

METAL BALL GRID ELECTRONIC PACKAGE

This invention relates to metallic components for a ball grid array electronic package. More particularly, the bending of that component is reduced minimizing solder ball fracture due to fatigue.

Ball grid array electronic packages are used to house one or more integrated circuit devices, such as silicon based semiconductor chips. The packages have a base component with a plurality of metallized circuit traces. A semiconductor device is bonded to a central portion of the base component and electrically interconnected to inner ends of the circuit traces. The opposing outer ends of the circuit traces form an array. Solder balls are bonded to the points of the array. Those solder balls also bond the package to an external structure, such as a printed circuit board. A cover encapsulates the central portion of the base component, the semiconductor device and the inner ends of the circuit traces.

Typically, the base component is formed from plastic, as disclosed in U.S. Patent No. 5,241,133 to Mullen, III et al., ceramic, or metal as disclosed in PCT International Publication No. WO96/02942, published February 1, 1996.

If the coefficient of thermal expansion of the electronic package base and of the external structure is different, fatigue related fracture of the solder balls may occur. Heating of the various components as a result of the semiconductor device generating heat during operation causes differential expansion of the various components to occur,

resulting in stress on the solder balls. Cyclical repetition of this stress propagates cracks through the solder ball. When a crack extends across the diameter of a solder ball, the package fails.

5 Solder ball fatigue has been studied in plastic and ceramic base components for ball grid array packages. In a ceramic package, the stresses applied to the solder ball are parallel to the bonding plane of the base component and the solder
10 balls in the row closest to the outer perimeter of the base fracture first. The increased distance from the center of the package to this outer row enhances the stress applied to the solder balls by thermally inducing movement of the package base.

15 One mechanism to reduce solder ball fatigue in a ceramic base component is disclosed in U.S. Patent No. 4,581,680 to Garner. The Garner patent discloses that by increasing the height of the solder balls in the outer rows, the elastic limit of
20 the solder joint is increased.

The Garner solution is inapplicable to metallic base components of ball grid array packages. With a metallic base, solder ball fracture is expected to occur in solder balls in the innermost row.

25 In a plastic package, the row of solder balls underlying the perimeter of the semiconductor device typically fail first.

There exists, therefore, a need to develop metal ball grid array package components that resist
30 solder ball fatigue while retaining the thermal conductivity advantage of metal.

Accordingly, it is an object of the invention to provide a metallic ball grid array electronic

package that reduces the stresses applied to solder balls and reduces solder ball fatigue and fracture.

It is a feature of the invention that the bending of the ball grid array package base is
5 reduced by one or more of the following:

- (1) forming the base with an integral stiffener;
- (2) bonding a cover component to an external structure; or
- 10 (3) forming a stress relieving depressed portion in the base.

An advantage of the invention is that the bending moment is reduced, reducing stresses applied to the solder balls. This reduces solder ball
15 fatigue and solder ball fracture, thereby reducing device failure.

In accordance with the invention, there is provided a component for an electronic package. The component has a first horizontal portion and a
20 second horizontal portion integral with the first. The first horizontal portion includes a plurality of metallized circuit traces. The second horizontal portion has a coefficient of thermal expansion less than that of the first horizontal portion.

25 In one embodiment of the invention, the base component has a semiconductor device bonded to a central portion and electrically interconnected to the inner ends of the metallized circuit traces. Solder balls are bonded to the outer ends of the
30 metallized circuit traces and a cover component encapsulates the semiconductor device and the inner portion of the circuit traces. The cover is bonded to an external structure.

In another embodiment of the invention, the ball grid array package base has a peripheral portion and a central portion with a depressed portion disposed therebetween.

5 The above stated objects, features and advantages will become more apparent from the specification and drawings that follow.

Figure 1 illustrates in cross-sectional representation a ball grid array electronic package
10 as known from the prior art.

Figure 2 illustrates in cross-sectional representation the bending of a metal ball grid array electronic package base.

Figure 3 illustrates in cross-sectional representation a structure to reduce the bending
15 moment of the package base in accordance with a first embodiment of the invention.

Figure 4 illustrates in cross-sectional representation a structure to reduce the bending
20 moment of the package base in accordance with a second embodiment of the invention.

Figure 5 illustrates in cross-sectional representation a structure to reduce the bending
moment of the package base in accordance with a
25 third embodiment of the invention.

