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ENHANCED RELIABILITY BALL GRID ARRAY PACKAGE

Field of the Invention

The present invention relates to integrated circuit packaging and more particularly, to ball-grid array packaging.

Background of the Invention

Current trends in electronic products toward size and cost reduction, and increased number of functions, have resulted in greater emphasis on the development of IC packaging technologies. Advantageously, such developments have led to a so-called "ball-grid array package." See U.S. Patent Nos. 5,045,921, 5,216,278, 5,241,133.

Fig. 1A shows an illustrative ball grid array package 10 disclosed in U.S. Patent No. 5,216,278. The packaging 10 includes an IC 18 mounted by adhesive 20 to a first carrier substrate 12. Bonding wires 22 are provided, including one bonding wire 22 for connecting each pad/terminal of the IC 18 to a respective conducting lead 48 formed on the first carrier 12. The conducting lead 48 provides a conducting path that is parallel to the plane of the top surface of the first carrier 12 on which the IC 18 is mounted. The first carrier 12 has a hole formed therethrough which is filled with an electrically conducting via 50. The via 50 provides a conducting path, that is normal to the top surface of the first carrier 12, from the lead 48 through to the bottom side of the first carrier 12.

The bottom surface of the first carrier 12 is mounted to a top surface of a second carrier 44. A conducting lead 46 is provided which connects to the via 50. The lead 46 extends the conducting path from the via 50 in a direction that is parallel to the top surface of the second

carrier 44. The second carrier 44 has a hole formed therethrough which is filled with an electrically conducting via 52. The via 52 provides a conducting path, that is normal to the top surface of the second carrier, from the lead 46 through to the bottom side of the second carrier 44. The second carrier has plural conducting pads 33 on its bottom surface, including the conducting pad 33 that is shown in Fig. 1. The conducting pad 33 extends the conducting path from the via 52, in parallel to the bottom surface of the carrier 44, to an electrically conducting solder ball 47. The solder ball 47 is preformed on the pad 33. In use, the package 10 is positioned in an appropriate mounting point of the PCB, with each solder ball 47 positioned over a corresponding conducting land of the PCB. Heat is applied to the solder balls 47 which reflow so as to electrically connect, and mount, the package 10 to the lands of the PCB. With the solder ball 47 reflowed, an electrical conduction path is provided from the pad of the IC 18, to bonding wire 22, lead 48, via 50, lead 46, via 52, pad 33 and reflowed solder "ball" 47 (the reflowing of the solder ball 47 changes its shape) to the appropriate land of the PCB.

However, a significant problem in the prior art BGA packages is a phenomena referred to as "popcorn cracking". Popcorn cracking occurs during surface mounting solder reflow at temperatures on the order of 225° degrees Celsius. In less severe cases, the die attach material may fracture or delamination may occur between the interfaces of the package, such as between the mold compound or encapsulant and the organic substrate, or between the die attach material and the silicon die or substrate. In particular, packages manufactured using plastic BGAs are even more susceptible to delamination and popcorn cracking than other plastic packages, such as QFP or SOJ, due to moisture absorption by the organic substrate. That is, plastic commonly used in the fabrication of BGA packages has an inherent tendency to absorb ambient moisture. The susceptibility of a BGA package to delamination and cracking is proportional to the amount of

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moisture absorbed, as cracking is primarily caused by the vapor pressure created by the moisture that has been absorbed at the solder reflow temperature.

Other factors may combine to aggravate the cracking. For example, high stresses caused by thermal mismatch and the evaporating moisture may weaken the interfacial adhesion between the packaging materials. This may subsequently lead to interfacial delamination. The expanding moisture may further aggravate the delamination, and may also increase pressure at the delaminated interfaces. The propagation of this delamination may cause the package to crack.

Several methods are commonly used to minimize the effects of popcorn cracking. One common solution is to simply pack and ship the BGA packages in hermetic bags to prevent the packages from absorbing moisture from the environment. However, if these bags are opened or the packages are otherwise exposed to the environment, the packages must be baked dry before the surface mounting process. These additional processes add to the overall cost of the package. Moreover, the shelf life of the package once removed from the hermetic bag is a finite amount of time.

Another method is to reduce the amount of metal used in the die pad area, which allows more contact area for the high strength bond between the silicon die and the molding compound. Yet another technique is to ramp the temperature more gradually during soldering to the printed circuit board. Still another technique used to minimize popcorn cracking is to plasma clean the BGA prior to the over-molding process. (*See* D.S. Chun, "Reduction of Popcorning in BGA's by Plasma cleaning," Proc. 1997 Pan Pacific Microelectronics Symposium). Other techniques involve increasing the adhesion strength between the encapsulation, lead frame, and silicon chip. (*See Generally* Samuel Kim, "The rose of Plastic Package Adhesion in IC Performance", Plaskon Electronic Materials, Rohm and Llaas Research Laboratories 1991).

