METHOD AND APPARATUS FOR CONTROLLING DIE ATTACH FILLET HEIGHT TO REDUCE DIE SHEAR STRESS

TECHNICAL FIELD

The present invention relates to the assembly and packaging of semiconductor chips. More particularly, the present invention relates to assembly and packaging of wire-bonded dies in semiconductor chips. Even more particularly, the present invention relates to reducing shear stress in the dies of semiconductor chips.

BACKGROUND ART

Currently, the semiconductor industry is demanding better die attach, better packaging, better wire-bonding, and the like, to improve product reliability. Each die is generally attached into a die attach area of a semiconductor package using a eutectic material layer, such as a gold-silicon (Au-Si) eutectic layer and a silver-silicon (Ag-Si), or an organic die attach material, such as an epoxy or a polyimide. Distal ends of a wire are generally respectively bonded to a die and to a lead. A chip is generally secured well into the package; and the die attachment area may provide electric coupling between the chip and the remainder of the lead system. A major requirement for the die attachment area is that it be extremely flat to intimately retain the chip in the package.

With respect to die attachment, the basic objective is to provide the best adhesion between the chip and the package as is possible and to provide the best electrically and/or thermally conducting path or even the best insulating material therebetween, depending on the specific chip application. As such, the die attachment should be strong to prevent delamination during subsequent processing steps or during use. The most widely used die attach materials include gold-filled (Au) and silver-filled (Ag) polyimides and epoxies for electrical and thermal conduction. For insulation purposes, silica-loaded polymers may be used as a die attach material. Unfortunately, both insulator-filled and conductor-filled related art die attach materials tend to delaminate and crack due to their inherent internal stresses after curing. Further, most molding compounds tend to flex around the die during temperature cycling, also inducing cracking or propagating pre-existing cracks.

The related art has attempted to address these issues by providing lower stress molding compounds and lower stress die attach epoxies. However, the use of lower stress molding compounds would require requalification of many existing products. Such product conversions are both difficult and exorbitant. In addition, using a lower stress molding compound requires a decreased loading of silica (SiO_2) particles which, then, compromises thermal performance. Similarly, using a lower stress die attach epoxy requires a decreased loading of Au or Ag particles, compromising not only thermal performance but also electrical performance.

Another related art approach has been to use a very low epoxy fillet height in the range of less than 33.33% (i.e., <5 mils (127μm) fillet height for a 15-mil (381μm) thick die) for reducing any thermally-induced stress only at the die/encapsulant interface, wherein the encapsulant specifically comprises a glob-top material. Typically, a glob-top encapsulant is known to have inherent weaknesses at the die/glob-top interface, because it is dispensed from a dispenser under ambient conditions over and onto the die's upper surface. As such, the glob-top encapsulant tends to be riddled with voids, compromising adhesion, and therefore, contributing to delamination. However, this

related art approach does not address the problem of shear stress in the fillet, in the cracking of a thicker die, nor between the metal circuitry and the bulk silicon on the die. Likewise, these related art techniques do not address problems related to packaging materials other than those associated with the glob-top variety. Therefore, a long-felt need is seen to exist for a method and an apparatus for controlling the die attachment process in order to prevent cracking as well as delamination in a semiconductor chip package under many processing and use conditions.

US 5,756,380 teaches that adhesion characteristics can be improved by rigorously cleaning *inter alia* the interface between the die attach material and the die pad and the die attach material and the die. It describes the formation of a fillet of die attach material when a die is mounted on a die pad.

US 6,265,784; US 5,218,234; and JP 04101437 each also show the formation of a fillet of die attach material when a die is mounted on a die pad.

US 5,892,289 also shows the formation of a fillet of die attach material when a die is mounted on a die pad. In this case overall stress is reduced by applying die attach material only at the corners of the die. The fillets described extend at least to the top of the die.