Figure 6 illustrates in cross-sectional representation a structure to reduce the bending
moment of the package base in accordance with a
fourth embodiment of the invention.

30 Figure 1 shows in cross-sectional representation a ball grid array electronic package 10 as known from the prior art. The package 10 has a metallic base 12 that is usually formed from

copper, aluminum or an alloy thereof. Surrounding the metal base 12 is a dielectric layer 14. When the metal base 12 is an aluminum alloy, a preferred dielectric layer is an anodic film having a
5 thickness of from about 5 microns to about 50 microns.

The metal base 12 has a central portion 16 that is preferably, as illustrated in Figure 1, depressed and is surrounded by a peripheral portion 18. A
10 semiconductor device 20 is bonded to the central portion 16 by a suitable die attach 22 such as a polymer adhesive.

Metallized circuit traces 24 extend from the central portion 16 to the peripheral portion 18.
15 The semiconductor device 20 is electrically interconnected to the inner ends of the metallized circuit traces that are adjacent to the central portion 16. Electrical interconnection is by any conventional means such as wire bonds, thin strips
20 of copper foil as utilized in tape automated bonding or by direct attachment to input/output pads on the semiconductor device such as in flip chip bonding.

A cover 26 that can be a polymer resin or an adhesively joined discrete component then
25 encapsulates the semiconductor device 20 and the inner ends of the metallized circuit traces 24.

The package 10 is bonded to an external structure, such as a printed circuit board 30. The printed circuit board 30 has a dielectric substrate
30 32 formed from ceramic or a glass-filled epoxy resin. Metallized circuit traces 34 form an array pattern that aligns with the array pattern formed by the outer ends of the metallized circuit traces 24.

Solder balls 36, typically a lead/tin alloy, both bond and electrically interconnect the two arrays.

When an electric signal passes through the semiconductor device 20, a portion of the electric energy is converted into heat. This heat passes into the metal base 12 and from there into the other package components, causing all components to expand by different amounts.

Figure 2 illustrates in cross-sectional representation alternative positioning of the metal base 12. The broken line indicates the metal base 12 at ambient (20°C) temperature. The solid outline indicates, in exaggerated fashion, how the metal base 12 deforms when heated. Unlike plastic bases, that have a coefficient of thermal expansion about equal to that of the printed circuit board 30, the aluminum bends. The results of this distortion is that the innermost row 38 of solder balls are stretched in the Z (perpendicular to the plane of the metallized circuit traces 24) direction. Each row of solder balls 36 progressively outward from the innermost row 38 is stressed in the Z direction to a progressively less extent.

The result of the stressing of the innermost row 38 is that in a ball grid array electronic package having an aluminum alloy base, the innermost row is calculated to fail after about 2,600 thermal cycles. The outermost row will survive approximately 56,000 thermal cycles before failure. By reducing the bending, the distance "D" between the position of the central portion 16 in the two alternative configurations of Figure 2 and the Z direction stress on the innermost row 38 of solder

balls 36 are both reduced. Figures 3-6 illustrate electronic package structures achieving this result.

Figure 3 illustrates in cross-sectional representation a metal ball grid array electronic package 40 in accordance with a first embodiment of the invention. Many of the structures of the metal ball grid array package 40 are similar to those of the package 10 of Figure 1 and are identified by like reference numerals. The base component 42 of the package 40 is a composite material having a first horizontal portion 44 and an integral second horizontal portion 46. Attachment between the first 44 and second 46 horizontal portions may be by bonding (i.e., brazing, soldering, polymer adhesive or cladding) or by chemical interaction (i.e., chemical vapor deposition or chemical conversion coating).

The metallized circuit traces 24 are formed on the first horizontal portion 44 with a dielectric layer 14 disposed therebetween. To reduce the bending, the second horizontal portion 46 has a lower coefficient of thermal expansion at the temperature the base 42 attains by semiconductor device 20 heating during operation. Typically, this temperature is about 90°C. The bimetallic base structure bends when heated in a direction opposite to the bending direction of the base illustrated in Figure 2.

Preferably, the second portion has a higher modulus of elasticity, is stiffer, than the first portion.

In one embodiment, the second horizontal portion 46 is copper or a copper alloy and the first

horizontal portion 44 is aluminum or an aluminum alloy. The first horizontal portion 44 is relatively thin when compared to the thickness of the second horizontal portion. The ratio of the maximum thickness of the first horizontal portion 44 to the maximum thickness of the second horizontal portion 46 is from about 1:5 to 1:10 and, preferably, from about 1:6 to about 1:8. The two portions are joined together by a process such as cladding.