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However, these above techniques tend to increase the overall complexity and time required to manufacture the BGA. Consequently, there is an increase in the total cost of the BGA package. Fig. 1D illustrates a plan view of a conventional BGA substrate design. Area 109 will subsequently have a silicon die attached thereto. The die 112 will be connected to conductive traces 105 by connecting wire bonds 108 to terminals 107 of the traces. This is shown in Fig. 1E. Fig. 1F shows a side view of the BGA package of Fig. 1E along the line A-A. As shown, silicon die 112 is attached to the substrate 106 by die bond 114.

A further solution in the prior art is shown in Fig. 1B and 1C. This BGA package is described in detail in Ahn, S.H., Kwon, Y.S., Shin, K.J. "Popcorn Phenomena in a Ball Grid Array Package", IEEE, 1994 ("the Ahn Reference"). Figs. 1B and 1C show alternative embodiments of the Ahn Reference. Both embodiments show a BGA package 100 with solder balls 102, electrically conductive vias 104, die 112, wire bond 108, encapsulation 110, and die bond 114. A plurality of vias may be used, although only on is shown. As shown in Fig. 1B, the thermal via 116 is open to both the die pad side and solder ball side. In another embodiment shown in Fig. 1C, the thermal via 116 is open to the die pad side but closed to the solder ball side by a solder resist layer 118.

At solder reflow temperatures, the moisture that has been absorbed will vaporize and exert a pressure at the die bond interfaces. These open thermal vias allow the pressure to be relieved during the reflow process. When the pressure is relieved, popcorn package cracking can be avoided. However, this technique poses a problem when attaching the die 112 with the die bond 114; namely, the die bond 114 may leak into the open thermal via 116 and 116'. When this occurs, the die bond integrity is jeopardized. This may be avoided by the use of, e.g., infrared (IR) tapes or any tape that can withstand the processing temperatures. However, this adds additional complication and thus ultimately increases the cost of the BGA. Further, the vias that

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are provided may provide a route for contaminants, such as corrosive agents, to enter into the package.

In yet another prior art design, U.S. Patent No. 5,729,050 describes a BGA package having tiny holes of about 0.1mm in diameter drilled in between spaces in the conductive traces. However, it is extremely difficult to provide holes in the highly dense area of the conductive traces. Further, forming holes in the conductive trace area will greatly limit the amount of possible holes and the size of each, thereby offering little delamination and cracking protection, if any.

It is therefore an object of the present invention to provide a BGA package that overcomes the problem of popcorn cracking.

It is a further object of the invention to provide the above BGA package without significantly increasing the steps required to manufacture the BGA.

It is yet another object of the present invention to provide the above BGA package without significantly increasing the overall cost of the package.

Summary of the Invention

These and other objects are achieved by the present invention. According to one embodiment, an integrated circuit package is provided with increased resistance to the popcorn cracking effect. This package comprises an insulating substrate, which further comprises a first side to which an integrated circuit is mounted, and a second, opposite side. The substrate includes a plurality of conducting paths extending from the first side through the substrate, to the second side, and are further connected to a plurality of solder balls. These solder balls are attached to the second side of the substrate. The substrate is provided with divider slots through

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the substrate between the first and second area on the substrate. The first area is the die attach area. The second area comprises the remainder of the substrate.

In one embodiment of the invention, these dividers are a series of interconnecting trenches which isolate the first and second areas. In another embodiment, those dividers are a series of through holes or slots of any convenient size or shape.

Brief Description of the Drawings

Fig. 1A shows a conventional BGA Package.

Fig. 1B BGA package known in the prior art.

Fig. 1C shows a second embodiment of the BGA package of Fig. 1B.

Fig. 1D shows a plan view of a third embodiment of a conventional BGA substrate design.

Fig. 1E shows a plan view of the third embodiment of a conventional BGA substrate package.

Fig. 1F shows a side view along A-A of the third embodiment of a conventional BGA substrate package.

Fig. 2 shows a cross sectional view of the BGA package of the present invention

Fig. 3 shows a plan view of a first embodiment of the present invention.

Fig. 4 shows a plan view of a second embodiment of the present invention.

Fig. 5A shows a plan view of a third embodiment of the present invention.

Fig. 5B shows a side view along A-A of the third embodiment of the present invention.

Fig. 6A shows a plan view of a fourth embodiment of the present invention.

Fig. 6B shows a side view along A-A of the fourth embodiment of the present invention.

Fig. 7 shows a plan view of a fifth embodiment of the present invention.

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Detailed Description of the Invention

Experience in the moisture sensitivity or popcorn reliability testing of conventional BGA packages has shown that under the condition in which the package has absorbed moisture and subjected to solder reflow temperature, BGA packages are very susceptible to delamination and package cracking. These may be grouped as follows: (1) The die attach material, typically a polymer, which bonds the silicon die to the substrate may fracture within itself under the action of the thermal and vapor stresses. Additionally, the silicon die/die attach interface or the die attach/substrate interface may become delaminated. Such fractures or delaminations tend to propagate into the mold compound/substrate interface, which is the subject of a second type of failure, it may propagate into the inner layers of the organic laminated substrate. (2) The mold compound or encapsulant delaminates from the substrate and propagates into the die attach area or to the package exterior, or the crack propagates into the inner layers of the substrate. The sketch below illustrates the various failure modes.