BRIEF SUMMARY OF THE INVENTION

Accordingly, the present invention provides a method and an apparatus for preventing cracking and delamination in a semiconductor chip package, especially a "plastic" package, such as a plastic quad flat package (PQFP), a thin quad flat package (TQFP), a plastic leadless chip carrier (PLCC) package, a small outline integrated circuit (SOIC) package, although less problematic, some undesirable shear stress may still exist), and any other standard or nonstandard plastic package. Particularly, a ball grid array (BGA) package with an over-molded compound (or "molding compound"), which also experiences cracking and delamination during thermal cycling, thermal shock, or normal operation.

The present invention solves these plastic packaging problems by controlling the die attach fillet height, thereby reducing shear stress in the die itself. The molding compound, such as is used with a BGA, may be applied by dispensing it through gate

in a transfer mold (e.g., RTM: resin transfer molding). After filling the mold with the molding compound, heat and pressure may be applied for curing, densifying, and devoiding the molding compound. This technique, when used in the present method for controlling fillet height, results in a non-delaminating semiconductor package, especially for a BGA.

By example only, the present invention empirical data corresponds to various fillet heights that are proportional to various die thicknesses in a range of approximately 4 mils (101 μm) to 30 mils (762 μm) contained in a BGA package under experimental conditions, such as thermal cycling and thermal shock. By using a fillet height in a preferred range of greater than approximately 33% to approximately 75% of the die thickness, the present invention circumvents both (1) the related art problem of coefficient of thermal expansion (CTE) mismatch among the elements within a packaged device, which would otherwise occur in the related art fillet height range of 75% of the die thickness. Surprisingly, the present invention experimental reliability data demonstrates that a nominal fillet height of approximately 50% of the die thickness induces the lowest shear stress in a thicker silicon die (e.g., in a range of approximately 8 mils (203 μm) to approximately 14 mils (356 μm), preferably in a range of approximately 10 mils (254 μm) to approximately 14 mils (356 μm)). Also surprisingly, a thinner die having a thickness in a range of less than 8 mils (203 μm), actually imparts adverse results in contravention to the semiconductor packaging industry's belief. A die attach pick-and-place machine, such as an ESEC 2007(TM), may be used in the present invention. More specifically, the present invention provides a method and an apparatus controlling the die attach epoxy height,

thereby controlling the die attach fillet height, and thereby reducing shear stress in the die itself.

Advantages of the present invention include increasing wire-bond reliability and package reliability without the need for requalification of existing products. By using currently qualified molding compounds and die attach epoxies in conjunction with the present technique for controlling the die attach epoxy height in order to control the die attach fillet height, the overall assembly process may be maintained. Thus, the present invention also has the advantage of compromising neither thermal performance nor electrical performance. Also, by controlling the fillet height by regulating the amount of die attach material to be applied, less die attach material is consumed in the packaging process. As such, the present invention method and apparatus prevent cracking and delamination in a semiconductor chip package, especially a ball grid array (BGA) package, during thermal cycling, thermal shock, and normal use, thereby resulting in a more robust package.

BRIEF DESCRIPTION OF THE DRAWING(S)

For a better understanding of the present invention, reference is made to the below-referenced accompanying drawings. Reference numbers refer to the same or equivalent parts of the present invention throughout the several figures of the drawings.

Figure 1 is a plan-view of a die attached to a semiconductor chip package in a die attachment area with a standard die attach fillet, in accordance with a preferred embodiment of the present invention.

Figure 2 is a cross-sectional view of the features as shown in Figure 1, further showing a die attach material forming a standard die attach fillet having a height of approximately 50% of the die thickness, in accordance with a preferred embodiment of the present invention.

Figure 3 is a cross-sectional side view of the features as shown in Figure 1, further showing a die attach material forming a standard die attach fillet having a height of approximately 50% of the die thickness, in accordance with a preferred embodiment of the present invention.

Figure 4 is an opposing cross-sectional side view of the features as shown in Figure 1, further showing a die attach material forming a standard die attach fillet having a height of approximately 50% of the die thickness, in accordance with a preferred embodiment of the present invention.