Alternatively, the first horizontal portion is applied by a deposition process such as plasma vapor deposition or jet vapor deposition. Typically, the second horizontal portion is copper or a copper alloy and, in this embodiment, the first horizontal portion is aluminum or a ceramic such as aluminum oxide, aluminum carbide, aluminum nitride, silicon carbide, silicon nitride or a diamond-like film. In this embodiment, the thickness of the first horizontal portion is much less than that of the second horizontal portion 46. The ratio of the thickness of the first horizontal portion 44 to thickness of the second horizontal portion 46 is from about 1:100 to 1:1000 and, preferably, from about 1:200 to about 1:400.

When the first horizontal portion 44 is a ceramic, glass or other insulative layer, it is not necessary to provide the dielectric layer 14. Also, since the ceramics and glasses are stiffer than most metals, in this embodiment, it is not necessary for the elastic modulus of the second horizontal portion 46 to be greater than that of the first horizontal portion 44.

In a second embodiment, illustrated in Figure 4, the metal ball grid array electronic package 50 has a cover component 52 that encapsulates the semiconductor device 20 and the inner ends of the metallized circuit traces 24. To reduce the bending moment, the cover component 52 is bonded to an external structure such as a printed circuit board 30. Bonding of the cover component 52 to the external structure 30 is by any conventional means such as a polymer adhesive 54 or a solder or a braze.

The polymer adhesive 54, or alternative bonding means, need not extend over the entire surface area of the cover 52, but may affix the cover, only in a central portion, a peripheral portion or any combination thereof.

Figure 5 illustrates in cross-sectional representation, a third embodiment of the invention. The metallic base 62 of the metal ball grid array electronic package 60 contains a depressed portion 64 disposed between the central portion 16 and peripheral portion 18. This depressed portion 64 functions as a stress relief moat to reduce the amount of force transmitted from the center of the package to the solder balls 36. Preferably, the depressed portion 64 is filled with a molding resin and typically the filler is a portion of the cover component 66.

Alternatively, rather than a continuous moat, a series of holes or slots extending into the base about the perimeter of the central portion provides the stress relief.

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A stress relieving moat for a glass sealed electronic package is disclosed in U.S. Patent No. 5,315,155 to O'Donnelly et al. and a moat to prevent die attach adhesive from contacting the inner leads of a leadframe is disclosed in U.S. Patent No. 5,239,131 to Hoffman et al.

In an embodiment illustrated in cross-sectional representation in Figure 6, a metal ball grid array electronic package 70 includes a heat spreader 72. The metallic base 12 has a plurality of circuit traces 24 integral with a first side 74 thereof. One or more semiconductor devices 20 are also bonded to the first side 74. The heat spreader 72 is bonded to the opposing second side 76 of the metallic base 12. The heat spreader 72 at least covers that portion of the second side 76 opposite the central portion 16 where the semiconductor device 20 is bonded. However, the heat spreader 72 may extend over the entire opposing second side 76 and, in preferred embodiments, extends down the sidewalls 78 of the metallic base 12 and is bonded, such as by an adhesive 80, to an external structure such as the printed circuit board 30.

While the preceding embodiments disclose a plastic molding resin as the cover component, it is within the scope of the invention for any of the embodiments to include a discrete cover 81 that may be any suitable plastic, metal, ceramic, or composite or compound thereof, bonded 82 to the metallic base 12 to encapsulate the semiconductor device 20 and the inner ends of the metallized circuit traces 24.

While the invention has been described in terms of ball grid array electronic packages, it is equally applicable to other leadless electronic package such as pad grid array packages and pin grid array packages.

The benefits of the invention will become more apparent from the Example that follows. The Example is exemplary and not intended to limit the scope of the invention.

