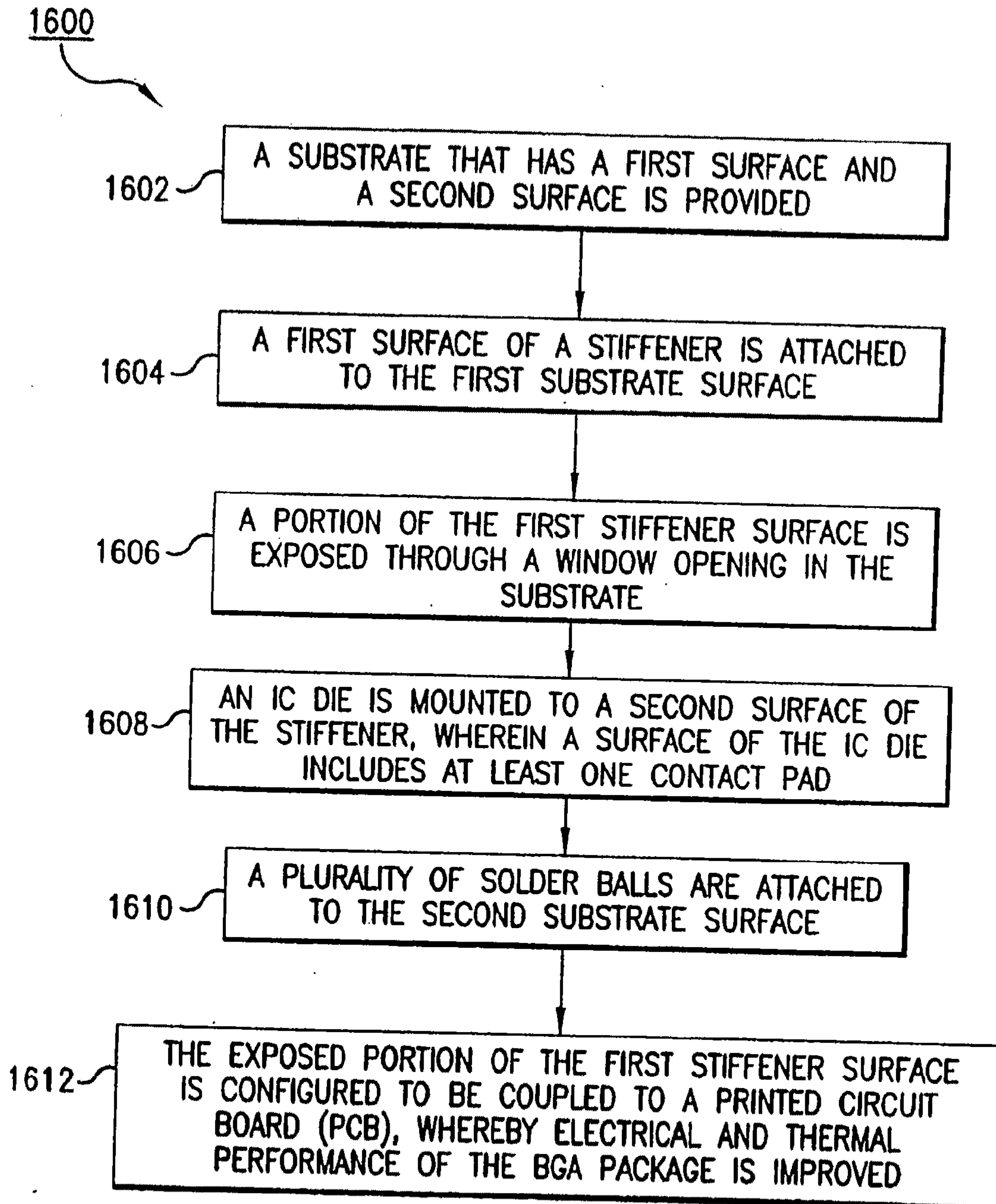


FIG.16A

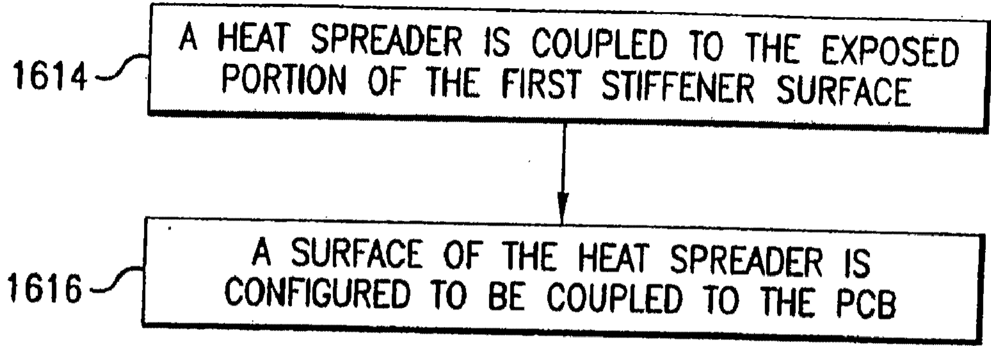


FIG.16B

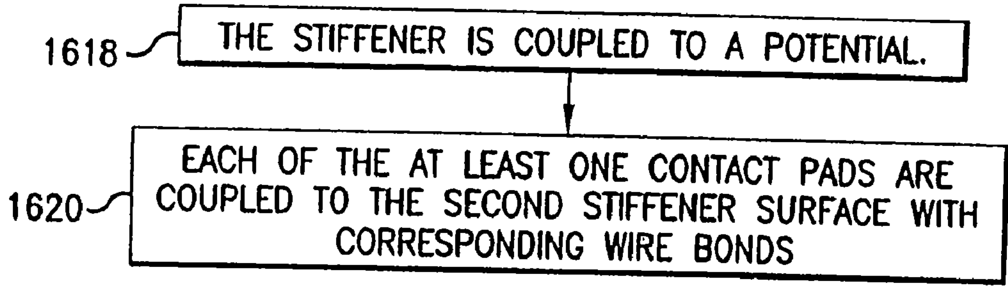


FIG.16C

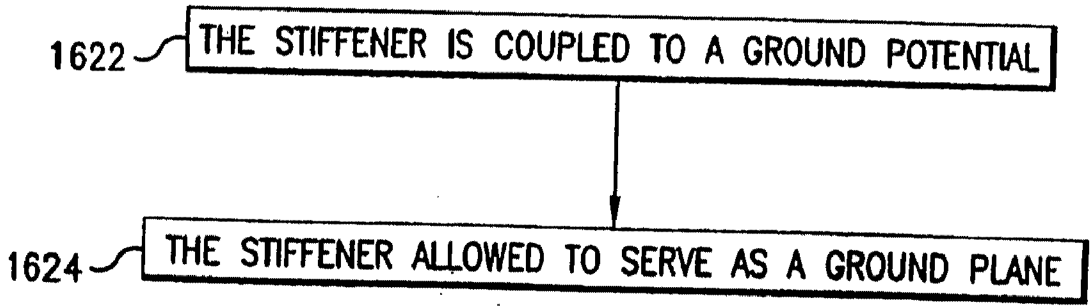


FIG.16D

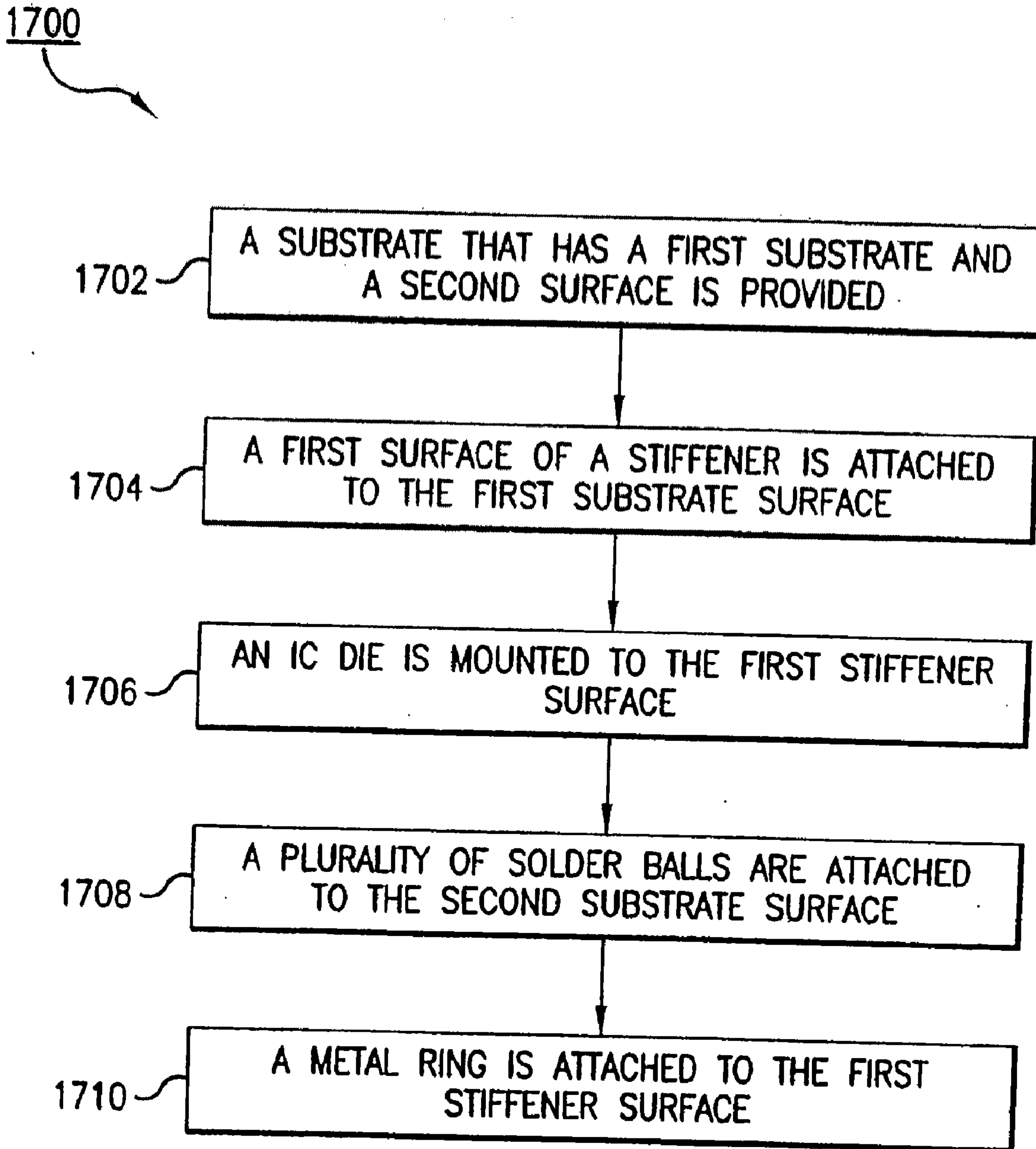


FIG.17

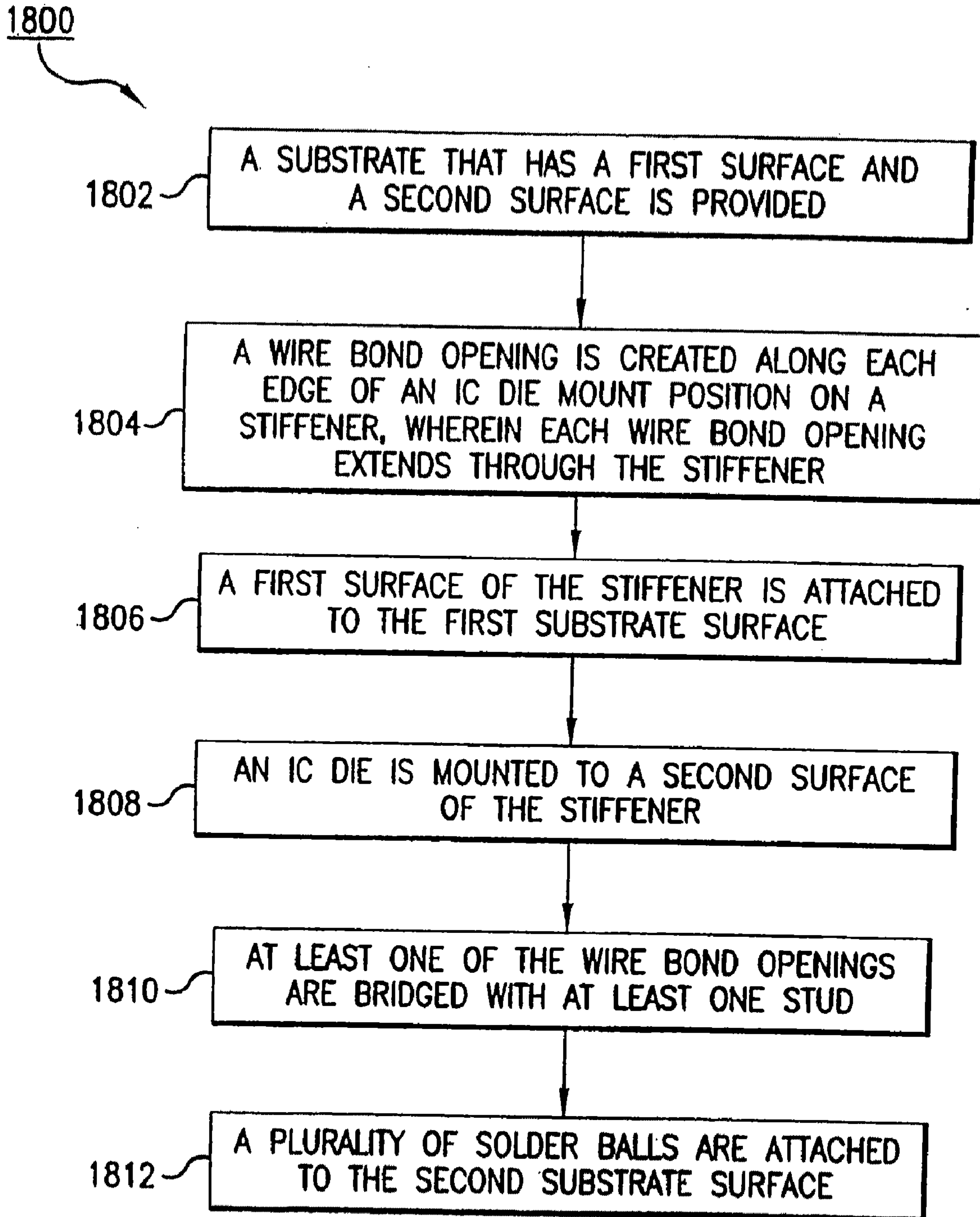


FIG. 18

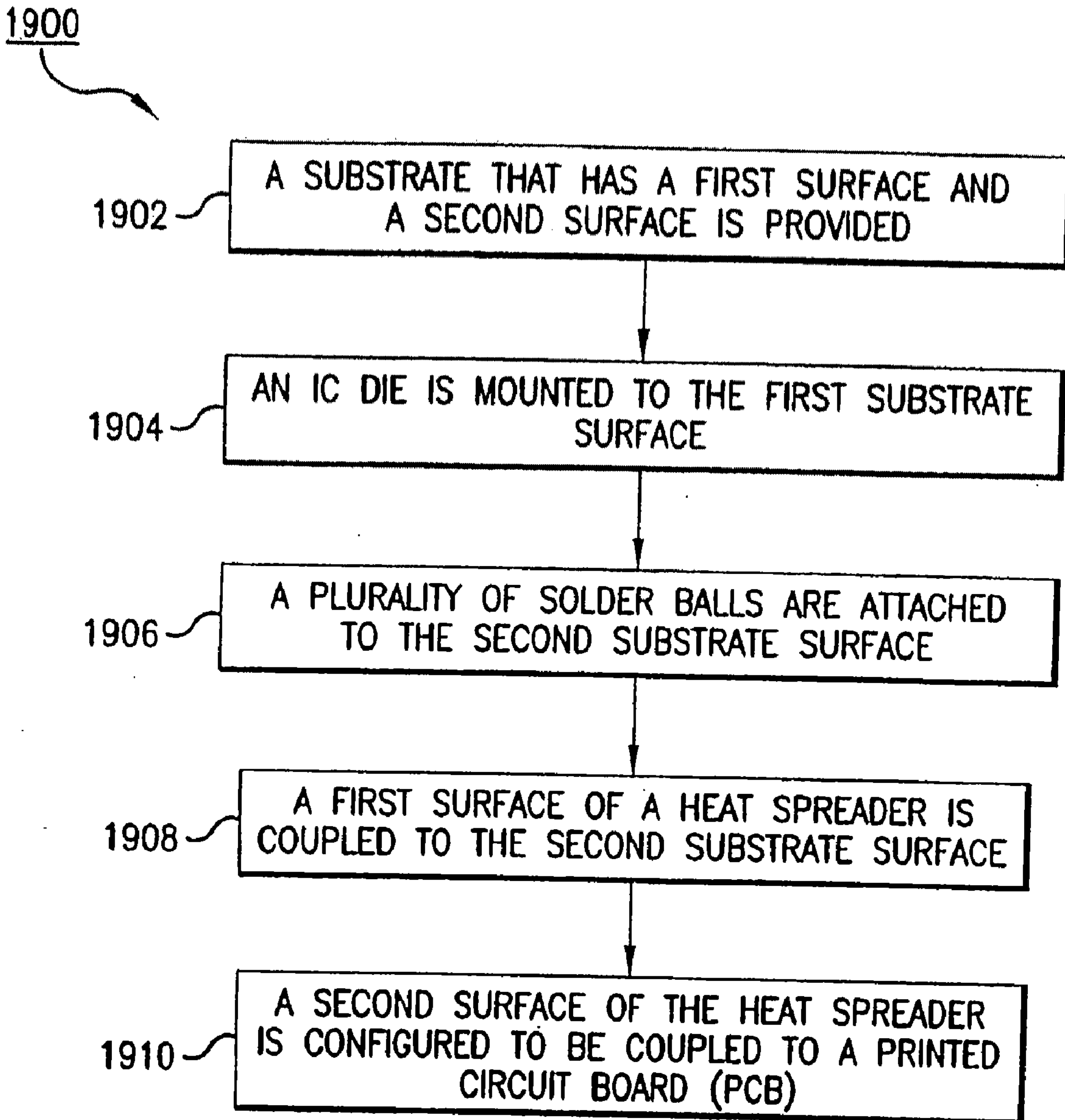


FIG.19A

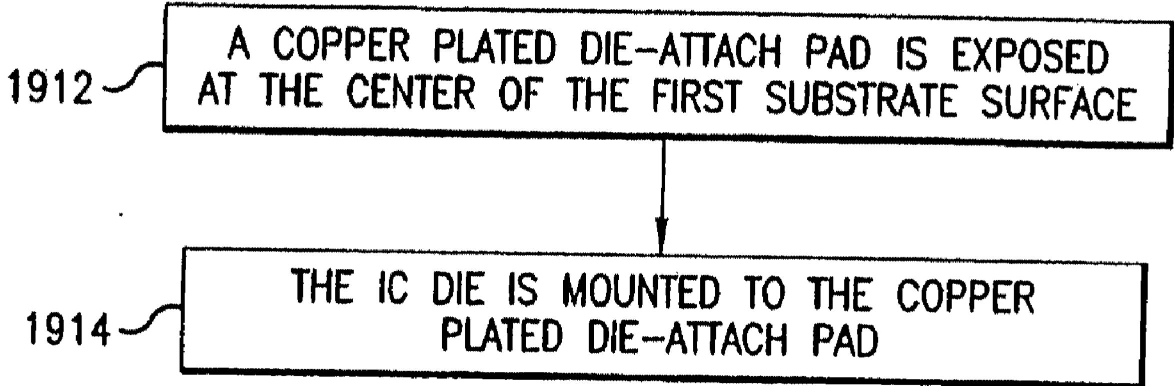


FIG.19B

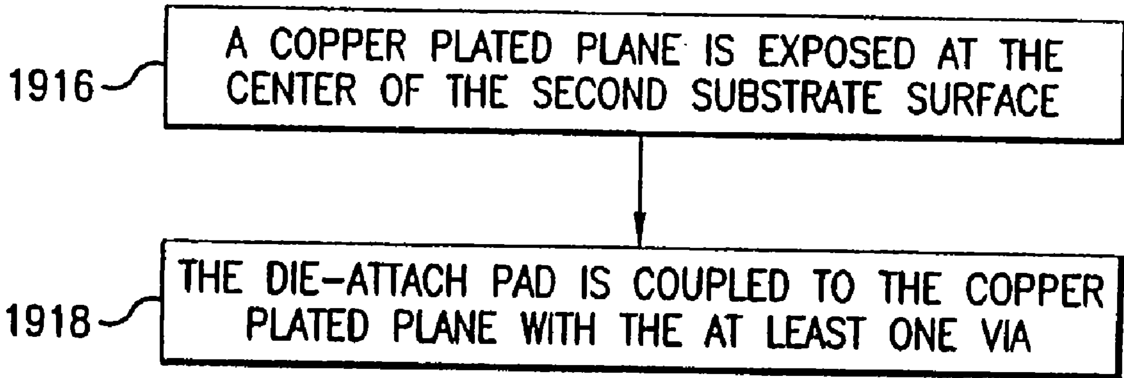


FIG.19C

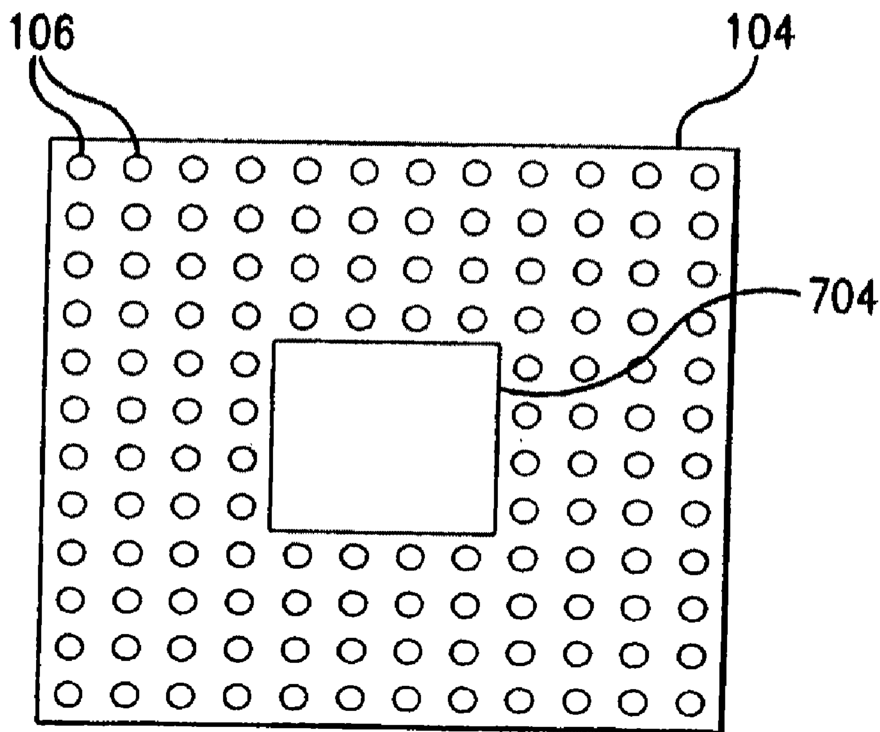


FIG.20

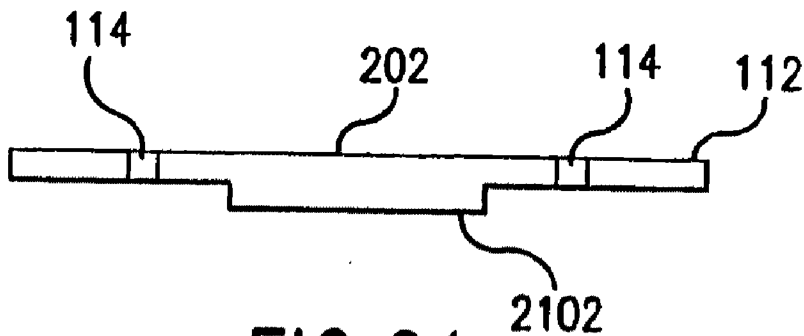


FIG.21

ENHANCED DIE-UP BALL GRID ARRAY AND METHOD FOR MAKING THE SAME

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] This application is a divisional of U.S. application Ser. No. 10/942,031, filed Sep. 16, 2004, which is a divisional of U.S. application Ser. No. 09/742,366, filed Dec. 22, 2000, now abandoned. All of the above-mentioned applications are incorporated herein by reference in their entireties.

BACKGROUND OF THE INVENTION

[0002] 1. Field of the Invention

[0003] The invention relates generally to the field of integrated circuit (IC) device packaging technology, and more particularly to substrate stiffening and heat spreading techniques in ball grid array (BGA) packages.

[0004] 2. Related Art

[0005] Integrated circuit (IC) dies are typically mounted in or on a package that is attached to a printed circuit board (PCB). One such type of IC die package is a ball grid array (BGA) package. BGA packages provide for smaller footprints than many other package solutions available today. A BGA package has an array of solder balls located on a bottom external surface of a package substrate. The solder balls are reflowed to attach the package to the PCB. The IC die is mounted to a top surface of the package substrate. Wire bonds typically couple signals in the IC die to the substrate. The substrate has internal routing which electrically couples the IC die signals to the solder balls on the bottom substrate surface.

[0006] A number of BGA package substrate types exist, including ceramic, plastic, and tape (also known as "flex"). In some BGA package types, a stiffener may be attached to the substrate to supply planarity and rigidity to the package. In such packages, the IC die may be mounted to the stiffener instead of the substrate. Openings in the stiffener may be used to allow the IC die to be wire-bonded to the substrate.

[0007] Die-up and die-down BGA package configurations exist. In die-up BGA packages, the IC die is mounted on a top surface of the substrate or stiffener, opposite of the side to which the solder balls are attached. In die-down BGA packages, the IC die is mounted on a bottom surface of the substrate or stiffener, on the same side as which the solder balls are attached.

[0008] Conventional BGA packages are subject to high thermal stresses that result from the heat given off during operation of the mounted IC die. The thermal stresses are primarily imposed on the IC die and solder balls due to the mismatch of the thermal expansion coefficient (CTE) between the semiconductor die and the metal stiffener. As a result, conventional flex BGA packages have difficulty in meeting reliability requirements for die sizes larger than 9 mm. See, e.g., Thompson, T., et al., *Reliability Assessment of a Thin* (*Flex*) *BGA Using a Polyimide Tape Substrate*, International Electronics Manufacturing Technology Symposium, IEEE, pp. 207-213 (1999).