Figure 5 is a plan-view of a die attached to a semiconductor chip package in a die attachment area with a high/even die attach fillet, in accordance with the related art.

Figure 6 is a cross-sectional view of the features as shown in Figure 5, further showing a die attach material forming a high/even die attach fillet having a height of approximately 90% of the die thickness, in accordance with the related art.

Figure 7 is a cross-sectional side view of the features as shown in Figure 5, further showing a die attach material forming a high/even die attach fillet having a height of approximately 90% of the die thickness, in accordance with the related art.

Figure 8 is an opposing cross-sectional side view of the features as shown in Figure 5, further showing a die attach material forming a high/even die attach fillet having a height of approximately 90% of the die thickness, in accordance with the related art.

Figure 9 is a plan-view of a die attached to a semiconductor chip package in a die attachment area with a high/low die attach fillet, in accordance with the related art.

Figure 10 is a cross-sectional view of the features as shown in Figure 9, further showing a die attach material forming a high/low die attach fillet, a high side of the die attach fillet having a height of approximately 90% of the die thickness and a low side of the die attach fillet having a height of approximately 25% of the die thickness, in accordance with the related art.

Figure 11 is a cross-sectional side view of the features as shown in Figure 9, further showing a die attach material forming a high/low die attach fillet, the high side of the die attach fillet having a height of approximately 90% of the die thickness, in accordance with the related art.

Figure 12 is an cross-sectional opposing side view of the features as shown in Figure 9, further showing a die attach material forming a high/low die attach fillet, the low side of the die attach fillet having a height of approximately 25% of the die thickness, in accordance with the related art.

Figure 13 is a partial cross-sectional view a die attached to a semiconductor chip package base in a die attachment area with a die attach fillet, showing the critical dimensional relationship between the die attach fillet height Z = B-A and the die thickness B, wherein A = the portion of the die thickness B not covered by the fillet, in accordance with the present invention.

Figure 14 is a partial cross-sectional view of a die attached to a BGA semiconductor chip package in a die attachment area with a die attach fillet, showing the critical structural relationship between the die attach fillet and the die, in accordance with the present invention.

Figure 15 is a partial cross-sectional view, a die attached to a semiconductor chip package base, such as a BGA package, in a die attachment area with a die attach fillet, showing the critical structural relationship (i.e., the fillet height being approximately 50% of the die thickness) between the die attach fillet and the die, further having a molding compound disposed on the die, on the fillet, on a portion of the die attach material, and on a portion of the package base, in accordance with the present invention.

Figure 16 is a cross-sectional view of a die having a die attach fillet, showing the preferred structural relationship (i.e., the fillet height being in a range of approximately 0% to approximately 75% of the die thickness along an approximately central 50% of the die width of any given side of the die), in accordance with the present invention.

MODES FOR CARRYING OUT THE INVENTION

Figures 5-12 illustrate the problematic features of the related art semiconductor packages which are discussed, infra, in relation with the problems solved by the present invention, as illustrated in Figures 1-4 and 12-15.

Figure 1 illustrates, in plan-view, a die 5 attached to a semiconductor chip package base 10 in a die attachment area with a standard die attach fillet (not shown), in accordance with a preferred embodiment of the present invention.

Figure 2 illustrates, in cross-sectional view, the features as shown in Figure 1, further showing a die attach

material 20 forming a standard die attach fillet 30 having a height of approximately 50% of the die 5 thickness, wherein the standard die attach fillet height comprises an approximately uniform height distribution around the die 5, in accordance with a preferred embodiment of the present invention.

Figure 3 illustrates, in cross-sectional side view, the features as shown in Figure 1, further showing a die attach material 20 forming a standard die attach fillet 30 having a height of approximately 50% of the die 5 thickness, wherein the standard die attach fillet height comprises an approximately uniform height distribution around the die 5, in accordance with a preferred embodiment of the present invention.

