

DIE-PAD FOR BALL GRID ARRAY PACKAGE

Field of the Invention

5 The present invention relates to ball grid array packages.

Background of the Invention

10 in order to achieve a high density of electrical contacts over a small area of a substrate containing, for example a semiconductor chip, the electronics industry has moved towards applying solder balls to the bottom of the multi-layer organic substrate in order to form a ball grid array (BGA).

15 A conventional BGA package, as shown in FIGS. 1 and 2, includes a substrate 12 having a die-pad 14 (which is a flat planar area of the substrate 12) with a silicon die 16 (also known as a chip) mounted thereon (shown in phantom). The die-pad 14 is coated with a die-attach adhesive 18 which bonds the silicon die 16 to the die-pad 14. It will be appreciated by those skilled in the art that the die-pad 14 is that area of the substrate 12 that is below the die 16. Fracture in the adhesive material, or delamination at the adhesive-substrate interface, or the adhesive-silicon interface are the most common causes of BGA package failure, especially in the popcorn test.

20 The typical popcorn test, also known as the IPC (Institute for Interconnecting and Packaging Electronic Circuits)/JEDEC (Joint Electronic Device Engineering Council) moisture sensitivity test is performed by first baking the test BGA package dry. Next, moisture is introduced into the package by placing the package in an oven with temperature and percent relative humidity (RH) controls. After a predetermined number of hours in the oven, the package is removed. The specifications concerning number of hours, % RH, etc. are defined by standards bodies such as IPC and JEDEC
25 (described more fully below). The package with moisture therein is then subject to

a heating cycle similar to that a package is subjected to when mounted on a printed circuit board (PCB). This is typically repeated 3 times. The purpose of this heating is to melt the solder so that the package is affixed to the PCB. The package is then examined for defects such as cracking, delamination or other damage.

5 Popcorn package cracking is a common failure mode in plastic surface mount devices, including the BGA package. Such failures typically occur during surface mounting solder reflow at temperatures on the order of 225° C, for example. Plastic packages have the tendency to absorb moisture from the environment, and it is generally accepted that the susceptibility of a package to crack under these
10 conditions is proportional to the amount of moisture that the package has absorbed. The failure is typically caused by a combination of factors including the high stresses resulting from the mismatch in the coefficient of thermal expansion of the various materials, the loss of adhesion between dissimilar materials at elevated temperature and the presence of moisture, the ensuing vaporization and the expansion of the
15 moisture that has been absorbed, and the fracture toughness of the packaging materials. The high stresses caused by thermal mismatch and the evaporating moisture weaken the interfacial adhesion. Therefore, interfacial fracture or delamination often occurs. The expanding moisture aggravates the delamination, and at the same time imposes a high pressure at the delaminated interfaces. The
20 propagation of interfacial delamination causes the package to crack.

 As a result of the above mentioned failure modes, most conventional BGA packages can only pass the IPC/JEDEC Level 3 moisture sensitivity test. Some advanced packages can pass the Level 2 test, but Level 1 remains very challenging. Where RH stands for relative humidity and IR stands for infra red (3xIR means that
25 the package is subject to infra red heating 3 times) the IPC/JEDEC moisture sensitivity tests are as follows:

- Level 1 - 85°C/85% RH for 168 Hours + 3xIR
- Level 2 - 85°C/65% RH for 168 Hours + 3xIR
- 30 Level 3 - 30°C/60% RH for 192 Hours + 3xIR

Many attempts to overcome these disadvantages have been proposed. For example, some BGA packages are shipped in hermetically sealed bags to prevent the packages from absorbing moisture from the environment. Also BGA packages are often baked before surface mounting in an attempt to eliminate moisture therein.

5 Both of these processes add to manufacturing costs.

Other attempts to eliminate the above-described problems involve increasing the adhesion strength between the substrate and the encapsulating material, and between the substrate and the adhesive/die-attach material. This can be done by cleaning the BGA with a plasma process before encapsulation, or by chemically

10 modifying the substrate surface by graft copolymerization. These processes are expensive and also add to manufacturing costs.

Further attempts involve providing minute through-holes in the substrate in the area directly below the die-attach material and the die which provide a path for the vaporizing moisture to escape through at solder reflow temperatures, thereby

15 avoiding a pressure build-up and popcorn package cracking.

A long felt need exists for a BGA package that minimizes instances of package cracking without substantial additional costs in the manufacturing process when compared with the related art.

Summary of the Preferred Embodiments

In accordance with a first embodiment of the present invention there is provided a substrate having first and second major faces to be affixed to a die of a ball grid array package having solder balls. The substrate includes a die-pad for receiving an adhesive. The die-pad has defined therein at least one recess extending from the first major face toward the second major face

In a preferred embodiment at least one recess extends between the first major face and the second major face. In another preferred embodiment, the substrate includes a plurality of openings symmetrically disposed about a center point thereof.

