MICROELECTRONIC ASSEMBLY WITH DIE SUPPORT AND METHOD

FIELD OF THE INVENTION

The present invention relates generally to microelectronic assemblies having an integrated circuit die attached to a substrate by a plurality of solder connections, and more specifically relates to a microelectronic assembly having a bead of polymeric material disposed about the periphery of the integrated circuit die. The bead of polymeric material connects the die to the substrate and operates to reduce breakage of the die and electrical connections.

BACKGROUND OF INVENTION

Many microelectronic assemblies are manufactured using the well-known flip chip on board (FCOB) technique. In FCOB assembly, an integrated circuit die is provided which includes a plurality of bond pads, with each of the bond pads having deposited thereon a solder bump. The die is turned over or flipped and is superimposed over a substrate having a plurality of bond pads, such that each of the solder bumps is aligned with a corresponding one of the bond pads on the substrate. The die and the substrate are then reflow-soldered together to form solder connections. The gap that remains between the downwardly facing die face and the upwardly facing substrate face is then filled using any one of a number of known underfill materials.

The underfill material, which typically contains silica or other particulates in a resin binder, serves to encapsulate the solder connections and serves to bond the die to the substrate. The underfill also increases the reliability of the microelectronic assembly during thermal cycling by enhancing the mechanical connection between the die and the substrate thereby mitigating the effects of thermal expansion problems.

Failure of integrated circuit dies from bending stresses, vibration

stresses and stresses due to thermal expansion occurs most often at or near the die edges. Semiconductor dies are formed of an inflexible material that does not bend easily or resist multiple bending cycles. When mounted on a circuit board, a die will tend to break most often near the edge of the device when the board is flexed. The circuit board of hand-held devices may flex frequently from activation of buttons and rough handling during manufacturing and operation. Since electrical connections between the die and the board are often located near or at the edge of the die, the outermost located connections themselves are particularly vulnerable to failing when subjected to bending loads.

One prior art method of applying an underfill material has been to simply apply the underfill material to the assembly after the reflow soldering has been completed. The underfill material is drawn into the gap between the die and the substrate by capillary action. The assembly is then placed in an oven for curing. Typically, a small radius of underfill material, referred to as a fillet, adheres between the substrate and the lower edge portions of the die. An alternate example of using an underfill material includes first attaching a die to a substrate, tilting the assembly and allowing underfill material to flow under the die by the force of gravity. In both examples, since the epoxy becomes located for the most part underneath the body of the die, the peripheral edges or portions of the die are left relatively unsupported and vulnerable to stress.

A different method of bonding a semiconductor chip to a substrate uses a vacuum chamber to evacuate the gap between the chip and the substrate. A polymeric underfill material is forced into the gap when air is allowed to re-enter the chamber.

A technique of producing a die with high resistance to stress is obtained by providing a die within a package that also includes a base plate and cap. The die is adhesively attached to the base plate and a cap is affixed to the base plate such that an air gap is formed between the die and the cap. The base plate and die assembly is mounted to a substrate, such as a circuit

board. The base plate tends to absorb stresses preferentially.

The methods described above do, to some extent, decrease the possibility of die and interconnect breakage due to stress by providing different means to support the die. However, these methods require additional manufacturing steps, materials and equipment. In some cases, encapsulating the die may itself exert stresses on the die, may be disadvantageous to marking techniques and may decrease the effective operating life of the die by reducing the capacity of the die to dissipate heat.

Accordingly, it would be desirable to provide a means of reducing die breakage that overcomes the disadvantages described above.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a cross-sectional view of a microelectronic assembly constructed in accordance with the teachings of an embodiment of the present invention;

FIG. 2 is a cross-sectional view of a microelectronic assembly of another embodiment of the present invention;

FIG. 3 is a side view of a semiconductor wafer positioned on a sheet of adhesive backing material;

FIG. 4 is a side view of the wafer on the backing material as shown in **FIG. 3** after the wafer has been separated into individual die;

FIG. 5 is a side view of the dies and backing material of **FIG. 4** with enlarged streets;

FIG. 6 is a side view of the dies and backing material of **FIG. 5** with the streets filled with a polymeric precursor material; and

FIG. 7 is a side view of dies and backing material as shown in **FIG. 6** after being re-separated into individual die with a bead of polymeric material located at the outer edges of each die.