10

EXAMPLE

The number of thermal cycles required to cause solder ball fracture was calculated using Finite Element Modelling taking into consideration the coefficient of thermal expansion and other physical properties of the package components and of the external structure, a glass-filled epoxy printed circuit board. The yield strength and the strain-hardening characteristics of a lead/tin alloy solder were also considered. More detail on the Finite Element Modeling techniques to calculate solder ball failure in a ball grid array electronic package is found in Chapter 13 of Ball Grid Array Technology by John H. Lau that was published in 1995. The four packages evaluated are as follows:

Package A - This package was similar to the metal ball grid array package 10 illustrated in Figure 1 and has a 1.02mm (0.040 inch) thick base formed from aluminum alloy 5086 (nominal composition, by weight, 4.0% magnesium, 0.4% manganese, 0.15% chromium and the balance aluminum). The central portion of the metallic base was in the form of a cavity having a

depth of 0.71mm (0.028 inch). The metallic base was square and had a length and width of 13.5mm (0.5315 inch). The cavity forming the central portion was also a square and had a length and width of 5.74mm
5 (0.2259 inch).

Disposed on the peripheral portion were four rows of solder balls extending from an innermost row, closest to the central portion and designated as row 1 to an outermost row, closest to the
10 sidewalls of the metallic base and designated as row 4.

Package B - This package was similar to Package A except that the metallic base 12 was formed from copper rather than an aluminum alloy.

15 Package C - This package was similar to the metal ball grid array package 40 illustrated in Figure 3. The first horizontal portion 44 was aluminum with a thickness of 0.13mm (0.005 inch) and the second horizontal portion 46 was copper with a thickness of
20 0.89mm (0.035 inch). The other package dimensions were similar to Package A.

Package D - This package was similar to Package A except the molded plastic cover was bonded to a glass-filled epoxy resin printed circuit board as
25 illustrated in Figure 4.

For each model, the packages were thermal cycled with each cycle comprising:

- heating the package to 100°C in 5 minutes;
- holding the package at 100°C for 5 minutes;
- 30 • cooling the package to 0°C in 5 minutes; and
- holding the package at 0°C for 5 minutes.

The cycle was repeated and the number of cycles to predicted failure calculated from the Finite

Element Model results. For each package, the following were calculated:

- 5 Characteristic life - the number of cycles required to form a crack equal to the diameter of a solder ball.
- Failure-free life - one-half the characteristic life.
- Row reliability - an estimate of the number of cycles before a solder ball in a given row fails
- 10 accounting for the number of solder balls per row.
- Component reliability - the lowest of the four row reliability values.

As shown in Table 1, both Package C and Package D increased the Characteristic life of the row 1

15 solder balls. The most dramatic improvement was with package D.

TABLE 1

Package Description		Predicted Cycle to Failure			
		Row 1	Row 2	Row 3	Row 4
Package A	Characteristic life	2611	21997	135573	55881
	Failure free life	1306	10998	67786	27941
	Row reliability	1591	13275	81161	33223
	Component reliability	1591			
Package B	Characteristic life	3372	5350	6432	6695
	Failure free life	1686	2675	3216	3347
	Row reliability	2055	3229	3851	3980
	Component reliability	2055			
Package C	Characteristic life	4361	21215	48773	41757
	Failure free life	2180	10607	24386	20879
	Row reliability	2657	12803	29198	24826
	Component reliability	2657			
Package D	Characteristic life	45681	62241	60265	30738
	Failure free life	22840	31120	30133	15369
	Row reliability	27837	37563	36078	18274
	Component reliability				18274

It is apparent that there has been provided in accordance with this invention a ball grid array electronic package having a metallic base with improved solder joint reliability that fully

5 satisfies the objects, features and advantages set forth hereinbefore. While the invention has been described in combination with specific embodiments and examples thereof, it is evident that many alternatives, modifications and variations will be

10 apparent to those skilled in the art in light of the foregoing description. Accordingly, it is intended to embrace all such alternatives, modifications and variations as fall within the spirit and broad scope of the appended claims.

WE CLAIM:

1. A component for an electronic package (40), characterized by:
 - a bimetallic substrate (42) having a first
5 horizontal portion (44); and
 - a second horizontal portion (46) integral with said first horizontal portion (44) wherein said first horizontal portion (44) includes a plurality of metallized circuit traces (24) and said second
10 horizontal portion (46) has a coefficient of thermal expansion that is less than the coefficient of thermal expansion of said first horizontal portion (44).
2. The component of claim 1 characterized in
15 that the ratio of the maximum thickness of the first horizontal portion (44) to the maximum thickness of the second horizontal portion (46) is from about 1:5 to 1:10.
3. The component of claim 2 characterized in
20 that said first horizontal component (44) is aluminum or an aluminum alloy and said second horizontal component (46) is copper or a copper alloy.
4. The component of any one of claims 1-3
25 characterized in that said first horizontal component (44) is clad to said second horizontal component (46).