In accordance with another preferred embodiment of the present invention there is provided a ball grid array package that includes a substrate having top and bottom faces and a die-pad for receiving an adhesive, a die affixed to the die-pad by the adhesive, and at least one solder ball proximate a bottom face of the substrate. The surface mount area has defined therein at least one recess extending from the top face toward the bottom face.

Other objects, features and advantages of the present invention will become apparent to those skilled in the art from the following detailed description. It is to be understood, however, that the detailed description and specific examples, while indicating preferred embodiments of the present invention, are given by way of illustration and not limitation. Many changes and modifications within the scope of the present invention may be made without departing from the spirit thereof, and the invention includes all such modifications.

Brief Description of the Drawings

The invention may be more readily understood by referring to the accompanying drawings in which

FIG. 1 is a bottom plan view of a prior art ball grid array package with the solder balls removed for sake of clarity.

FIG. 2 is a cross-sectional view taken along line 2--2 of FIG. 1.

FIGS. 3A-3F are a series of cross-sectional side views showing the typical assembly of a ball grid array package.

FIG. 4 is a bottom plan view of a ball grid array package having an opening in the substrate thereof in accordance with a first embodiment of the present invention
5 with the solder balls removed for the sake of clarity.

FIG. 5 is a cross-sectional view taken along line 5--5 of FIG. 4.

FIG. 6 is a bottom plan view of a ball grid array package having a plurality of openings in the substrate thereof in accordance with a second embodiment of the present invention with the solder balls removed for the sake of clarity.

10 FIG. 7 is a cross-sectional view taken along line 7--7 of FIG. 6.

FIG. 8 is a bottom plan view of a ball grid array package having a plurality of openings in the substrate thereof in accordance with a third embodiment of the present invention with the solder balls removed for the sake of clarity.

FIG. 9 is a cross-sectional view taken along line 9--9 of FIG. 8.

15 FIG. 10 is a bottom plan view of a ball grid array package having an opening in the substrate thereof in accordance with a fourth embodiment of the present invention with the solder balls removed for the sake of clarity.

FIG. 11 is a cross-sectional view taken along line 11--11 of FIG. 10.

20 FIG. 12 is a bottom plan view of a ball grid array package having a plurality of openings in the substrate thereof in accordance with a fifth embodiment of the present invention with the solder balls removed for the sake of clarity.

FIG. 13 is a cross-sectional view taken along line 13--13 of FIG. 12.

25 FIG. 14 is a cross-sectional view of the ball grid array package of FIGS. 4 & 5 having a heat sink disposed in the opening of the substrate thereof in accordance with yet another embodiment of the present invention.

FIG. 15 is an enlarged cross-sectional view of a portion of FIG. 14 showing the channel defined between the heat sink and substrate.

30 FIG. 16 is a cross-sectional view of the ball grid array package of FIGS. 6 & 7 having a heat sink disposed in the opening of the substrate thereof in accordance with a further embodiment of the present invention.

Like numerals refer to like parts throughout the several views of the drawings.

Detailed Description of the Preferred Embodiments

5 With reference generally to FIGS. 3A-16 a plurality of embodiments of improved ball grid array packages will be shown and described. The ball grid array packages generally include a substrate 12 (common to the related art as shown in FIGS. 1 and 2) including a die-pad 14, a die 16, typically made of silicon, an adhesive 18 affixing the die 16 to the die-pad 14 and a plurality of solder balls 20 adjacent the bottom of substrate 12.

10 For purposes of understanding a typical ball grid array package assembly will be described. FIGS 3A-3G illustrate the steps employed in a typical ball grid array package assembly process. It will be understood that the assembly process is not a limitation on the present invention. First, the desired substrate 12 is selected, as shown in FIG. 3A. The adhesive 18 is then disposed onto the die-pad area 14 of the
15 substrate 12 as shown in FIG. 3B. The adhesive 18 can be an epoxy or other adhesive known in the art, for example, a polyimide, polymeric paste or other polymeric material. The die 16 is then placed on the adhesive 18, as shown in FIG. 3C, and the adhesive is cured at an appropriate temperature so that the adhesive 18 is set. Lead wires 19 are then applied to electrically connect the die 16 to the
20 substrate 12 as shown in FIG. 3D. This process is called wire bonding. The die 16 is then encapsulated by a molding compound 22 as shown in FIG. 3E. It will be understood that any of the above components (substrate 12, die-pad 14, die 16 and adhesive 18) or a portion thereof may be encapsulated by a molding compound 22, such as an epoxy molding compound to provide protection and enhance the package
25 reliability. The solder balls 20 are placed adjacent the bottom of the substrate 12 and are then reflowed to attach them thereto as shown in FIG. 3F.