DETAILED DESCRIPTION OF THE PRESENTLY PREFERRED EMBODIMENTS

The following descriptions of the presently preferred embodiments are not intended to limit the scope of the invention to the precise forms disclosed, but instead are intended to be illustrative of the principles of the invention so that others may follow its teachings.

FIG. 1 illustrates a cross-sectional view of a microelectronic assembly constructed in accordance with the teachings of an embodiment of the present invention. The microelectronic assembly **10** includes an integrated circuit die **12** of the type generally well known in the art. The die **12** includes a die body **14**, a die face **16**, and a plurality of lateral edge portions **18**. The die **12** has circuitry formed thereon (not shown) as is well known, and also includes a plurality of bond pads (not shown) both disposed on the die face **16** with solder bumps **30** formed thereon. The die **12** is typically mass produced from a silicon wafer (not shown) which has formed thereon a plurality of integrated circuit dies which are diced, sawn, separated or otherwise singulated into one or more dies **12** as is well known in the art.

A substrate **22**, such as a printed wiring board of the type commonly employed in the art and having circuitry (not shown) defined thereon, includes a substantially planar die attach surface **24**. The substrate may be formed of standard substrate materials including ceramic, epoxy board, paper/epoxy/glass laminates, composites, flex, polyimide, polyester, and FEP (Teflon) materials and may include a stiffener layer of copper, aluminum, or an alloy material. Pluralities of bond pads (not shown) are spaced about the die attach surface **24**. It should be understood that the bond pads on the die and the bond pads on the surface **24** of the substrate **22** are designed to line up or index to each other to provide electrical connection therebetween.

It will also be noted that when the die **12** is aligned over the substrate **22**, a gap **28** is formed between the die attach surface **24** of the substrate **22** and the face **16** of the die **12**. As is known in the art, solder connections are typically formed from solder bumps **30** which are deposited on either each of

the bond pads of the die **12** or on each of the bond pads of the substrate **22** prior to assembly of the microelectronic assembly **10**. The solder connections are formed from the solder bumps **30** after the die **12** is positioned over the substrate **22** and properly aligned, typically by using the reflow soldering method as is known.

In accordance with this invention, a polymeric bead **32** is disposed about the periphery of the outer edges of the die. A number of precursor materials are suitable for use in forming the polymeric bead. The bead **32** materials may consist of an epoxy prepolymer, which hardens in the presence of heat, i.e. a thermoset. The polymeric precursor material may consist of 60-80% by weight of a prepolymer (typically an epoxy prepolymer), 20-40% by weight of a hardener, 0.1-1.0% by weight of a catalyst, and 0.01-0.10% by weight of an adhesion promoter. The material may further include a range of filler between about 25% to about 75% by weight of particulate fillers, typically silica. Epoxy formulations typically include a hardener that reacts with the precursor to form the product resin. A suitable hardener is an amine-terminated polyether compound, preferably triethyleneglycol diamine. Alternatively the hardener may contain in its molecular structure two or more 2,5-dialkyl substituted furan group or two or more dienophiles (alkynes having electron withdrawing groups attached to both sides of the ethyne moiety e.g. ester and keto groups). Other suitable hardeners are isocyanates, melamines, aziridines, and anhydrides.

A catalyst is typically added to promote reaction of the constituents during curing. A preferred catalyst is 2-phenylimidazole. Other suitable catalysts are amines, acids and anhydrides.

The adhesion promoter is an aminosilane that enhances wetting of the substrate to promote adhesion of the resultant encapsulant. A preferred adhesion promoter is gamma-aminopropyltriethoxysilane. Other suitable adhesion promoters are fluoropolymers and silicones.

Such a thermoset material is preferably partially curable to a B stage polymer to form an essentially non-flowing bead **32** (i.e., a bead exhibiting

some shear strength). The thermoset material is preferably fully curable at reflow temperatures to form the bead. The fully cured material is known as having been C staged.