[0009] The tape substrate used in flex BGA packages is typically polyimide, which has very low values of thermal conductivity. Consequently, the IC die is separated from the PCB internally by the tape substrate thermal barrier. The lack of direct thermal connection from IC die to PCB leads to relatively high resistance to heat transfer from IC die-to-board (theta-jb).

[0010] A stiffener attached to a substrate enhances heat spreading. However, the openings on the stiffener for wire bond connections tend to reduce the thermal connections between the IC die and the edges of the stiffener. As a result, heat spreading is limited largely to the region of the IC die attach pad, while areas at the stiffener peripheral do not contribute effectively to heat spreading.

[0011] Furthermore, because of the high density of the substrate routing circuitry, it is difficult to bond each power and ground pad on the IC die to the substrate by a corresponding bond finger. As a result, the distribution of ground and power signals connecting to the IC die is frequently compromised in conventional BGA packages.

[0012] Ball grid array packages that use plastic substrates (for example, BT or FR4 plastic) are commonly known as plastic BGAs, or PBGAs. See, e.g., Lau, J. H., *Ball Grid Array Technology*, McGraw-Hill, New York, (1995). A PBGA package, for example, may add solder balls to the bottom substrate surface under the IC die to aid in conducting heat to the PCB. Solder balls such as these are referred to as thermal balls. The cost of the PBGA package, however, will increase with the number of thermal balls. Furthermore, a large array of thermal balls may be necessary for heat dissipation into the PCB for high levels of IC device power.

[0013] Hence, what is needed are BGA packages with improved heat spreading capabilities, while also providing for high levels of IC electrical performance.

BRIEF SUMMARY

[0014] A method of assembling a ball grid array (BGA) package is provided. The method includes providing a tape substrate that has a first surface and a second surface, attaching a first surface of a stiffener to the first substrate surface, mounting an IC die to the second stiffener surface, mounting a heat spreader to the IC die, and attaching a plurality of solder balls to the second substrate surface.

[0015] Another method of assembling a ball grid array (BGA) package includes providing a substrate that has a first surface and a second surface, providing at least one opening in a stiffener from a first surface of the stiffener to the second surface of the stiffener, attaching the first stiffener surface to the first substrate surface, mounting an integrated circuit (IC) die to the second stiffener surface, coupling a contact pad to the second stiffener surface, attaching a plurality of solder balls to the second substrate surface, inside an outer dimensional profile of the IC die, and coupling the plurality of solder balls through corresponding vias in the substrate to the first stiffener surface. A first surface of the IC die includes the contact pad.

[0016] Another method of assembling a ball grid array (BGA) package, includes the steps of providing a substrate that has a first surface and a second surface, attaching a first surface of a stiffener to the first substrate surface, mounting an IC die to the first stiffener surface, attaching a plurality of solder balls to the second substrate surface, and attaching a metal ring to the first stiffener surface.