In operation, the ball grid array package is surface mounted. An appropriate surface is selected, such as that of a printed circuit board (PCB) or printed wiring board (PWB). Solder paste 21 is applied to the surface of the PCB 23 at locations
30 corresponding to the solder balls 20 of the ball grid array package as shown in FIG.

3G. The solder balls 20 are then reflowed or appropriately melted to bond the ball grid array package to the PCB, thereby providing the desired electrical contacts.

It will be appreciated that terms such as "bottom" and "top" used hereinbelow are used merely for ease of description and refer to the orientation of the components as shown in the Figures. It should be understood that any orientation of the ball grid array package described herein is within the scope of the present invention.

With particular reference to FIGS. 4-5, according to a first embodiment of the present invention, the ball grid array package 10 has an opening 24 defined transversely through the center of the die-pad 14 and the substrate 12 thereof. Opening 24 can be defined in substrate 12 by mechanical means such as sawing, stamping, routing or other known method. Alternatively, opening 24 can be defined only through a portion of substrate 12. As illustrated, the opening 24 may be contiguous with the substrate 12 through which it is defined. However, it should be understood that the opening 24 can be defined such that it is offset from a central through hole of substrate 12. Alternatively, opening 24 can be defined such that when viewed from the bottom it is surrounded by the substrate 12 on only three sides.

Opening 24 reduces the surface area of the die-pad 14, thereby reducing the surface area over which adhesive 18 can be disposed for securing die 16 thereto. The reduced amount of surface area over which adhesive 18 can be disposed minimizes the risk of package cracking originating from the die 16 - die-pad 14 interface or die-attach area. As explained above, package cracking often results from heat generated expansion and movement of the various materials comprising the elements of the package. In particular, the cracking often results from differences in the thermal coefficients of expansion between the adhesive 18 and the interfacing die 16 and die-pad 14. For example, while the adhesive 18 cures, thermal shrinkage and/or expansion stresses are created which can result in large tensile and shear forces being imposed on the die and/or die-pad. Therefore, with a reduced interface surface area between the adhesive 18 and the die 16 and die-pad 14, lower stresses are generated, thereby minimizing package cracking and crack propagation.

Furthermore, the portion of the die 16 corresponding to the opening 24 is left exposed, thereby creating better heat dissipation from die 16 to the outside air. Alternatively, opening 24 may be partially or completely filled with molding compound 22, thereby further increasing package reliability. The molding compound 22 is preferably a thermoset compound. The package is typically subjected to a curing process at elevated temperatures typically on the order of 170° C for several hours in order for the thermoset compound to complete the cross-linking of the polymeric chains. It will be understood that other molding compounds known to those in the art are within the scope of the present invention.

FIGS. 6-13 show embodiments of the present invention having various opening configurations. Each of the various opening configurations are designed such that in different uses of the BGA package, any directional expansion of the materials of the substrate 12, die 16 or die-pad 14 is minimized. FIGS. 6 and 7 show a second embodiment of a BGA package 26. BGA package 26 has a window-pane opening configuration 26.

FIGS. 8-9 show a third embodiment of a BGA package 30. BGA package 30 also has a window pane opening configuration 32, but the individual openings are spaced further apart than in the second embodiment 26. Also, in BGA package 30, the openings 32 are at least partially encapsulated by mold compound 22. It will be understood that in any embodiment of the present invention described herein the opening(s) can be at least partially encapsulated by mold compound 22 or other encapsulant to increase the package reliability and durability and protect the die 16.

FIGS. 10-11 show a fourth embodiment of a BGA package 34. BGA package 34 includes an opening 36 having a plurality of tabs 38 extending inwardly from the corners thereof. The tabs 38 provide the die-pad 14 to which the die 16 can be attached. Using these tabs 38 minimizes the die-attach area and maximizes the exposed area of the die 16 for heat dissipation and reduction in package cracking. It will be understood that any number and configuration of tabs 38 is within the scope of the present invention.

FIGS. 12-13 show a fifth embodiment of a BGA package 40. BGA package 40 includes an opening configuration 42 having four trapezoid shaped openings that are symmetrically spaced about a center point of the die-pad 14.

5 It will be understood that the opening configuration in the substrate 12 and die-pad 14 is not a limitation on the present invention. Any opening configuration that reduces the surface area of the die-pad 14 at the die - die-pad interface is within the scope of the present invention. For example, the opening can be square, rectangular, keystone, window-pane, circular, triangular or any other geometric shape. The above described embodiments are merely exemplary of different opening configurations
10 within the scope of the present invention.