Figure 4 illustrates, in opposing cross-sectional side view, the features as shown in Figure 1, further showing a die attach material 20 forming a standard die attach fillet 30 having a height of approximately 50% of the die 5 thickness, wherein the standard die attach fillet height comprises an approximately uniform height distribution around the die 5, in accordance with a preferred embodiment of the present invention.

Figure 5 illustrates, in plan-view, a die 5 attached to a semiconductor chip package base 10 in a die attachment area with a high/even die attach fillet (not shown), in accordance with the related art.

Figure 6 illustrates, in cross-sectional view, the features as shown in Figure 5, further showing a die attach material 20 forming a high/even die attach fillet 30 having a height of approximately 90% of the die 5 thickness, wherein the high/even die attach fillet height comprises an approximately uniform height distribution around the die 5, in accordance with the related art.

Figure 7 illustrates, in cross-sectional side view, the features as shown in Figure 5, further showing a die attach material 20 forming a high/even die attach fillet 30 having a height of approximately 90% of the die 5 thickness, wherein the high/even die attach fillet height comprises an approximately uniform height distribution around the die 5, in accordance with the related art.

Figure 8 illustrates, in opposing cross-sectional side view, the features as shown in Figure 5, further showing a die attach material 20 forming a high/even die attach fillet 30 having a height of approximately 90% of the die 5 thickness, wherein the high/even die attach fillet height comprises an approximately uniform height distribution around the die 5, in accordance with the related art.

Figure 9 illustrates, in plan-view, a die 5 attached to a semiconductor chip package base 10 in a die attachment area with a high/low die attach fillet (not shown), in accordance with the related art.

Figure 10 illustrates, in cross-sectional view, the features as shown in Figure 9, further showing a die attach material 20 forming a high/low die attach fillet 30, a high side of the die attach fillet 30 having a height of approximately 90% of the die 5 thickness and a low side of the die attach fillet 30 having a height of approximately 25% of the die 5 thickness, wherein the high/low die attach fillet height comprises a non-uniform height distribution around the die 5, in accordance with the related art.

Figure 11 illustrates, in cross-sectional side view, the features as shown in Figure 9, further showing a die attach material 20 forming a high/low die attach fillet 30, a high side of the die attach fillet 30 having a height of approximately 90% of the die 5 thickness and a low side of the die attach fillet 30 having a height of approximately 25% of the die 5 thickness, wherein the high/low die attach fillet height comprises a non-uniform height distribution around the die 5, in accordance with the related art.

Figure 12 illustrates, in cross-sectional opposing side view, the features as shown in Figure 9, further

showing a die attach material 20 forming a high/low die attach fillet 30, a high side of the die attach fillet 30 having a height of approximately 90% of the die 5 thickness and a low side of the die attach fillet 30 having a height of approximately 25% of the die s thickness, wherein the high/low die attach fillet height comprises a non-uniform height distribution around the die 5, in accordance with the related art.

FIG. 13 illustrates, in partial cross-sectional view, a die 5 attached to a semiconductor chip package base 10 in a die attachment area with a die attach fillet 30, showing the critical dimensional relationship between the die attach fillet height Z=B-A and the die thickness B, wherein A=the portion of the die thickness B not covered by the fillet 30, in accordance with the present invention.

FIG. 14 illustrates, in partial cross-sectional view, a die 5 attached to a semiconductor chip package base 10, such as a BGA package, in a die attachment area with a die attach fillet 30, showing the critical structural relationship (i.e., the fillet height being approximately 50% of the die thickness) between the die attach fillet 30 and the die 5, in accordance with the present invention.

FIG. 15 illustrates, in partial cross-sectional view, a die 5 attached to a semiconductor chip package base 10, such as a BGA package, in a die attachment area with a die attach fillet 30, showing the critical structural relationship (i.e., the fillet height being approximately 50% of the die thickness) between the die attach fillet 30 and the die 5, further having a molding compound 60 disposed on the die 5, on the fillet 30, on a portion of the die attach material 20, and on a portion of the package base 10, in accordance with the present invention.