[0017] Another method of assembling a ball grid array (BGA) package, includes the steps of providing a substrate that has a first surface and a second surface, mounting an IC die to the first substrate surface, attaching a plurality of solder balls to the second substrate surface, coupling a first surface

of a heat spreader to the second substrate surface, and configuring a second surface of the heat spreader to be coupled to a printed circuit board (PCB).

[0018] Further aspects, features, and advantages of the present invention, as well as the structure and operation of the various embodiments of the present invention, are described in detail below with reference to the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS/FIGURES

[0019] The accompanying drawings, which are incorporated herein and form a part of the specification, illustrate the present invention and, together with the description, further serve to explain the principles of the invention and to enable a person skilled in the pertinent art to make and use the invention.

[0020] FIGS. **1**A and **1**B illustrate conventional flex BGA packages.

[0021] FIG. **2**A shows a top view of a stiffener.

[0022] FIG. **2**B shows a temperature distribution for a stiffener during operation of an IC device in a flex BGA package.

[0023] FIG. **2**C shows an top view of an alternative stiffener configuration.

[0024] FIG. **3** shows a cross-sectional view of a conventional die-up plastic BGA package.

[0025] FIG. **4** illustrates a cross-sectional view of a die-up flex BGA package with heat spreader, according to an embodiment of the present invention.

[0026] FIG. **5** show a cross-sectional view of an alternative BGA package, according to embodiments of the present invention, where the heat spreader is internal to the BGA package.

[0027] FIG. **6** illustrates a cross-sectional view of a die-up flex BGA package with stiffener ground plane, according to an embodiment of the present invention.

[0028] FIG. **7** illustrates a cross-sectional view of a die-up flex BGA package with patterned stiffener, according to an embodiment of the present invention.

[0029] FIG. **8** illustrates a cross-sectional view of a die-up flex BGA package with ground/thermal connector, according to an embodiment of the present invention.

[0030] FIG. **9**A illustrates a cross-sectional view of a die-up tape BGA package with metal ring, according to an embodiment of the present invention.

[0031] FIG. **9**B illustrates a top view of the die-up tape BGA package with metal ring of FIG. **9**A, according to an embodiment of the present invention.

[0032] FIG. **10**A illustrates a stiffener that includes one or more thermal studs, according to an embodiment of the present invention.

[0033] FIG. **10**B illustrates an IC die that is wire bound to a substrate through openings in the stiffener of FIG. **10**A, according to an embodiment of the present invention.

[0034] FIG. **11** illustrates a cross-sectional view of a die-up PBGA package with ground/thermal connector, according to an embodiment of the present invention.

[0035] FIG. **12**A illustrates a cross-sectional view of a die-up BGA package.

[0036] FIGS. **12**B and **12**C illustrate exemplary solder ball arrangements for the die-up BGA package of FIG. **12**A.

[0037] FIG. **13** shows exemplary routing in a substrate layer.

[0038] FIG. **14** shows a flowchart related to FIGS. **4** and **5**, that provides operational steps of exemplary embodiments of the present invention.