In another embodiment, as shown in FIGS. 14-16, a heat spreading material or heat sink 44 may be disposed in the opening in the substrate 12 to further aid in heat dissipation from the silicon die 16. FIG. 14 illustrates the first embodiment BGA package 10 described above with the heat sink 44 disposed in opening 24. The heat
15 sink 44 can be made of a metal, such as copper, aluminum or alloys thereof. The heat sink 44 conducts heat away from the die 16 to prevent the die 16 from overheating. In a preferred embodiment, as illustrated in FIG. 15, the heat sink 44 is spaced from the substrate 12, thereby defining a channel 45 therebetween. Heat and moisture vapor are vented through this channel 45.

20 FIG. 16 illustrates the second embodiment BGA package 26 described above with the heat spreading material 44 disposed in the opening configuration 28.

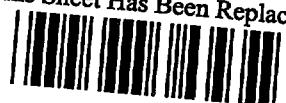
It will be appreciated by those skilled in the art that other applications wherein a substrate similar to that described above is employed, such as, wire bonding or flip-chip bonding are within the scope of the present invention. Any substrate wherein
25 openings, whether singular or plural, are defined in the die-pad area of the substrate is within the scope of the present invention.

The present invention provides the following advantages: Minimized risk of BGA package failure due to popcorn package cracking, reduced need for packing BGA packages in hermetic bags to prevent absorption of moisture, reduced need for baking
30 dry the BGA packages before packing or surface mounting, and manufacturing costs

- 10 -

savings. In accordance with the IPC/JEDEC moisture sensitivity tests described above, the present invention more readily passes the Level 1 test than conventional BGA packages.



This Sheet Has Been Replaced


- 11 -

What is claimed is:

1. A substrate having first and second major faces to be affixed to a die of a ball grid array package having solder balls, said substrate comprising a die-pad for receiving an adhesive, said die-pad having defined therein at least one recess
5 extending from said first major face toward said second major face.
2. The substrate of claim 1 wherein said at least one recess extends between said first major face and said second major face.
- 10 3. The substrate of claim 1 including one recess extending from said first major face toward said second major face.
4. The substrate of claim 1 including a plurality of recesses extending from said first major face toward said second major face.
15
5. The substrate of claim 1 including an array of recesses extending from said first major face toward said second major face, wherein said array of recesses are positioned for directional expansion.
- 20 6. The substrate of claim 1 including an array of recesses extending from said first major face toward said second major face, wherein said array of recesses are disposed about a center point of said substrate.
7. The substrate of claim 6 wherein said array of recesses are disposed
25 symmetrically about said center point of said substrate.
8. The substrate of claim 7 wherein said array of recesses includes four square shaped recesses.

THIS SHEET HAS BEEN
REPLACED



This Sheet Has Been Replaced



- 12 -

9. The substrate of claim 7 wherein said array of recesses includes four trapezoid shaped recesses.

5 10. The substrate of claim 3 wherein said recess includes at least one tab extending inwardly from a periphery of said recess.

11. The substrate of claim 10 wherein said recess includes an array of tabs extending inwardly from a periphery of said recess.

10 12. A ball grid array package comprising:

- a) a substrate including top and bottom faces and a die-pad for receiving an adhesive, said die-pad having defined therein at least one recess extending from said top face toward said bottom face,
- c) a die affixed to said die-pad by said adhesive, and
- 15 d) at least one solder ball proximate said bottom face of said substrate.

13. The ball grid array package of claim 12 wherein said at least one recess extends between said top face to said bottom face.

20 14. The ball grid array of claim 13 wherein said substrate includes one recess extending therethrough.

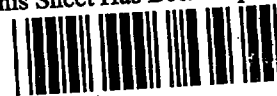
15 25 15. The ball grid of claim 13 wherein said substrate includes a plurality of recesses extending therethrough.

16. The ball grid array of claim 13 further comprising a heat dissipating material disposed in at least a portion of said at least one recess in said at least one recess in said substrate.

THIS SHEET HAS BEEN
REPLACED



This Sheet Has Been Replaced



- 13 -

17. The ball grid array of claim 12 further comprising a molding compound surrounding at least a portion of said die.

5 18. A ball grid array for use with a substrate having first and second major faces to be affixed to a die of a ball grid array package having solder balls, said substrate comprising a die-pad for receiving an adhesive, said die-pad having defined therein at least one recess extending from said first major face toward said second major face.

10 19. A method of manufacturing a ball grid array package, said method comprising the steps of:

- (a) selecting a substrate including a die-pad,
- (b) defining an opening in said die-pad,
- (c) adhering a die to said die-pad, and
- 15 (d) disposing at least one solder ball proximate a bottom face of said substrate.

THIS SHEET HAS BEEN
REPLACED