FIG. 16 illustrates, in cross-sectional view, a die 5 having a die attach fillet 30, showing the critical structural relationship (i.e., the fillet height Z=B-A being in a range of approximately 0% to approximately 75% of the die thickness Y=B along an approximately central 50% of the die width X of any given side of the die 5), in accordance with the preferred embodiment present invention. In essence, $Z \approx (0\% \text{ to } 75\%)Y \approx (0\% \text{ to } 75\%)B$ is the constraint for a location approximately $\geq 25\%$ X (i.e., at least 25% inboard from each edge 6 on any given side of the die 5). Preferably, $Z \approx (>33\% \text{ to } 75\%)$ $Y \approx (>33\% \text{ to } 75\%)B$ is the constraint for a location approximately $\geq$ 25% X (i.e., at least 25% inboard from each edge 6 on any given side of the die 5). This constraint for the preferred embodiment is surprisingly effective in reducing overall shear stress in the packaged device. During the assembly process, controlling the fillet height in the outboard regions (i.e., less than 25% X) is very difficult. Thus, the present method constrains the fillet height in the inboard region (i.e., at least 25% inboard from each edge 6 on any given side of the die 5) where the potential damage suffered from shear stress would otherwise be at its greatest. In so doing, the present method results in a packaged device having significantly reduced shear stress.

The present invention method of reducing shear stress in a packaged semiconductor chip, generally comprises the steps of: providing a semiconductor chip package base 10 having a semiconductor chip disposed therein and having a die attachment area; providing a die 5 having a thickness Y, a width X, and at least one side; providing a die attach material 20; controlling an amount of the die attach material 20 disposed between the die 5 and the semiconductor chip package base 10, whereby at least one portion of the die attach material 20 forms at least one meniscus on the at least one side of the die 5, whereby the at least one meniscus forms at least one die attach fillet 30 upon curing of the die attach material 20, thereby controlling at least one height Z=B-A of the at least one die attach fillet 30, and thereby reducing shear stress in the die5; and completing packaging of the semiconductor chip.

The present invention reduced shear stress packaged semiconductor chip, generally comprises: a semiconductor chip package base 10 having a semiconductor chip disposed therein and having a die attachment area; a die 5 having at least one side; a controlled amount of die attach material 20 disposed between the die 5 and the semiconductor chip package base 10; at least one portion of the die attach material 20 forming at least one meniscus on the at least one side of the die 5, the at least one meniscus forming at least one die attach fillet 30 upon curing of the die attach material 20, the at least one die attach fillet 30 having at least one controlled height Z=B-A, and the die 5 having reduced shear stress.

In the present method and apparatus for reducing shear stress in a packaged semiconductor chip, the die 5 may comprise silicon and have a thickness in a range of approximately 4 mils (101 μm) to approximately 30 mils (762 μm), preferably approximately 10 mils (254 μm) to approximately 14 mils (356 μm), as a somewhat thicker die has surprisingly superior crack resistance. A die 5, which is sawn by step-cut, is preferable as having less pre-existing internal stresses and may preferably be approximately 367 mils<2 >in plan area. The die attach material 20 may comprise an epoxy, and may comprise a filler selected from a group consisting essentially of a conductor and an insulator.

The die attach fillet height (i.e., "fillet percentage") is calculated by the simple relationship, fillet % = 100(B-A)/B, wherein B=the die thickness, and wherein A=vertical distance of a die side which has not been coated with the die attach material. The die attach fillet 30 may also comprise a standard height Z in a range of approximately 40% to approximately 60% (nominally approximately 50%) of the die thickness Y=B. By purposefully constraining the die attach fillet height to approximately 50% of the die thickness, the present invention also reduces shear stress in the die which, in turn, reduces overall stress in the packaged semiconductor chip. The preferred embodiment (i.e., greater than approximately 33%-approximately 75% of the die thickness has been discussed, supra, with respect to FIG. 16.