[0039] FIG. **15** shows a flowchart related to FIG. **6** that provides operational steps of exemplary embodiments of the present invention.

[0040] FIGS. **16**A-D show flowcharts related to FIGS. **7** and **8** that provide operational steps of exemplary embodiments of the present invention.

[0041] FIG. **17** shows a flowchart related to FIGS. **9**A and **9**B that provides operational steps of exemplary embodiments of the present invention.

[0042] FIG. **18** shows a flowchart related to FIGS. **10**A and **10**B that provides operational steps of exemplary embodiments of the present invention.

[0043] FIGS. **19**A-C show flowcharts related to FIG. **11** that provide operational steps of exemplary embodiments of the present invention.

[0044] FIG. **20** illustrates a substrate that has a central window opening, according to an embodiment of the present invention.

[0045] FIG. **21** illustrates a side view of a stiffener that has a downward protruding portion, according to an embodiment of the present invention.

[0046] The present invention will now be described with reference to the accompanying drawings. In the drawings, like reference numbers indicate identical or functionally similar elements. Additionally, the left-most digit(s) of a reference number identifies the drawing in which the reference number first appears.

DETAILED DESCRIPTION OF THE INVENTION

Overview

[0047] The present invention is directed to a method and system for improving the mechanical, thermal, and electrical performance of BGA packages. The present invention is applicable to all types of BGA substrates, including ceramic, plastic, and tape (flex) BGA packages. Furthermore the present invention is applicable to die-up (cavity-up) and die-down (cavity-down) orientations.

[0048] Numerous embodiments of the present invention are presented herein. In a first embodiment, BGA package thermal stress at the IC die/stiffener interface is released or altered with the introduction of a heat spreader on the top surface of the IC die, enabling large size dies with high input and output (I/O) counts to be packaged using BGA technology. In a second embodiment, BGA package thermal resistance and the length of the current return path are reduced by introducing thermal/ground balls underneath or within close proximity of the IC die. In a third embodiment, the package thermal resistance and ground inductance are reduced by removing center solder balls, and enabling the attachment of a die pad to the PCB. The die pad is attached to the PCB with novel patternings of the metal stiffener, or by positioning a thermal/ground connector in between the IC die pad and the PCB. In a fourth embodiment, the package thermal resistance is reduced by attaching a metal ring to the top surface of a stiffener. In a fifth embodiment, the package thermal resistance is reduced by bridging the die pad to the outer regions of the stiffener with metal studs.

[0049] In further embodiments according to the present invention, the electrical performance of the BGA package is improved. In a sixth embodiment, electrical performance is

improved by connecting ground bonds from the IC die to the stiffener. In such a configuration, the stiffener operates as a package ground plane. The package ground plane may be connected to PCB ground through either thermal/ground balls or thermal/ground connectors mentioned in embodiments above, and further described herein. In a seventh embodiment, package power distribution is enhanced by using a layer in a tape substrate as a power or ground plane.

[0050] In still further embodiments according to the present invention, plastic ball grid array (PBGA) package thermal and electrical performances are improved. In an eighth embodiment, replacing the center solder balls with a solid conductor reduces the package junction-to-board thermal resistance and package ground inductance of a PBGA package.

[0051] Ball grid array package types are described below. Further detail on the above described embodiments, and additional embodiments according to the present invention, are presented below. The embodiments described herein may be combined in any applicable manner, as required by a particular application.

Ball Grid Array (BGA) Package

[0052] A ball grid array (BGA) package is used to package and interface an IC die with a printed circuit board (PCB). BGA packages may be used with any type of IC die, and are particularly useful for high speed ICs. In a BGA package, solder pads do not just surround the package periphery, as in chip carrier type packages, but cover the entire bottom package surface in an array configuration. BGA packages are also referred to as pad array carrier (PAC), pad array, land grid array, and pad-grid array packages. BGA packages types are further described in the following paragraphs. For additional description on BGA packages, refer to Lau, J. H., Ball Grid Array Technology, McGraw-Hill, New York, (1995), which is herein incorporated by reference in its entirety.

[0053] Die-up and die-down BGA package configurations exist. In die-up BGA packages, the IC die is mounted on a top surface of the substrate or stiffener, in a direction away from the PCB. In die-down BGA packages, the IC die is mounted on a bottom surface of the substrate or stiffener, in a direction towards the PCB.

[0054] A number of BGA package substrate types exist, including ceramic, plastic (PBGA), and tape (also known as "flex"). FIG. **1**A illustrates a conventional flex BGA package **100**. Flex BGA package **100** includes an IC die **102**, a tape substrate **104**, a plurality of solder balls **106**, and one or more wire bonds **108**. Tape or flex BGA packages are particularly appropriate for large IC dies with large numbers of input and outputs, such as application specific integrated circuits (ASIC) and microprocessors.

[0055] Tape substrate **104** is generally made from one or more conductive layers bonded with a dielectric material. For instance, the dielectric material may be made from various substances, such as polyimide tape. The conductive layers are typically made from a metal, or combination of metals, such as copper and aluminum. Trace or routing patterns are made in the conductive layer material. Substrate **104** may be a single-layer tape, a two-layer tape, or additional layer tape substrate type. In a two-layer tape, the metal layers sandwich the dielectric layer, such as in a copper-Upilex-copper arrangement.

[0056] IC die **102** is attached directly to substrate **104**, for example, by an epoxy. IC die **102** is any type of semiconductor integrated circuit, separated from a semiconductor wafer.

[0057] One or more wire bonds **108** connect corresponding bond pads **118** on IC die **102** to contact points **120** on substrate **104**.

[0058] An encapsulate, mold compound, or epoxy **116** covers IC die **102** and wire bonds **108** for mechanical and environmental protection.

[0059] As shown in FIG. **1**A, flex BGA package **100** does not include a stiffener. In some BGA package types, particularly in flex BGA packages, a stiffener can be attached to the substrate to add planarity and rigidity to the package. FIG. **1**B illustrates a flex BGA package **110**, similar to flex BGA package **100**, that incorporates a stiffener **112**. Stiffener **112** may be laminated to substrate **104**. Stiffener **112** is typically made from a metal, or combination of metals, such as copper, tin, and aluminum, or may be made from a polymer, for example. Stiffener **112** also may act as a heat sink, and allow for greater heat spreading in BGA package **110**. One or more openings **114** in stiffener **112** may be used to allow for wire bonds **108** to connect IC die **102** to substrate **104**. Stiffener **112** may be configured in other ways, and have different opening arrangements than shown in FIG. **1**B.

[0060] The use of a stiffener in a flex BGA package requires additional considerations when attempting to manage heat spreading. FIG. **2**A shows a top view of a stiffener **112**. Stiffener **112** includes an opening **114** adjacent to all four sides of an IC die mounting position **202** in the center of stiffener **112**. FIG. **2**B shows a temperature distribution **204** of a stiffener, such as stiffener **112**, during operation of an IC die in a flex BGA package. Temperature distribution **204** shows that heat transfer from IC die mounting position **202** to the edges of stiffener **112** is substantially limited by openings **114**. Openings **114** act as thermal barriers to heat spreading in stiffener **112**.

[0061] FIG. **2**C shows a top view of an alternative configuration for stiffener **112**, according to an embodiment of the present invention. Stiffener **112** includes an opening **206** adjacent to all four sides of an IC die mounting position **202** in the center of stiffener **112**. Openings **206** are similar to openings **114** of FIG. **2**A, but of different shape. Further alternatively shaped openings in stiffener **112** are applicable to the present invention.

[0062] FIG. **3** shows a cross-sectional view of a conventional die-up PBGA package **300**. PBGA package **300** includes a plastic substrate **302**, an IC die **304**, a plurality of solder balls **306**, a plurality of wire bonds **308**, a die pad **310**, one or more vias **314**, and one or more thermal/ground vias **316**.

[0063] Plastic substrate **302** includes one or more metal layers formed on an organic substrate (for example, BT resin or FR4 epoxy/glass). IC die **304** is mounted to die pad **310**. IC die **304** may be attached to die pad **310** with an epoxy, such as a silver-filled epoxy. Wire bonds **308** connect signals of IC die **304** to substrate **302**. For instance, gold bonding wire is bonded from aluminum bond pads on IC die **304** to gold-plated contact pads on substrate **302**. The contact pads on substrate **302** connect to solder balls **306** attached to the bottom surface of substrate **302**, through vias **314** and routing within substrate **302** using copper conductors **312**. Thermal/ground vias **316** connect die pad **310** to one or more thermal/ground balls **322** on the center bottom surface of substrate

302. An encapsulate, mold compound, or epoxy **320** covers IC die **304** and wire bonds **308** for mechanical and environmental protection.

[0064] As described above, a BGA package includes an array of solder balls located on a bottom external surface of the package substrate. FIG. **12**A illustrates a cross-sectional view of a die-up BGA package **1200**. FIGS. **12**B and **12**C illustrate exemplary solder ball arrangements for die-up BGA package **1200**. As shown in FIG. **12**A, BGA package **1200** includes an IC die **1208** mounted on a substrate **1212**. IC die **1208** is electrically connected to substrate **1212** by one or more wire bonds **1210**. Wire bonds **1210** are electrically connected to solder balls **1206** underneath substrate **1212** through corresponding vias and routing in substrate **1212**. The vias in substrate **1212** can be filled with a conductive material, such as solder, to allow for these connections. Solder balls **1206** are attached to substrate **1212**, and are used to attach the BGA package to a PCB.

[0065] Note that although wire bonds, such as wire bonds **1210**, are shown and described herein, IC dies may be mounted and coupled to a substrate with solder balls located on the bottom surface of the IC die, by a process commonly referred to as "C4" or "flip chip" packaging.

[0066] As shown in FIG. **12**B, solder balls **1206** may be arranged in an array.

[0067] FIG. **12**B shows a 14 by 14 array of solder balls on the bottom surface of BGA package **1200**. Other sized arrays of solder balls are also applicable to the present invention. Solder balls **1206** are reflowed to attach BGA package **1200** to a PCB. The PCB may include contact pads to which solder balls **1206** are bonded. PCB contact pads are generally made from a metal or combination of metals, such as copper, nickel, tin, and gold.

[0068] FIG. **12**C shows a bottom view of BGA package **1200**, with an alternative solder ball array arrangement. BGA package **1200** attaches an array of solder balls **1206** on a bottom surface of substrate **1212**. As shown in FIG. **12**C, solder balls **1206** are located in a peripheral area of the bottom surface of substrate **1212**, away from a substrate center **1224**. For example, solder balls **1206** on the bottom surface of substrate **1212** may be located outside an outer profile area of an IC die mounted on the opposite surface of substrate **1212**. The solder ball array may be organized in any number of ways, according to the requirements of the particular BGA package application.

[0069] The solder ball arrangement shown in FIG. **12**C is particularly applicable to embodiments of the present invention described below, such as for attaching a heat spreader or ground/thermal connector to a bottom surface of a BGA package. The heat spreader or ground/thermal connector may be connected in substrate center **1224**.

