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TITLE OF THE INVENTION

METHODS FOR MAKING SEMICONDUCTOR PACKAGES WITH LEADFRAME GRID ARRAYS

CROSS-REFERENCE TO RELATED APPLICATION

[0001] This application is a divisional of Singapore Application No 200202206-9 filed on 16 April 2002.

BACKGROUND OF THE INVENTION

[0002] The present invention relates to grid array semiconductor packages and methods of assembling and evaluating the same. In particular, the present invention relates to leadframes for mounting a semiconductor chip for encapsulating to form a complete semiconductor package. The leadframe includes a plurality of leads having a similar length, with offset array pads forming a grid array on the surface of the package.

[0003] Semiconductor chips or dice are typically enclosed in semiconductor assemblies, or packages, prior to use. These packages protect chips from the conditions of the surrounding environment and provide leads or other connection points, allowing a chip to be electrically accessed. Packages have typically included a semiconductor chip bonded to a leadframe, either seated on a die paddle or directly to the leads in a leads-over-chip ("LOC") attachment. The contact pads on the semiconductor die are then electrically connected to the chip by wires in wirebond fashion. The connected leadframe and chip are then placed in a mold cavity and encapsulated in a mold compound to form a complete package. The leads extend out from the mold compound, allowing the chip to be electrically accessed. Typically, the leads extend laterally from the package in a flat array, which may be trimmed and formed into a desired conformation.

[0004] As electronic devices have decreased in size, alternative methods of assembling and packaging semiconductor dice have been used. These methods decrease the "real estate" or area that is required to install the die on higher-level packaging, such as a printed circuit board. Flip-chip installation of a chip using a ball grid array ("BGA") reduces the real estate used to an area the same as or only slightly larger than the chip dimensions, but introduces a number of difficulties and shortcomings into the manufacturing process. Attempts have been made in the

art to provide a semiconductor assembly that includes the benefits of a flip-chip type of attachment while keeping the benefits of a conventional molded package.

[0005] Many attempts to combine a grid array onto a molded package have included a leadframe as a component of the complete assembly. The leadframe supplies a number of advantages to the finished assembly. Leads not only furnish electrical connections, but also provide a pathway to conduct heat from a package while in operation. Examples of some such packages are disclosed in U.S. Patent No. 5,847,455 issued December 8, 1998 to Manteghi and U.S. Patent No. 5,663,593 issued September 2, 1997 to Mostafazadeh et al., the disclosure of each of which is incorporated by reference in its entirety herein. These patents are directed to assemblies including both leadframes and ball grid arrays that allow the assembly to be mounted in a flip-chip fashion. These assemblies are formed by attaching a semiconductor die to a leadframe die paddle, wirebonding the die to the leads and placing an encapsulant, such as a mold compound, over the semiconductor die and the die face of the leadframe. A soldermask is then applied to the opposite face of the leadframe, and holes are formed in the soldermask. Solder balls are disposed within the holes to form a ball grid array.

[0006] With these soldermask-covered leadframe packages, the complete structure of the flat leadframe is protected only by the soldermask on one side. The soldermask adds an additional laminate layer to the assembly, providing additional points for potential contaminant and moisture entry. Applying the soldermask and forming the holes therein add additional steps to package fabrication, increasing manufacturing costs and the opportunity for error.

[0007] U.S. Patents 5,715,593 and 6,028,356 issued February 10, 1998 and February 22, 2000, respectively to Kimura, represent an attempt to resolve these shortcomings. A flat leadframe is attached to a semiconductor die using wire bonds. The package is then encapsulated in two steps, one encapsulating the chip and the chip side of the leadframe and one encapsulating the leadframe. In the latter step, the mold includes bumps which contact the leadframe, producing dimples that allow the leads to be accessed. Solder balls may then be created in the dimples.

[0008] By placing the solder balls into package dimples, Kimura-type devices introduce additional problems into package formation. As the molds are reused, wear can erode the surface of the contact bumps, requiring replacement and preventing contact with the leadframe. Mold compound that intrudes between the leadframe and a contact bump can form a resin film that

requires removal or can interfere with the electrical connection. Removal of this thin film is difficult as it is recessed within the dimples.

[0009] U.S. Patent No. 5,866,939 issued February 2, 1999 to Shin et al., the disclosure of which is incorporated herein by reference in its entirety, is directed to another semiconductor package including a BGA. The Shin-type device is a semiconductor package featuring a semiconductor die attached to a leadframe. The leads of the leadframe are bent, causing the lead ends to terminate at a surface of the package. The lead ends are used to form a grid array. The position of the lead end is determined by the length of the lead and the direction of the lead path. Shin-type devices thus have multiple leads of differing lengths. This approach may result in a relatively weaker structure, as reinforcement from the leadframe may be reduced compared to packages where the leads are of similar length and run throughout the package. Further, the varied lead lengths may compromise signal transmission, especially in higher-speed, higher-frequency devices. Additionally, in the Shin-type packages, the semiconductor die is connected to the leadframe through wirebonding, solder joints or bumping, thus adding fabrication steps and materials.