5. A component for an electronic package (40), characterized by:

a ceramic first horizontal portion (44) selected from the group consisting of aluminum nitride, aluminum carbide, silicon nitride, silicon carbide and diamond-like film; and

a metallic second horizontal portion (46) integral with said first horizontal portion (44) wherein said first horizontal portion (44) includes a plurality of metallized circuit traces (24).

6. The component of claim 5 characterized in that said second horizontal portion (46) is aluminum or an aluminum alloy.

7. A component for an electronic package (40), characterized by:

a ceramic first horizontal portion (44) selected from the group consisting of aluminum oxide, aluminum nitride, aluminum carbide, silicon nitride and diamond-like film; and

a copper or copper alloy second horizontal portion (46) integral with said first horizontal portion wherein said first horizontal portion (44) includes a plurality of metallized circuit traces (24).

8. The component of either claim 6 or claim 7 characterized in that the ratio of the thickness of said first horizontal portion (44) to the thickness of said second horizontal portion (46) is from about 1:100 to 1:1000.



9. A ball grid array electronic package (40), characterized by:

a base component (42) having a first horizontal portion (44) integral with a second horizontal portion (46) wherein said first horizontal portion (44) includes a plurality of metallized circuit traces (24) extending from a peripheral portion (18) of said base (44) to a central portion (16) thereof, and said second horizontal portion (46) has a coefficient of thermal expansion that is less than the coefficient of thermal expansion of said first horizontal portion (44);

a plurality of solder balls (36) bonded to said metallized circuit traces (24) at a peripheral portion (18) of said base (42);

a semiconductor device (20) electrically interconnected to said metallized circuit traces (24) and bonded to a central portion (16) of said base (44); and

a cover component (26) encapsulating said semiconductor device (20) and a portion of said circuit traces (24), said cover (20) further bonded to an external structure (30).

10. The electronic package (40) of claim 9 characterized in that the ratio of the maximum thickness of the first horizontal portion (44) to the maximum thickness of the second horizontal portion (46) is from about 1:5 to 1:10.



11. The electronic package (40) of claim 10 characterized in that said first horizontal portion (44) is aluminum or an aluminum alloy and said second horizontal portion (46) is copper or a copper alloy.

12. The electronic package (40) of claim 9 characterized in that said first horizontal portion (44) is ceramic and said second horizontal portion (46) is a metal or metal alloy.

13. A ball grid array electronic package (60), characterized by:

a base component (62) having a peripheral portion (18) and a central portion (16) with a depressed portion (64) disposed therebetween;

a plurality of circuit traces (24) having a peripheral end and an inner end, said inner end adjacent said depressed portion (64);

a semiconductor device (20) bonded to said central portion (16) of said base component (62) and electrically interconnected to inner ends of said circuit traces (24);

a plurality of solder balls (36) bonded to said peripheral ends of said circuit traces (24); and

a cover component (26) encapsulating said central portion (16) and said depressed portion (64) of said base (62) and said inner ends of said circuit traces (24).

14. The package (60) of claim 13 characterized in that said cover (26) is a polymer resin.



15. The package (60) of claim 14 wherein said polymer resin extends into said depressed portion (64).

5 16. A ball grid array electronic package (70), characterized by:

- a base component (12) having a peripheral portion (18) and a central portion (16);
- a plurality of circuit traces (24) integral with a first side (74) of said base component (12), said circuit traces (24) having an inner end and a peripheral end;
- a semiconductor device (20) bonded to said central portion (16) of said base component (12) and electrically interconnected to the inner ends of
- 10 said circuit traces (24);
- a plurality of solder balls (36) bonded to the peripheral ends of said circuit traces (24);
- a cover (26) encapsulating said central portion (16) of said base component (12), said
- 20 semiconductor device (20) and said inner ends of said circuit traces (24); and
- a stiffener (72) integral with an opposing second side (76) of said base component (12).

25 17. The package (70) of claim 16 characterized in that said stiffener (72) extends over the entire second side (76) of said base component (12).

30 18. The package (70) of claim 17 characterized in that said stiffener (72) extends along the sidewalls (78) of said base component (12) and is bonded to an external structure (30).



19. The package (70) of any one of claims 16-18 characterized in that said stiffener (72) is a heat spreader.

20. The package (70) of any one of claims 16-18 characterized in that said cover (26) is also bonded to said external structure (30).