[0070] As described above, the BGA package substrate provides vias and routing on one or more layers to connect contact pads for wire bonds on its upper surface to solder balls attached to the bottom substrate surface. FIG. **13** shows an example routing **1304** in a substrate layer **1302** for accomplishing this.

[0071] The present invention is applicable to improving thermal and electrical performance in the BGA package types described herein, and further BGA package types.

BGA Embodiments According to the Present Invention

[0072] Further details of structural and operational implementations of ball grid array packages of the present invention are described in the following sections. These structural and operational implementations are described herein for illustrative purposes, and are not limiting. For instance, the present invention as described herein may be implemented in both die-up and die-down BGA package types, as well as other IC package types. Furthermore, each of the embodiments presented below are applicable to tape substrate BGA packages, plastic substrate BGA packages, and ceramic substrate BGA packages. The description below is adaptable to these and other package types, as would be understood to persons skilled in the relevant art(s) from the teachings herein. For instance, in plastic substrate BGA packages, and some tape BGA packages, a stiffener may not be required in the BGA package.

[0073] Features of each of the embodiments presented below may be incorporated into BGA packages independently, or may be combined in any manner, as would be apparent to persons skilled in the relevant art(s) from the teachings herein.

Drop-in Heat Spreader Embodiments

[0074] According to an embodiment of the present invention, a heat spreader may be used in a BGA package to provide for thermal stress relief and heat dissipation. In a preferred embodiment, a drop-in heat spreader is attached to the top surface of an IC die in a flex BGA package to provide for thermal stress relief and heat dissipation.

[0075] FIG. **4** illustrates a cross-sectional view of a die-up flex BGA package **400**, according to an embodiment of the present invention. BGA package **400** includes IC die **102**, substrate **104**, plurality of solder balls **106**, one or more wire bonds **108**, stiffener **112**, epoxy **116**, a drop-in heat spreader **402**, and an epoxy **404**. Refer to the discussion above related to FIGS. **1**A-**1**B for additional detail on the structure and operation of some of these elements.

[0076] Substrate **104** has a top surface to which a bottom surface of stiffener **112** is mounted. A bottom surface of substrate **104** attaches the plurality of solder balls **106**. The plurality of solder balls **106** connect to vias and/or points on the bottom surface of substrate **104** to which signals internal to substrate **104** are routed and exposed.

[0077] Stiffener **112** has a top surface to which IC die **102** is mounted. In alternate embodiments, BGA package **400** does not require a stiffener, and does not include a stiffener **112**. In such an alternate embodiment, IC die **102** is mounted to substrate **104**.

[0078] One or more wire bonds **108** connect corresponding bond pads **118** on IC die **102** to contact points **120** on substrate **104**. When a stiffener **112** is present, as shown in FIG. **4**, wire bonds **108** extend through one or more openings **114** in stiffener **112** to form connections with substrate **104**.

[0079] Heat spreader **402** is attached to the top surface (active surface) of IC die **102** using epoxy **404**. The epoxy **404** may be the same substance as epoxy **116**, or may be a different substance. Silver filled epoxies may be used for epoxy **404** to enhance heat extraction from IC die **102**.

[0080] As shown in FIG. **4**, heat spreader **402** is smaller in area than the upper surface of IC die **102**. Alternative sizes for heat spreader **402** are also applicable to the present invention, including sizes equal to the area of IC die **102**, or larger areas. Heat spreader **402** is shaped and configured to spread heat from IC die **102**, as is required by the application.

[0081] As shown in FIG. **4**, the top surface of heat spreader **402** forms a portion of a top surface of BGA package **400**.

Heat dissipation to the environment can be improved by exposing the top surface of heat spreader **402**. Furthermore, in such a configuration, additional heat sinks may be attached to heat spreader **402**. FIG. **5** show a cross-sectional view of an alternative BGA package **500**, according to embodiments of the present invention, where a heat spreader **502** is internal to BGA package **500**. Heat spreader **502** is completely encapsulated by epoxy **116**.

[0082] By attaching heat spreader **402** to the top surface of IC die **102**, the mechanical structure of BGA package **400** becomes more symmetrical in its center region, particularly when ground/thermal solder balls do not exist on the bottom surface of substrate **104** underneath the outer profile of IC die **102**. Thermal stress at the interface of IC die **102** and stiffener **112** is substantially released or altered by heat spreader **402**. Deformation caused by thermal stress in stiffener **112** and substrate **104** is substantially reduced through the use of heat spreader **402**. Drop-in heat spreader **402** allows for even larger sizes for IC die **102** and greater I/O counts by providing for greater heat spreading capacity in BGA package **400**.

[0083] FIG. **14** shows a flowchart **1400** providing operational steps for assembling one or more embodiments of the present invention. The steps of FIG. **14** do not necessarily have to occur in the order shown, as will be apparent to persons skilled in the relevant art(s) based on the teachings herein. Other structural embodiments will be apparent to persons skilled in the relevant art(s) based on the following discussion. These steps are described in detail below.

[0084] Flowchart **1400** begins with step **1402**. In step **1402**, a substrate that has a first surface and a second surface is provided. For example, the substrate is flex substrate **104**, or another substrate type suitable for a BGA package. For example, an IC die mounting position and/or contact points are provided on a first, upper surface, and solder ball pads are provided on a second, bottom surface.

[0085] In step **1404**, a first surface of a stiffener is attached to the first substrate surface. For example, the stiffener is stiffener **112**, which is attached to substrate **104**. In alternative embodiments, a stiffener is not required.

[0086] In step **1406**, an IC die is mounted to the second stiffener surface. For example, the IC die is IC die **102**, which is mounted to stiffener **112**. In alternative embodiments, when a stiffener is not used, IC die **102** is mounted directly to the substrate.

[0087] In step **1408**, a heat spreader is mounted to the IC die, wherein the heat spreader dissipates heat from the IC die. For example, the heat spreader is heat spreader **402** or **502**, which is mounted with epoxy **404** or other attachment means to the upper surface of IC die **102**. Heat spreader **402** or **502** typically is mounted to the center of the upper surface of IC die **102**, and covers less than the entire upper surface of IC die **102**. For instance, the smaller area of heat spreader **402** or **502** allows for bond pads **118** to be exposed on the upper surface of IC die **102** for wire bond connections. In alternative embodiments, heat spreader **402** or **502** is of the same size, or comprises a larger area than the upper surface of IC die **102**.

[0088] In step **1410**, a plurality of solder balls are attached to the second substrate surface. For example, the plurality of solder balls are plurality of solder balls **106**, which connect to vias and/or solder ball pads on the bottom surface of substrate **104**. The solder balls may be arranged on the bottom surface of substrate **104** as shown in FIGS. **12**B and **12**C, or in alternative arrangements. The solder balls are used to attach a BGA package to a PCB.

[0089] A benefit of performing the steps of flowchart **1400** is that the heat spreader relieves thermal stress at an interface of the IC die and the first stiffener surface.

[0090] Flowchart **1400** may include the additional step where the second stiffener surface is encapsulated. For instance, the second stiffener surface may be encapsulated by a resin or molding compound, that also encapsulates the IC die, heat spreader, and wire bonding.

Stiffener Ground Plane Embodiments

[0091] According to an embodiment of the present invention, electrical performance of an IC die, and thermal performance of a corresponding BGA package may be improved by allowing a stiffener to act as a ground plane. In a preferred embodiment, a stiffener in a die-up tape BGA (Flex BGA) package is coupled to PCB ground through one or more vias to ground solder balls. Ground contact pads of the IC die are connected to the stiffener by ground wire bonds. In a further aspect, one or more metal layers of a flex tape substrate may be coupled to a ground or power potential, to operate as a ground or power plane.

[0092] FIG. **6** illustrates a cross-sectional view of a die-up flex BGA package **600**, according to an embodiment of the present invention. BGA package **600** includes IC die **102**, substrate **104**, plurality of solder balls **106**, one or more wire bonds **108**, stiffener **112**, epoxy **116**, one or more ground bonds to stiffener **602**, one or more ground/thermal vias **604**, one or more ground/thermal balls **606**, one or more ground contact pads **608**, one or more power contact pads **610**, and one or more power vias **612**.

[0093] Substrate **104** has a top surface to which a bottom surface of stiffener **112** is mounted. A bottom surface of substrate **104** attaches the plurality of solder balls **106**. The plurality of solder balls **106** connect to vias and/or points on the bottom surface of substrate **104** to which signals internal to substrate **104** are routed and exposed.

[0094] Stiffener **112** has a top surface to which IC die **102** is mounted.

[0095] One or more wire bonds **108** connect corresponding bond pads **118** on IC die **102** to contact points **120** on substrate **104**. Wire bonds **108** extend through one or more openings **114** in stiffener **112** to form connections with substrate **104**.

[0096] IC die **102** has a top surface that includes at least one ground pad **608**. Ground pad **608** is coupled to a ground potential signal in IC die **102**. A ground wire bond **602** connects ground pad **608** to stiffener **112**. The bottom surface of stiffener **112** is coupled to a ground potential signal in the PCB to which BGA package **600** is attached, to cause stiffener **112** to operate as a ground plane. Stiffener **112** is coupled to PCB ground through one or more of ground/thermal via **604** that extend through substrate **104**. The one or more of ground/thermal vias **604** are located in substrate **104**, underneath IC die **102**, and can be filled with a conductive material, such as solder. A ground/thermal solder ball **606** is attached to each ground/thermal via **604** on the bottom surface of substrate **104**. Ground/thermal solder ball **606** forms the connection to PCB ground, when reflowed to attach to the PCB. Each ground/thermal via **604** connects the respective ground/thermal solder ball **606** to stiffener **112** both electrically and thermally.

[0097] In a further embodiment, a tape substrate is configured such that a metal layer is used as a package power or

ground plane. For instance, with a two-layer tape substrate, the bottom metal layer may be used as a power or ground plane.

[0098] In FIG. **6**, PCB package **600** includes a bottom metal layer **614** of a two-layer tape substrate **104** that is coupled to a potential to operate as a power plane, according to an embodiment of the present invention. One or more power contact pads **610** on IC die **102** are coupled to a power potential signal in IC die **102**. Power contact pad **610** on IC die **102** is connected to a corresponding power via **612** by a power wire bond **616**. When a stiffener **112** is present, power wire bond **616** extends through opening **114**. Power via **612** extends through substrate **104**. Power via **612** can be filled with a conductive material, such as solder. Each power via **612** is coupled to the bottom metal layer **614** of substrate **104**. Furthermore, one or more power vias **612** may be connected to corresponding solder balls on the bottom of substrate **104**, to connect bottom metal layer **614** to PCB power pads when the solder balls are reflowed.

[0099] The introduction of a stiffener ground plane, and/or a power/ground plane using a metal layer of a tape substrate allows for very short power and ground connections. Current return path lengths are shortened, voltage drop across planes is reduced, and power/ground inductance is reduced. The shorter power and ground paths are also significant in reducing a power/ground path resistance, which advantageously reduces required IC device power levels.