BRIEF SUMMARY OF THE INVENTION

[0010] The present invention includes apparatus and methods for fabricating semiconductor packages, or assemblies. One type of semiconductor assembly includes a leadframe with leads featuring an offset portion exposed at a surface of the package to form a grid array. A volume of electrically conductive material, such as solder or a conductive or conductor-filled epoxy, may be disposed or formed on each exposed portion to form an array of solder balls, or other connection structures, in a ball grid array ("BGA") or similar array structure. Semiconductor assemblies may include a leadframe where a lead has an inner bond end wire bonded or thermocompressively bonded to a bond pad of the semiconductor chip to enable electrical communication therewith. Leads to be thermocompressively bonded may include a section proximate the inner bond end with increased flexibility to improve the thermocompressive bond. Leadframes and methods of forming semiconductor assemblies are included within the present invention.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011] In the drawings, which depict the best mode presently known for carrying out the invention:

[0012] FIG. 1 is a cutaway perspective view of one embodiment of a semiconductor assembly made in accordance with the principles of the present invention.

[0013] FIG. 1A is a view of an alternative embodiment of an array offset in accordance with the principles of the present invention.

[0014] FIG. 2 is a cutaway side view of a section of the embodiment of FIG. 1.

[0015] FIG. 3 is a top view of a ball grid array package made in accordance with the principles of the present invention.

[0016] FIG. 4 is a cutaway side view of a section of another embodiment of a semiconductor assembly made in accordance with the principles of the present invention.

[0017] FIG. 5 is a side view of part of a lead of the embodiment of FIG. 4.

DETAILED DESCRIPTION OF THE INVENTION

[0018] Reference will now be made to FIGS. 1 and 2. FIG. 1 depicts a perspective cutaway view of one embodiment of a semiconductor assembly 10 made in accordance with the principles of the present invention. FIG. 2 depicts a sectional side view of a section of the embodiment of FIG. 1. A semiconductor assembly 10 includes a semiconductor chip 12 attached in leads-over-chip ("LOC") fashion to a leadframe 14 by an adhesive element 16. In the depicted embodiment, the adhesive element 16 is an adhesive strip, such as a double-sided adhesive polyimide tape such as a KAPTONJ tape, but it will be appreciated that any suitable adhesive may be used, including a liquid or gel adhesive.

[0019] Leadframe 14 includes a plurality of leads 18, such as leads 18A and 18B. Groups of leads 18 are organized into lead sets, such as first lead set 15 and a second lead set 17 on opposing sides of the longitudinal axis L of the semiconductor chip 12. Within a first lead set 15, the leads 18 have substantially similar lengths, running from a side 11 of the assembly 10 toward the longitudinal axis L. Each lead 18 comprises a lead shaft 20 that generally runs within a first common plane P1. Along its length the lead shaft 20 includes an offset 22 formed as the lead shaft 20 extends out of the first common plane and then returns to the first common plane. The offset 22 may include an array pad 24 having a flat surface, although any suitable array pad design may be used. The array pad may vary in width or shape from the remainder of the lead.

For example, FIG. 1A shows an assembly 10A including leads with circular array pads 24A, which can be useful for forming solder balls therein. Desirably, the array pads 24 of the various leads 18 lie within a second common plane, although small variations such as two or more separate common planes may be used for specific applications. It will be appreciated that the leadframe may be constructed of any suitable material known presently, or in the future, to those skilled in the art, including aluminum, copper and alloys thereof as well as ferrous alloys.

[0020] In the embodiment depicted in FIG. 1, leads 18 protrude from side 11 of molding compound 26 of semiconductor assembly 10. In fabricating assemblies 10 in accordance with the principles of the present invention, it may be advantageous to produce leadframe 14 as one of a number of leadframes 14 on a strip. A number of assemblies 10 may be fabricated on the strip, which assemblies 10 are then separated by cutting the strip. Protruding lead ends 19 of leads 18 may result from such a procedure. Alternatively, lead ends 19 may be trimmed flush at side 11. Embodiments where the lead ends 19 are enclosed within the molding compound 26 are also contemplated as within the scope of the invention, but may be somewhat more difficult to fabricate. In addition to providing electrical connection to chip 12, leads 18 may also act to conduct heat from assembly 10 during operation. The leads 18 are all of substantially similar length, and two opposite lead sets 15 and 17 extend across the majority of the active surface of the chip 12 to be in contact with and accessible to bond pads thereon. Exposed lead ends 19 increase the ability of leads 18 to conduct heat from the assembly 10, increasing the potential functional life of the assembly 10.