The present invention introduces divider slots between the silicon die and the wire bond terminal pads on the substrate. The purpose of the slots are to reduce or eliminate delamination or popcorn cracking the BGA packages by: (1) Providing a space for the mold compound or encapsulant to flow into the substrate as it encapsulates the silicon die, thereby providing mechanical anchors to reinforce the robustness of the silicon die-substrate assembly; (2) Substantially isolating that portion of the substrate on which the silicon die is mounted from the remaining part of the substrate, thereby reinforcing the robustness of the package; (3) Reinforcing the adhesion at the mold compound/substrate interface; and (4) Preventing any delamination, cracks or any other forms of physical damage from propagating along the mold compound/substrate interface, along the die attach/substrate interface, or into the inner layers of the substrate.

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Fig. 2 shows a BGA package according to the present invention. As shown, the package includes a substrate 212, an encapsulation 202, solder balls 208, a die attach area 206, a second area 204, divider slots 210, and bonding wires 216. An IC 218 is mounted to the die attach area 206. The IC 218 is mounted to a top surface on the die attach area 206 by, for example, die bond 214. The IC 218, top surface of the substrate 212, and divider slots 210 are covered by transfer molding or encapsulation 202. Multiple pads or terminals are provided on the IC 218. An Al or Au bonding wire 216 is provided for electrically connecting each IC pad to the second area 208.

Further, the die attach area 206 is substantially isolated from the surrounding second area 204 by the divider slots 210. As shown in Fig. 3, the divider slots 210 may be a series of slots or trenches, having diameters or widths greater than 0.1mm forming a rectangular annulus that substantially isolates the die attach area 206 from the second area 204.

In a second embodiment, as shown in Fig. 4, the divider slots 210' may be through holes, rather than a trench. These holes lie on a rectangular boundary between the die attach area 206 and the second area 204 and similarly substantially isolate the die attach area 206 from the second area 204. Moreover, although the divider slots 210, 210' are shown as defining a substantially rectangular shape, they may also define any convenient shape or size.

The purpose of the divider slots 210, 210' is to allow absorbed moisture to escape when heat is applied to the BGA package. A further advantage is achieved in that the divider slots 210, 210' are filled with the molding or encapsulation 202. This provides the specific advantage of prohibiting a route for contaminants, such as corrosive agents, to enter into the package.

In an experiment, a conventional BGA package was compared with the BGA of the present invention. Both were subjected to a IPC/JEDEC (Institute for Interconnecting and Packaging Electronic Circuits / Joint Electronic Devices Engineering Council) level 1_and IPC/JDEC level 3 test. The IPC/JEDEC level 1 test subjects a BGA package to 85 degrees

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Celsius, at 85% relative humidity for 168 hours followed by 3 times solder reflow (3xIR). An IPC/JEDEC level 3 test subjects the BGA package to 30 degrees Celsius at 60% relative humidity, for 192 hours. The experiment was conducted using a typical ball grid array with a substrate, referred to as FR4, and 255 terminals. As may be seen from the following results, an otherwise conventional BGA package without the divider slots of the present invention could not pass even the considerably milder level 3 test:

Popcorn Failure/Number of Tests Performed

BGA Package	Level 1	Level 3
Conventional BGA	6/6	6/6
BGA of the present invention	0/6	0/6

According to the standards, the popcorn sensitivity of a package is defined by its ability to retain its integrity (no cracks or delamination) after deliberately introducing moisture into the package and then subjecting the package to solder reflow temperatures. Essentially, the test simulates soldering packages with absorbed moisture onto PCBs. Thus, the test consists of subjecting packages to an environment of a specific temperature and relative humidity for a predetermined time period, and then subjecting the package to solder reflow temperatures, e.g., greater than 225 degrees C. The BGA packages of the present invention have been proven to have significantly higher popcorn sensitivity *vis-a-vis* the conventional BGA packages.

Therefore, the BGA package of the present invention provides significant protection against the popcorn cracking effect. However, the above-described embodiments of the present invention are intended to be illustrative only. Numerous alternative embodiments may be devised by those skilled in the art without departing from the spirit and scope of the following claims.

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CLAIMS

The claimed invention is:

1. A ball grid array package comprising;

a substrate having a first side and a second side, said first side having first and second regions,

a plurality of solder balls connected to said second side of said substrate,

a die pad for attaching an integrated circuit connected to said first region;

one or more divider slots through said substrate, said divider slots being arranged between said first and second regions to substantially isolate said first region from said second region, wherein said second regions comprises conductive traces.

2. The ball grid array package of claim 1 further comprising an encapsulation covering said first side and filling said divider slots.

3. The ball grid array package of claim 1, wherein said divider slots are a series of interconnected slots.

4. The ball grid array package of claim 1, wherein said divider slots are a series of non-interconnected through holes arranged on a boundary that separates said first and second regions.

5. The ball grid array package of claim 1, wherein said divider slots form an annular border around said first region.

6. The ball grid array package of claim 1, wherein said divider slots form a

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substantially rectangular border around said first region.

7. The ball grid array package of claim 1 wherein said one or more divider slots comprises substantially greater than half of the area between said first and second regions.

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