Alternatively, the polymer precursor may contain moieties of a 2,5-dialkyl substituted furan instead of epoxy end groups. Such a polymer precursor material is available from Shell®, a more complete description of which may be found in U.S. Patent No. 5,760,337 issued to Iyer and assigned to Shell®. In another embodiment of the invention, the bead **32** includes a thermoplastic polymer, such as a phenoxy resin. One such commercially available phenoxy resin is Paphen manufactured by Phenoxy Associates. Other suitable thermoplastic materials, which soften in the presence of heat, may be employed as long as such thermoplastics exhibit a softening point below the melting point of the solder material. It should be understood that the while the bead **32** appears to be shown as two elements, the present embodiment preferably contemplates that the bead is in the form of a substantially continuous bead, buttress, skirt or the like which is attached to the outer or peripheral edges of the die **12** and also attached to the surface **24** of the substrate **22**. However, in alternate embodiments the bead **32** may be formed on less than all the outer edges of the die. In this manner, the microelectronic assembly may be used in applications where space is limited or less structural support is needed, for example. In the illustrated embodiment, the bead has a rectangular or square cross-section. Other cross-sections are also contemplated, such as round and oval cross-sections. Preferably, the bead **32** attaches to most, or all, of the edge surface **18** of the die **12** portion of the assembly **10**. Attaching the bead **32** to a major portion of the edge surface **18** functions to support the edge of the die **12**, and operates to absorb stresses which otherwise would be experienced directly by the die or the interconnect. Further, in the present embodiment, the exposed surface **34** of the bead is substantially coplanar with the die back surface **15**.

FIG. 2 illustrates a cross-sectional view of a microelectronic assembly constructed in accordance with the teachings of another embodiment of the

present invention. In **FIG. 2**, the elements of the invention shared with the embodiment shown in **FIG. 1** have the same reference characters. The microelectronic assembly **100** has generally the same features as that shown in **FIG. 1** with the exception of the bead **42**. Bead **42** differs from bead **32** (see **FIG. 1**) in that the bead material also fills gap **28**. In other words, the bead **42** not only surrounds the die **12**, but also fills the gap **28** between the die **12** and the substrate **22**. Thereby, the assembly **100** includes both bead material about the outer edges **18** of the die **12** and bead material in the gap **28** of the assembly **100**.

With reference to **FIGS. 3-7**, a method of forming the microelectronic assembly of the present invention is illustrated. As shown in **FIG. 3**, a semiconductor wafer **202** formed by standard methods is placed on an adhesive backing material **204**. The wafer **202** is positioned with the active surface **216** facing outwardly such that the active surface **216** and the bond pads (not shown) formed thereon are in an exposed condition. In the present embodiment, solder bumps **230** are formed on the bond pads on the active surface **216** of the wafer **202** using well-known methods.

As shown in **FIG. 4**, the wafer is separated into a plurality of individual dies **212A**, **212B**, **212C** using known methods. A preferred method of dicing the wafer is sawing. Typically, semiconductor wafers include a number of integrated circuits arranged in rows and columns with the periphery of each integrated circuit or die being rectangular. Typically, the wafer is sawn or "diced" into rectangular shaped discrete dies along two mutually perpendicular sets of parallel lines or streets **250A** lying between each of the rows and columns thereof. Hence, the separated or singulated integrated circuits are commonly referred to as dice or die.

The lanes between the die are referred to as streets. In one embodiment, stretching the backing material **204** expands the streets **250B** (see **FIG. 5**). The expanded streets **250B** are filled with a polymeric precursor material **232** (see **FIG. 6**). After filling the expanded streets **250B** with the polymeric precursor material **232**, the diced wafer **212A**, **212B**, **212C**,

polymeric precursor material **232** and backing are preferably heated to partially cure or B stage the material. If a thermosetting material is used, it is allowed to cool or set up. The streets **250C** are re-sawn which re-separate the individual die **212A, 212B, 212C** (see **FIG. 7**).

The die is selected, scanned for alignment, and superimposed over the substrate. With each solder bump in alignment with a corresponding bond pad, the die may be then tacked to the substrate using a vaporizable flux having a tacking agent. The subassembly is then heated to reflow in an oven (i.e., at least to the liquidus point of the solder material). It is noted that the bumps **230** can be formed on the substrate or on both the substrate and die.