[0100] For further description of the use of a thermal vias in a flex tape substrate, and of the use of a thermal ball coupled to a heat spreader in a die-down TBGA package, refer to U.S. Pat. No. 6,020,637, which is incorporated by reference in its entirety herein. For further description of the use of a thermal via and a thermal ball in a plastic substrate BGA package, refer to U.S. Pat. No. 5,894,410, which is incorporated by reference in its entirety.

[0101] FIG. **15** shows a flowchart **1500** providing operational steps for assembling one or more embodiments of the present invention. The steps of FIG. **15** do not necessarily have to occur in the order shown, as will be apparent to persons skilled in the relevant art(s) based on the teachings herein. Other structural embodiments will be apparent to persons skilled in the relevant art(s) based on the following discussion. These steps are described in detail below.

[0102] Flowchart **1500** begins with step **1502**. In step **1502**, a substrate that has a first surface and a second surface is provided. For example, the substrate is flex substrate **104**, or another substrate type suitable for a BGA package. For example, an IC die mounting position and/or contact points are provided on a first, upper surface, and solder ball pads are provided on a second, bottom surface.

[0103] In step **1504**, at least one opening in a stiffener from a first surface of the stiffener to a second surface of the stiffener is provided. For example, the at least one opening includes openings **114** in stiffener **112**. In a preferred embodiment, an opening **114** is located on each of the four edges of IC die **102**.

[0104] In step **1506**, the first stiffener surface is attached to the first substrate surface. For example, the stiffener is stiffener **112**, which is attached to substrate **104**. In alternative embodiments, a stiffener is not required, and is not attached to the substrate.

[0105] In step **1508**, an integrated circuit (IC) die is mounted to the second stiffener surface, wherein a first surface of the IC die includes a contact pad. For example, the IC die is IC die **102**, which is mounted to stiffener **112**. In alternative embodiments, when a stiffener is not used, IC die **102** is mounted directly to the substrate. For example, the contact pad is ground contact pad **608**.

[0106] In step **1510**, the contact pad is coupled to the second stiffener surface. For instance, contact pad is ground contact pad **608**, which is connected to stiffener **112** by ground wire bond **602**. Ground wire bond **602** may be soldered, or otherwise attached to stiffener **112**.

[0107] In step **1512**, a plurality of solder balls is attached to the second substrate surface, inside an outer dimensional profile of the IC die. For example, the plurality of solder balls include one or more ground/thermal balls **606**, which are arranged on the bottom surface of substrate **104** in the region of substrate center **1224**, shown in FIG. **12**C. The outer dimensional profile of the IC die is the area bounded by the edges of IC die **102**.

[0108] In step **1514**, the plurality of solder balls are coupled through corresponding vias in the substrate to the first stiffener surface. For example, the vias include ground/thermal via **604**. The vias can be filled with a conductive material, such as solder, to allow the electrical connection of the solder balls to stiffener **112**.

[0109] In a further embodiment according to flowchart **1500**, the substrate includes a metal layer, wherein the metal layer is coupled to a second potential. The stiffener has at least one opening extending from the first stiffener surface to the second stiffener surface. The second IC die surface includes a second contact pad. The second contact pad is coupled to the metal layer through one of the openings in the stiffener and through a corresponding via that extends through the substrate. The second contact pad may be coupled to a power or ground potential in the IC die. For example, the second contact pad is power contact pad **610**, the metal layer is metal layer **614**, and the corresponding via is power via **612**.

[0110] In an embodiment, flowchart **1500** may include an additional step, where the contact pad is coupled to a ground potential in the IC die. For example, the contact pad may be connected to a ground plane or ground signal in IC die that is routed to the contact pad.

[0111] Flowchart **1500** may include the additional step where the second stiffener surface is encapsulated. For instance, the second stiffener surface may be encapsulated by a resin or molding compound, that also encapsulates the IC die and wire bonding.

[0112] Flowchart **1500** may include the additional step where a second plurality of solder balls is attached to the second substrate surface, outside an outer dimensional profile of the IC die. For example, the second plurality of solder balls are plurality of solder balls **106**, which connect to vias and/or solder ball pads on the bottom surface of substrate **104**. The solder balls are arranged on the bottom surface of substrate **104** as shown in FIG. **12**B, outside of substrate center **1224**. The solder balls are used to attach a BGA package to a PCB.

Embodiments With Stiffener Coupled to a PCB

[0113] According to an embodiment of the present invention, electrical performance of the IC device, and thermal performance of a BGA package is improved by enabling an IC die pad to attach to a PCB. In an embodiment, the IC die pad is attached to the PCB by a novel patterning of the metal stiffener in a die-up tape BGA package. In an alternate embodiment, the IC die pad is attached to the PCB by placing

a thermal/ground connector between the IC die pad and PCB in a die-up tape BGA package.

[0114] A BGA package junction-to-board thermal resistance can be substantially reduced by the attachment of a metal die-attach pad directly to a PCB. Metal die-attach pads are coupled to a PCB for package junction-to-board thermal resistance minimization in an exposed pad quad flat pack (QFP), a QFP with exposed heat sink at bottom, and a leadless plastic chip carrier (i.e. LPCC, QFN, SON, QLP) package, for instance. All existing such designs that involve an exposed die pad or an exposed heat sink at package bottom are "lead frame" packages. The present invention provides for an exposed die-attach pad or heat sink at the bottom of flex BGA packages.

[0115] FIG. **7** illustrates a cross-sectional view of a die-up flex BGA package **700**, according to an embodiment of the present invention. BGA package **700** includes IC die **102**, substrate **104**, plurality of solder balls **106**, one or more wire bonds **108**, stiffener **112**, epoxy **116**, ground wire bond to stiffener **602**, ground contact pad **608**, and a stiffener cavity **702**.

[0116] Substrate **104** has a top surface to which a bottom surface of stiffener **112** is mounted. A bottom surface of substrate **104** attaches the plurality of solder balls **106**. The plurality of solder balls **106** connect to vias and/or points on the bottom surface of substrate **104** to which signals internal to substrate **104** are routed and exposed. Substrate **104** in FIG. **7** has a central window-shaped opening **704**, under which solder balls are preferably not connected. FIG. **20** illustrates a bottom view of a substrate **104** that has a central window opening **704**, according to an embodiment of the present invention.

[0117] Stiffener **112** has a top surface to which IC die **102** is mounted. Stiffener **112** in FIG. **7** is patterned with a cavity **702**, which protrudes downward for attachment of IC die **102**. As described above, a central window-shaped opening **704** exists in substrate **104**. This opening **704** exists to allow stiffener **112** to protrude through, and make contact with soldering pads on a PCB to which BGA package **700** is to be mounted. The bottom exposed surface of cavity **702** can be plated with solder to facilitate surface mount to solder plated metal pads on a PCB to which BGA package **700** is mounted. Hence, stiffener **112** may act as a conduit for heat to be transferred from IC die **102** to the PCB.

[0118] Stiffener **112** may optionally be configured to operate as a ground plane. One or more ground pads **608** may be coupled to a ground potential signal in IC die **102**. A ground wire bond **602** connects each ground pad **608** to stiffener **112**. With one or more ground wire bonds **602** coupled to stiffener **602**, the bottom exposed surface of cavity **702** may function both as an exposed ground pad of BGA package **700**, and as an exposed heat spreader. As described above, the bottom exposed surface of cavity **702** may be plated with solder to allows stiffener **112** to be surface mounted to one or more soldering pads on the PCB. The pads on the PCB can be connected to a PCB ground plane to shorten the length of electrical current return paths, as well as to form a conductive heat dissipation path from BGA package **700** to the PCB.

[0119] Direct electrical and thermal connection from BGA package ground to a PCB ground plane is also possible by attaching a heat spreader between the stiffener and PCB. FIG. **8** illustrates a cross-sectional view of a die-up flex BGA package **700**, according to an embodiment of the present invention. Substrate **104** in FIG. **8** has a central window-shaped opening, under which no solder balls are connected. A portion of the bottom surface of stiffener **112** is exposed through the central window-shaped opening **704** of substrate **104**. A heat spreader (for example, manufactured from copper or aluminum), shown as ground/thermal connector **802**, is coupled to the exposed portion of stiffener **112**. Ground/thermal connector **802** can be made from the same material as stiffener **112**. Material different from stiffener **112** may be used for ground/thermal connector **802** to compensate for the mismatch of thermal expansion coefficient between the die **102** and stiffener **112**. Ground/thermal connector **802** may be laminated to the exposed portion of stiffener **112** using conductive epoxy. The bottom surface of ground/thermal connector **802** may be plated with solder to facilitate its surface mount to soldering pads on the PCB. Metal pads on the PCB may be connected to a PCB ground plane to shorten the length of electrical current return paths, as well as enhance the conductive heat dissipation path from IC die **102** to the PCB. An advantage of this design is a high efficiency in the metal connector lamination process.

[0120] In a further embodiment, stiffener **112** and ground/thermal connector **802** may be manufactured from a single piece of metal, and hence consist of a single metal piece. FIG. **21** illustrates a side view of stiffener **112** that has a downward protruding portion **2102**, according to an embodiment of the present invention. When stiffener **112** shown in FIG. **21** is attached to substrate **104**, portion **2102** extends partially or entirely through window-shaped opening **704**. Portion **2102** may be directly connected to the PCB, or may be connected to a ground/thermal connector **802** that is connected to the PCB. Because of the thermal and electrical improvement enabled by the coupling of stiffener **112** to a PCB, length of wire bonds can be reduced by moving opening **114** closer to the proximity of die **102** without compromising thermal performance significantly.

[0121] FIG. **16**A shows a flowchart **1600** providing operational steps for assembling one or more embodiments of the present invention. FIGS. **16**B-D provide operational steps according to further embodiments. The steps of FIGS. **16**A-D do not necessarily have to occur in the order shown, as will be apparent to persons skilled in the relevant art(s) based on the teachings herein. Other structural embodiments will be apparent to persons skilled in the relevant art(s) based on the following discussion. These steps are described in detail below.

[0122] Flowchart **1600** begins with step **1602**. In step **1602**, a substrate that has a first surface and a second surface is provided. For example, the substrate is flex substrate **104**, or another substrate type suitable for a BGA package. For example, an IC die mounting position and/or contact points are provided on a first, upper surface, and solder ball pads are provided on a second, bottom surface.

[0123] In step **1604**, a first surface of a stiffener is attached to the first substrate surface. For example, the stiffener is stiffener **112**, which is attached to substrate **104**.

[0124] In step **1606**, a portion of the first stiffener surface is exposed through a window opening in the substrate. For example, substrate **104** has a window opening **704** in its center. A portion of the bottom surface of stiffener **112** is exposed through window opening **704**.

[0125] In step **1608**, an IC die is mounted to a second surface of the stiffener, wherein a surface of the IC die includes at least one contact pad. For example, the IC die is IC die **102**, which is mounted to stiffener **112**.