Information as herein shown and described in detail is fully capable of attaining the above-described object of the invention, the presently preferred embodiment of the invention, and is, thus, representative of the subject matter which is broadly contemplated by the present invention. The scope of the present invention fully encompasses other embodiments which may become obvious to those skilled in the art, and is to be limited, accordingly, by nothing other than the appended claims, wherein reference to an element in the singular is not intended to mean "one and only one" unless explicitly so stated, but rather "one or more."

INDUSTRIAL APPLICABILITY

The present invention industrially applies to the assembly and packaging of semiconductor chips. More particularly, the present invention industrially applies to assembly and packaging of wire-bonded dies in semiconductor chips. Even more particularly, the present invention industrially applies to reducing shear stress in the dies of semiconductor chips by providing a method and an apparatus for preventing cracking and delamination in a semiconductor chip package. The present invention industrially applies to solving plastic packaging problems by controlling the die attach fillet height, thereby reducing shear stress in the die itself.

CLAIMS:

1. A reduced shear stress packaged semiconductor chip, comprising:

a semiconductor chip package base (10) having a die attachment area;

a die (5) having at least one side and at least one edge (6),

said die (5) comprising a semiconductor material selected from a group consisting essentially of silicon (Si), germanium (Ge), and gallium arsenide (GaAs), and each said at least one side having a thickness (Y) and a width (X); and

a controlled amount of die attach material (20) disposed between said die (5) and said semiconductor chip package base (10);

at least one portion of said die attach material (20) forming at least one meniscus on said at least one side of said die (5),

said at least one meniscus forming at least one die attach fillet (30) upon curing of said die attach material (20),

said at least one die attach fillet (30) having at least one controlled height,

characterized in that said at least one controlled height comprising a range of approximately 33% to approximately 75% of said at least one die side thickness (Y) at a location of at least 25% inboard from each said at least one edge (6) of any given at least one die side, and said die having reduced shear stress.

2. A packaged semiconductor chip as claimed in claim 1, wherein said die (5) comprises a thickness (Y) in a range of approximately 4 mils (101 μm) to approximately 30 mils (762 μm).

3. A packaged semiconductor chip as claimed in claim 1 or claim 2, wherein said die attach material (20) comprises an epoxy.

4. A packaged semiconductor chip as claimed in any one of claims 1 to 3, wherein said at least one die attach fillet (30) has controlled height (Z) in a range of greater than approximately 33% to approximately 75% of said die thickness (Y).

5. A packaged semiconductor chip as claimed in claim 4, wherein said controlled height (Z) is constrained in said range of greater than approximately 33% to approximately 75% of said die side thickness (Y) along an approximately central 50% of said die width (X).

6. A packaged semiconductor chip as claimed in any one of claims 1 to 5, further comprising a molding compound disposed on said die (5), on said fillet (30), on at least one portion of said die attach material (20), and on at least one portion of said package base (10).

7. A packaged semiconductor chip as claimed in any one of claims 1 to 6, wherein said semiconductor chip package base (10) comprises a ball grid array (BGA).

8. A method of reducing a die shear stress comprising the steps of:

providing a semiconductor chip package base (10) having a die attachment area;

providing a die (5) having a thickness (Y), and at least one side of width (X);

providing a die attach material (20);

controlling an amount of die attach material (20) disposed between the die (5) and the semiconductor chip package base (10), whereby at least one portion of the die attach material (20) forms at least one meniscus on the at least one side of the die (5), whereby the at least one meniscus forms at least one die attach fillet (30) extending to a height (Z) from the bottom of the die (5) upon curing of the die attachment material (20), characterized in that:

the amount of the die attach material (20) disposed between the die (5) and the semiconductor chip package base (10) is controlled so that the fillet height (Z) is between 33% and approximately 75% of the die thickness (Y) along an approximately central 50% of said width (X) of the die (5).

9. A method as claimed in claim 8, wherein: the amount of die attach material (20) disposed between the die (5) and the semiconductor chip package base (10) is controlled so that the fillet height (Z) is greater than approximately 33% to approximately 75% of the die height (Y) along an approximately central 50% of said width (X) of the die (5).