Using known assembly techniques, at reflow temperature the solder bumps, aided by the fluxing agents form the solder connections. The bead flows, droops or expands in the presence of heat to contact and connect to the substrate. Exposure to the reflow temperature causes the bead to form a bond with the die and substrate. The reflow temperature also may cause the bead to become C staged or fully cured when the bead material includes a thermoset material.

The present invention may be embodied in other specific forms without departing from its spirit or essential characteristics. The described embodiments are to be considered in all respects only as illustrative and not restrictive.

WE CLAIM

1. A method of forming a microelectronic assembly comprising:

providing a substrate having a plurality of bond pads;

providing an integrated circuit die component having at least one edge and a die face with a plurality of solder bumps disposed on the die face;

forming a bead on at least one outer edge of the die, the bead being made of a polymeric precursor material;

superimposing the die face over the substrate so that each solder bump contacts a corresponding one of the plurality of bond pads and wherein the die face is spaced apart from the substrate by a gap;

heating the die and the substrate to a temperature sufficient to reflow the solder bumps to form solder connections to corresponding bond pads, and to flow the polymeric precursor material onto the substrate.

2. The method of forming the microelectronic assembly of claim 1 wherein at least a portion of the polymeric precursor material is drawn into the gap to encapsulate the solder connection.

3. The method of forming the microelectronic assembly of claim 1 wherein the integrated circuit die component is a die with four edges, at least one of which has a bead formed thereon.

4. A method of forming a microelectronic assembly comprising:

providing a substrate having a plurality of bond pads;

providing an integrated circuit die component having at least one edge and a die face with a plurality of solder bumps disposed on the die face;

applying a bead on at least one edge of the die, the bead being made of a polymeric precursor material adapted to flow at an elevated temperature;

superimposing the die face over the substrate so that each solder bump contacts a corresponding one of the plurality of bond pads and

wherein the die face is spaced apart from the substrate by a gap;

heating the die and the substrate to a temperature sufficient to reflow the solder bumps to form connections to corresponding bond pads, and to concurrently cause the polymeric precursor material to flow into the gap and cure to form an encapsulant; wherein the encapsulant protects the connection between the bond pads and the solder bumps.

5. The method of forming the microelectronic assembly of claim 4 wherein the polymeric precursor material connects the die and the substrate during heating and subsequent cooling of the microelectronic assembly.

6. The method of forming the microelectronic assembly of claim 4 wherein the polymeric precursor material is cured during heating.

7. The method of forming the microelectronic assembly of claim 4 wherein the polymeric precursor material is partially cured before the die is superimposed over the substrate.

8. A method of forming a microelectronic assembly comprising the steps of:

providing a semiconductor wafer having a wafer face, the wafer face having at least one integrated circuit die component formed thereon, each die component including a die face, a plurality of solder bumps disposed on the die face and a plurality of edges;

placing the semiconductor wafer onto an adhesive backing material with the wafer face facing outwardly from the adhesive backing material;

forming streets around each of the die components;

filling the streets with a polymeric precursor material;

separating the die components, each of the die components including a bead formed of the polymeric precursor material, the bead located

on at least one of the edges of each of the die components;

providing a substrate having a plurality of bond pads;

superimposing the die face over the substrate so that each solder bump contacts a corresponding one of the plurality of bond pads;

heating the die component and the substrate to a temperature sufficient to reflow the solder bumps to form solder connections to corresponding bond pads and to flow the polymeric precursor material onto the
substrate.

9. A microelectronic assembly comprising:

a substrate having a plurality of bond pads on a die attach surface;

an integrated circuit die component having at least one edge and a die face, the die face being adjacent the die attach surface, a plurality of bond pads being formed on the die face and electrically connected to the bond pads of the substrate; and

a polymeric bead formed of polymeric precursor material located on at least one of the edges of the integrated circuit die component and making contact between at least one of the edges of the integrated circuit die component and a corresponding portion of the die attach surface of the substrate.

10. The microelectronic assembly of claim 11 wherein the integrated circuit die component and the die attach surface of the substrate are spaced apart by a gap and wherein the polymeric precursor material contacts substantially the entire portion of all of the edges of the die component and fills at least a portion of the gap.