[0126] In step **1610**, a plurality of solder balls are attached to the second substrate surface. For example, the plurality of solder balls are plurality of solder balls **106**, which connect to vias and/or solder ball pads on the bottom surface of substrate **104**. The solder balls are arranged on the bottom surface of substrate **104** as shown in FIG. **12**B, exclusive of the area of window opening **704**. The solder balls are used to attach a BGA package to a PCB.

[0127] In step **1612**, the exposed portion of the first stiffener surface is configured to be coupled to a printed circuit board (PCB), whereby electrical and thermal performance of the BGA package is improved.

[0128] FIG. **16**B provides exemplary steps for performing step **1612**:

[0129] In step **1614**, a heat spreader is coupled to the exposed portion of the first stiffener surface. For example, the heat spreader is ground/thermal connector **802**, which is coupled to stiffener **112** through window opening **702**.

[0130] In step **1616**, a surface of the heat spreader is configured to be coupled to the PCB. In an embodiment, step **1612** further includes the step where the heat spreader surface is plated with solder to allow the heat spreader surface to be surface mounted to soldering pads on the PCB.

[0131] In an alternate embodiment, step **1612** comprises the step where the stiffener is shaped to have a centrally-located cavity shaped portion that protrudes through the window opening. In an embodiment, step **1612** further includes the step where a surface of the cavity shaped portion is plated with solder to allow the stiffener to be surface mounted to soldering pads on the PCB. For example, stiffener **112** is patterned with a cavity **702**, which protrudes downward in window opening **704**. The bottom surface of cavity **702** is plated with solder.

[0132] FIG. **16**C provides additional exemplary steps for flowchart **1600** of FIG. **16**A:

[0133] In step **1618**, the stiffener is coupled to a potential. For example, the stiffener may be coupled to ground or power on the PCB. The bottom surface of cavity **702** may be coupled to the ground or power potential on the PCB, or ground/thermal connector **802** may make the connection to the PCB.

[0134] In step **1620**, each of the at least one contact pads are coupled to the second stiffener surface with corresponding wire bonds.

[0135] FIG. **16**D provides exemplary steps for performing step **1618**:

[0136] In step **1622**, the stiffener is coupled to a ground potential.

[0137] In step **1624**, the stiffener allowed to serve as a ground plane.

[0138] Flowchart **1600** may include the additional step where the second stiffener surface is encapsulated. For instance, the second stiffener surface may be encapsulated by an epoxy, that also encapsulates the IC die and wire bonding.

Metal Ring Embodiments

[0139] According to an embodiment of the present invention, the mechanical and thermal performance of a BGA package is enhanced by attaching a metal ring to the top surface of the stiffener. In a preferred embodiment, a metal ring is attached to the top surface of the stiffener in a die-up tape BGA package.

[0140] FIG. **9**A illustrates a cross-sectional view of a die-up tape BGA package **900**, according to an embodiment of the present invention. BGA package **900** includes IC die **102**, substrate **104**, plurality of solder balls **106**, one or more wire bonds **108**, stiffener **112**, epoxy **116**, and a ring **902**. FIG. **9**B illustrates a top view of die-up tape BGA package **900**, with ring **902**.

[0141] Substrate **104** has a top surface to which a bottom surface of stiffener **112** is mounted. A bottom surface of substrate **104** attaches the plurality of solder balls **106**. The plurality of solder balls **106** connect to vias and/or points on the bottom surface of substrate **104** to which signals internal to substrate **104** are routed and exposed.

[0142] One or more wire bonds **108** connect corresponding bond pads **118** on IC die **102** to contact points **120** on substrate **104**. Wire bonds **108** extend through one or more openings **114** in stiffener **112** to form connections with substrate **104**. Stiffener **112** has a top surface to which IC die **102** is mounted. Furthermore, ring **902** is attached to the top surface of stiffener **112**. Ring **902** may be laminated to stiffener **112**, after wire bonding is completed. Epoxy **116** is filled in and flushed to ring **902** after the attachment of ring **902**. Ring **902** is preferably made of a metal, such as copper or aluminum, or a combination thereof, but may be constructed from other applicable materials. Preferably, ring **902** is made from the same material as stiffener **112**, to minimize the mismatch of the thermal expansion coefficient. Ring **902** is preferably flush with the outer edges of stiffener **112** to form an outer edge of BGA package **900**, but may also reside entirely within an outer profile of stiffener **112**.

[0143] A primary benefit of attaching ring **902** to stiffener **112** is an increase in stiffness of BGA package **900**. Ring **902** also aids in reducing the amount of warp of BGA package **900**. Furthermore, ring **902** promotes heat dissipation from stiffener **112**, reduces junction-to-case thermal resistance, and facilitates the attachment of an external heat spreader to BGA package **900**.

[0144] Furthermore, ring **902** enhances the process of encapsulation of the BGA package. Ring **902**, with stiffener **112**, creates a cavity that may be filled with a dispensed glob top or encapsulating material, that locks IC die **102** and surrounding elements in place.

[0145] FIG. **17** shows a flowchart **1700** providing operational steps for assembling one or more embodiments of the present invention. The steps of FIG. **17** do not necessarily have to occur in the order shown, as will be apparent to persons skilled in the relevant art(s) based on the teachings herein. Other structural embodiments will be apparent to persons skilled in the relevant art(s) based on the following discussion. These steps are described in detail below.

[0146] Flowchart **1700** begins with step **1702**. In step **1702**, a substrate that has a first surface and a second surface is provided. For example, the substrate is flex substrate **104**, or another substrate type suitable for a BGA package. For example, an IC die mounting position and/or contact points are provided on a first, upper surface, and solder ball pads are provided on a second, bottom surface.

[0147] In step **1704**, a first surface of a stiffener is attached to the first substrate surface. For example, the stiffener is stiffener **112**, which is attached to substrate **104**. In alternative embodiments, a stiffener is not required, and is not attached to the substrate.

[0148] In step **1706**, an IC die is mounted to the first stiffener surface. For example, the IC die is IC die **102**, which is mounted to stiffener **112**. In alternative embodiments, when a stiffener is not used, IC die **102** is mounted directly to the substrate.

[0149] In step **1708**, a plurality of solder balls are attached to the second substrate surface. For example, the plurality of solder balls are plurality of solder balls **106**, which connect to vias and/or solder ball pads on the bottom surface of substrate **104**. The solder balls may be arranged on the bottom surface of substrate **104** as shown in FIGS. **12**B and **12**C, or in alternative arrangements. The solder balls are used to attach a BGA package to a PCB.

[0150] In step **1710**, a metal ring is attached to the first stiffener surface. Attaching the metal ring enhances heat dissipation from the stiffener. For example, the metal ring is ring **902**. In alternative embodiments, when a stiffener is not used, ring **902** is attached directly to the substrate.

[0151] Flowchart **1700** may include the additional step where the second stiffener surface within the volume encompassed by the ring is encapsulated. For example, such a filled upper surface may be called a "glob top". For instance, this volume may be encapsulated by a resin or molding compound, that also encapsulates the IC die and wire bonding.

Embodiments Using Metal Studs to Bridge Stiffener Openings

[0152] According to an embodiment of the present invention, the thermal performance of a BGA package is improved by bridging an IC die pad to which the IC die is mounted to the outer regions of the stiffener. In a preferred embodiment, one or more metal studs are used as thermal bridges, to bridge the openings in the stiffener that surround the IC die, in a die—up tape BGA package.

[0153] The openings on a stiffener surface allow for wire bond connections between an IC die and a substrate. These openings have the additional effect of reducing the amount of heat that can spread to the outer surface regions of the stiffener, hampering the ability of the stiffener to act as a heat spreader. This effect is illustrated in FIG. 2B, which is further described above. To promote heat spreading according to the present invention, the stiffener is patterned such that one or more short studs run across each wire bond opening. More than one stud may be used to bridge each wire bond opening to promote heat spreading. The manufacturing process used for lead frame patterning may be adapted to pattern a stiffener with studs across the wire bond openings. The use of the studs, however, may reduce space for wire bonds, and may reduce BGA package I/O capability, in some situations.

[0154] FIG. **10**A illustrates a stiffener **1000**, that includes one or more studs **1002**, according to an embodiment of the present invention. Stiffener **1000**, having one or more studs **1002**, may be incorporated into a BGA package in the same manner as is described elsewhere herein for stiffener **112**. As shown in FIG. **10**A, a stud **1002** bridges each opening **114** in stiffener **1000**. In alternative embodiments, more than one stud **1002** per opening **114** may be used. Furthermore, each opening **114** may be bridged by a different number of studs **1002**. Some of openings **114** may be bridged by one or more studs **1002**, while other openings **114** may not be bridged at all.

[0155] FIG. **10**B provides an illustration where IC die **102** is wire bound to substrate **104** through stiffener **1000**, according to an embodiment of the present invention. One or more wire bonds **108** connect corresponding bond pads **118** on IC die **102** to contact points **120** on substrate **104**. Wire bonds **108** avoid studs **1002** when making connections to substrate **104**.

[0156] FIG. **18** shows a flowchart **1800** providing operational steps for assembling one or more embodiments of the present invention. The steps of FIG. **18** do not necessarily have to occur in the order shown, as will be apparent to persons skilled in the relevant art(s) based on the teachings herein. Other structural embodiments will be apparent to persons skilled in the relevant art(s) based on the following discussion. These steps are described in detail below.

[0157] Flowchart **1800** begins with step **1802**. In step **1802**, a substrate that has a first surface and a second surface is provided. For example, the substrate is flex substrate **104**, or another substrate type suitable for a BGA package. For example, an IC die mounting position and/or contact points are provided on a first, upper surface, and solder ball pads are provided on a second, bottom surface.

[0158] In step **1804**, a wire bond opening is created along each edge of an IC die mount position on a stiffener, wherein each wire bond opening extends through the stiffener. For example, the wire bond openings are wire bond openings **114** in stiffener **1000**. The IC die mount position is IC die mounting position **202**, shown in FIG. **10**A.

[0159] In step **1806**, a first surface of the stiffener is attached to the first substrate surface. For example, the stiffener is stiffener **1000**, which is attached to substrate **104**.

[0160] In step **1808**, an IC die is mounted to a second surface of the stiffener. For example, the IC die is IC die **102**, which is mounted to stiffener **1000**, in IC die mounting position **202**.

[0161] In step **1810**, at least one of the wire bond openings are bridged with at least one stud. For example, one or more of wire bond openings **114** are bridged with one or more studs **1002**. Studs **1002** allow for increased heat spreading across corresponding wire bond openings **114** to the outer edges of stiffener **1000**.

[0162] In step **1812**, a plurality of solder balls are attached to the second substrate surface. For example, the plurality of solder balls are plurality of solder balls **106**, which connect to vias and/or solder ball pads on the bottom surface of substrate **104**. The solder balls may be arranged on the bottom surface of substrate **104** as shown in FIGS. **12**B and **12**C, or in alternative arrangements. The solder balls are used to attach a BGA package to a PCB.

[0163] The flowchart **1800** may include the further step where a contact pad on the IC die is coupled to the substrate with a wire bond, wherein the wire bond passes through one of the wire bond openings in the stiffener.

[0164] Flowchart **1800** may include the additional step where the second stiffener surface is encapsulated. For instance, the second stiffener surface may be encapsulated by a resin or molding compound, that also encapsulates the IC die and wire bonding.

PBGA Thermal/Ground Connector Embodiments

[0165] According to an embodiment of the present invention, the electrical and thermal performance of a plastic BGA (PBGA) package is improved by attaching a thermal/ground connector to the bottom surface of a PBGA package. The thermal/ground connector couples the bottom center of a plastic substrate of a die-up PBGA to the PCB. Heat from an IC die is more easily spread to the PCB through the thermal/ground connector, which is attached to the plastic substrate underneath the IC die.

[0166] In the discussion above regarding FIG. **8**, embodiments were described that used a ground/thermal connector

to couple a flex BGA package to a PCB, to reduce package junction-to-board thermal resistance. Aspects of this discussion above is adaptable to other die-up BGA package types. These include BGA packages having an organic substrate, such as PBGA and fine pitch ball grid array (FBGA) packages. Further detailed description is provided in the following discussion that is applicable to BGA packages with organic substrates.

[0167] FIG. **11** illustrates a cross-sectional view of a die-up PBGA package **1100**, according to an embodiment of the present invention. PBGA package **1100** includes plastic substrate **302**, IC die **304**, plurality of solder balls **306**, plurality of wire bonds **308**, die pad **310**, one or more vias **314**, one or more thermal/ground vias **316**, epoxy **320**, a ground/thermal connector **1102**, epoxy **1104**, a plurality of ground bonds **1106**, and a plurality of ground bond pads **1108**.

[0168] IC die **304** is mounted to die pad **310**. Wire bonds **308** connect signals of IC die **304** to contact pads on substrate **302**. The contact pads on substrate **302** connect to solder balls **306** attached to the bottom surface of substrate **302**, through vias **314** and routing within substrate **302**.

[0169] Thermal/ground vias **316** connect die pad **310** to an exposed metal plated plane **1110** at the bottom center of substrate **302**. For instance, die pad **310** and metal plated plane **1110** may be exposed copper pads of plastic substrate **302**.

[0170] Solder balls are not attached to the bottom region of substrate **302** covered by metal plated plane **1110**. Ground/thermal connector **1102** is attached to metal plated plane **1110**. For instance, ground/thermal connector **1102** may be a metal piece (copper or aluminum, for example) that is laminated to metal plated plane **1110** at the bottom center of substrate **302** using a conductive epoxy **1104**. A bottom surface **1112** of ground/thermal connector **1102** may be plated with solder for surface mount to soldering pads on the PCB.

[0171] BGA package **1100** provides a thermal path of IC die **304**, to die pad **310**, to thermal/ground vias **316**, to metal plated plane **1110**, to epoxy **1104**, to ground thermal connector **1102** (and bottom surface **1112**) to the PCB soldering pads. Heat spreading is improved by a direct thermal path from IC die **304** to the PCB.

[0172] Metal pads on the PCB can be connected to a PCB ground plane to advantageously shorten the length of electrical current return paths, as well shorten the conductive heat dissipation path from device junctions of IC die to the PCB.

[0173] Ground bonds **1106** may be used to couple ground bond pads **1108** on IC die **304** to die pad **310**, when die pad **310** is coupled to ground. This provides for very short ground connections for signals in IC die **304**.

[0174] FIG. **19**A shows a flowchart **1900** providing operational steps for assembling one or more embodiments of the present invention. FIGS. **19**B-C provide operational steps according to further embodiments. The steps of FIGS. **19**A-C do not necessarily have to occur in the order shown, as will be apparent to persons skilled in the relevant art(s) based on the teachings herein. Other structural embodiments will be apparent to persons skilled in the relevant art(s) based on the following discussion. These steps are described in detail below.

[0175] Flowchart **1900** begins with step **1902**. In step **1902**, a substrate that has a first surface and a second surface is provided. For example, the substrate is plastic substrate **302**, or another substrate type suitable for a BGA package. For example, an IC die mounting position and contact points are provided on a first, upper surface, and solder ball pads are provided on a second, bottom surface.

[0176] In step **1904**, an IC die is mounted to the first substrate surface. For example, the IC die is IC die **304**, which is mounted to substrate **302**. IC die **304** may be mounted to a die pad **310** attached to substrate **302**.

[0177] In step **1906**, a plurality of solder balls are attached to the second substrate surface. For example, the plurality of solder balls are plurality of solder balls **306**, which connect to vias and/or solder ball pads on the bottom surface of substrate **302**. The solder balls may be arranged on the bottom surface of substrate **302** as shown in FIG. **12**B, or in other arrangements. The solder balls are used to attach a BGA package to a PCB.

[0178] In step **1908**, a first surface of a heat spreader is coupled to the second substrate surface. For example, the heat spreader is ground/thermal connector **1102**, which is coupled to substrate **302** with epoxy **1104**. Ground/thermal connector **1102** may be mounted to metal plated plane **1110** on substrate **302** by epoxy **1104**.

[0179] In step **1910**, a second surface of the heat spreader is configured to be coupled to a printed circuit board (PCB). Second heat spreader surface is bottom surface **1112**. In an embodiment, step **1910** may include the step where the second surface of the heat spreader is plated with solder.

[0180] Flowchart **1900** may comprise the additional step where the first substrate surface is coupled to the heat spreader through at least one via that extends through the substrate. For example, the first substrate surface may be coupled to the heat spreader by one or more ground/thermal vias **316**.

[0181] FIG. **19**B provides exemplary steps for performing step **1904**:

[0182] In step **1912**, a copper plated die-attach pad is exposed in the center of the first substrate surface. The copper plated die-attach pad, die pad **310**, may be an exposed portion of a metal layer of plastic substrate **302**.

[0183] In step **1914**, the IC die is mounted to the copper plated die-attach pad. For example, the IC die may be mounted with an epoxy.

[0184] FIG. **19**C provides exemplary steps for performing step **1908**:

[0185] In step **1916**, a copper plated plane is exposed in the center of the second substrate surface. The copper plated plane, metal plated plane **1110**, is an exposed portion of a metal layer of plastic substrate **302**.

[0186] In step **1918**, the die-attach pad is coupled to the copper plated plane with the at least one via.

[0187] Flowchart **1900** may include the additional step where the first substrate surface is encapsulated. For instance, the first substrate surface may be encapsulated by a resin or molding compound, that also encapsulates the IC die and wire bonding

CONCLUSION

[0188] While various embodiments of the present invention have been described above, it should be understood that they have been presented by way of example only, and not limitation. It will be apparent to persons skilled in the relevant art that various changes in form and detail can be made therein without departing from the spirit and scope of the invention. Thus, the breadth and scope of the present invention should not be limited by any of the above-described exemplary

embodiments, but should be defined only in accordance with the following claims and their equivalents.

What is claimed is:

1. A method of assembling a ball grid array (BGA) package, comprising the steps of:

providing a tape substrate that has a first surface and a second surface;

attaching a first surface of a stiffener to the first substrate surface;

mounting an IC die to the second stiffener surface;

mounting a heat spreader to the IC die; and

attaching a plurality of solder balls to the second substrate surface.

2. The method of claim **1**, wherein said heat spreader mounting step comprises the step of:

causing thermal stress to be reduced at an interface of the IC die and the first stiffener surface during operation of the IC die.

3. A method of assembling a ball grid array (BGA) package, comprising the steps of:

providing a substrate that has a first surface and a second surface;

providing at least one opening in a stiffener from a first surface of the stiffener to the second surface of the stiffener;

attaching the first stiffener surface to the first substrate surface;

mounting an integrated circuit (IC) die to the second stiffener surface, wherein a first surface of the IC die includes a contact pad,

coupling the contact pad to the second stiffener surface;

attaching a plurality of solder balls to the second substrate surface, inside an outer dimensional profile of the IC die; and

coupling the plurality of solder balls through corresponding vias in the substrate to the first stiffener surface.

4. The method of claim **3**, wherein the substrate includes a metal layer, wherein the metal layer is coupled to a second potential;

wherein the stiffener has at least one opening extending from the first stiffener surface to the second stiffener surface;

wherein the second IC die surface includes a second contact pad, wherein the method further comprises the step of:

coupling the second contact pad to the metal layer through one of the at least one openings in the stiffener and through a corresponding via that extends through the substrate.

5. The method of claim **4**, further comprising the step of:

coupling the second contact pad to a power potential in the IC die.

6. The method of claim **3**, further comprising the step of:

coupling the contact pad to a ground potential in the IC die.

7. A method of assembling a ball grid array (BGA) package, comprising the steps of:

providing a substrate that has a first surface and a second surface;

attaching a first surface of a stiffener to the first substrate surface;

mounting an IC die to the first stiffener surface;

attaching a plurality of solder balls to the second substrate surface; and

attaching a metal ring to the first stiffener surface.

8. The method of claim **7** wherein said metal ring attaching step comprises the step of dissipating heat from the stiffener with the metal ring.

9. A method of assembling a ball grid array (BGA) package, comprising the steps of:

providing a substrate that has a first surface and a second surface;

creating a wire bond opening along each edge of an IC die mount position on a stiffener, wherein each wire bond opening extends through the stiffener;

attaching a first surface of the stiffener to the first substrate surface;

mounting an IC die to the IC die mount position on a second surface of the stiffener;

bridging at least one of the wire bond openings with at least one stud; and

attaching a plurality of solder balls to the second substrate surface.

10. The method of claim **9**, wherein the IC die includes a contact pad, wherein the method further comprises the step of:

coupling the contact pad to the substrate with a wire bond, wherein the wire bond passes through one of the wire bond openings in the stiffener.

11. A method of assembling a ball grid array (BGA) package, comprising the steps of:

providing a substrate that has a first surface and a second surface;

mounting an IC die to the first substrate surface;

attaching a plurality of solder balls to the second substrate surface;

coupling a first surface of a heat spreader to the second substrate surface; and

configuring a second surface of the heat spreader to be coupled to a printed circuit board (PCB).

12. The method of claim **11**, further comprising the step of coupling the first substrate surface to the heat spreader through at least one via that extends through the substrate.

13. The method of claim **12**, wherein said mounting step comprises the steps of:

exposing a copper plated die-attach pad to the center of the first substrate surface; and

mounting the IC die to the copper plated die-attach pad.

14. The method of claim **12**, wherein said step of coupling the first substrate surface to the heat spreader comprises the steps of:

exposing a copper plated plane to the center of the second substrate surface; and

coupling the die-attach pad to the copper plated plane with the at least one via.

15. The method of claim **11**, wherein said configuring step comprises the step of:

plating the second surface of the heat spreader with solder.

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