[0021] Leads 18 are electrically connected to the semiconductor chip 12. In this depicted embodiment, the connection is accomplished by wirebonding. A gold or aluminum wire bond 25 connects an inner bond end 23 of each lead 18 to a bond pad 13 on the active surface of the chip 12 (FIG. 2). The wire bond 25 may be formed by any suitable means known to those skilled in the art. It will be appreciated that any suitable electrical connection, such as tab bonding using conductive traces carried on a flexible dielectric film, or the direct thermocompressive bonding of an inner bond end 23 of lead 18 as discussed further herein, may be used and is within the scope of the present invention.

[0022] The mechanically and electrically connected semiconductor chip 12 and leadframe 14 are encapsulated within a dielectric molding compound 26 to form a molded package. One surface 28 of the molding compound 26 lies in the second common plane P2 of the outer surfaces of array pads 24, leaving exposed at least one surface of the array pads 24. In

forming the assembly 10, the connected semiconductor chip 12 and leadframe 14 are placed in a mold cavity, which is then transfer molded, injection molded or pot molded with molding compound 26 to form the complete molded package of the assembly 10. In a currently preferred embodiment, the molding process is transfer molding using a silicone particle-filled thermoplastic polymer. The array pads 24 of the leads 18 contact a surface of the mold cavity, resulting in the molding compound surface 28 residing in the same common plane P2 as the array pads 24. As a molding compound 26 enters the mold cavities as a flow front under high pressure and temperature, a thin film or "flash" of molding compound 26 may form between the array pads 24 and the adjacent mold cavity surface. Depending on the thickness of the film, it may be necessary to clean the film from the array pads 24 to allow an electrical connection to be made to those pads 24. This cleaning may require as little as a mechanical scrub of the array pads 24 or it may require that a chemical etch be performed to expose the surface of the array pads 24.

[0023] Desirably, a volume of electrically conductive material is then disposed on each of the array pads 24 to allow the assembly to be mounted and attached in a flip-chip fashion to higher-level packaging such as a circuit board. In the depicted embodiment, the conductive attachment material is shown as solder balls 30 disposed on the array pads 24. It will be appreciated that any suitable electrically conductive material known now, or in the future, to those skilled in the art may be used for discrete conductive elements to enable the assembly to be attached. Suitable conductive materials include tin/lead solder, electrically conductive epoxy, conductively-filled epoxy or any other suitable electrically conductive material that may be fashioned into a discrete conductive element by those of ordinary skill in the art. Examples of such discrete conductive elements include solder balls and conductive columns or pillars. The electrically conductive material may be disposed upon the accessible array pads 24 by disposing masses of solder paste upon the array pads followed by flowing the solder to form solder balls. Suitable techniques for alternative structures known to those skilled in the art may similarly be used. It is also contemplated that a Z-axis anisotropically conductive film may be disposed over the surface of the molded package having the exposed array pads 24 in lieu of using discrete conductive elements.

[0024] An offset 22 may be located at any position along the shaft 20 of a lead 18. Desirably, leads 18 of a first lead set 15 will include several subsets, each subset having offsets 22 located at a common position. The leads 18 of each subset may be alternated, as shown in FIG. 1, to produce four rows of array pads 24. This places the array pads 24 of the first lead set

15 at several different common lateral positions with respect to longitudinal axis L, creating a grid array of array pads 24.

[0025] FIG. 3 depicts a top view of a semiconductor assembly 40 fabricated in accordance with the principles of the present invention. Surface 48 features solder balls 42 disposed on the exposed array pads 24 (not visible), forming a ball grid array. One embodiment of a desirable grid array is depicted. By positioning offsets 22, an even number of rows of array pads 24 are aligned around longitudinal axis of centerline L of the assembly 40, which may also serve as a centerline of the leadframe 14 and semiconductor chip 12. Each set of rows is formed by a first lead set 15 having substantially equal length, with the individual rows formed by subsets of leads 18 with array pads 24 at common positions as described above. Within a set of rows, there is an inner row 44 located proximal to the centerline L and a distal outer row 46. It will be appreciated that any desired number of rows are possible and that embodiments which lack a uniform row structure in favor of an individualized pattern are also possible. All such embodiments are within the scope of the present invention.

[0026] From the foregoing description, it can be seen that the principles of the present invention result in a semiconductor assembly including a leadframe having substantially the same length leads that create a multiposition grid array through a mold compound surface of a molded package. Such an assembly has a number of advantages, including relatively small size, enhanced heat conduction, a robust structure and improved sealing of the assembly components.

[0027] Turning to FIG. 4, a side view of a section of another embodiment of a semiconductor assembly 60 made in accordance with the principles of the present invention is depicted. A semiconductor chip 62 is attached to a lead 68 of a leadframe (depicted as a section of neighboring lead 64) by an adhesive element 66 in LOC chip fashion. As described above, with respect to FIGS. 1 and 2, an offset 72 includes an array pad 74 exposed through molding compound 76 on surface 78. Solder balls 80 disposed on the array pads 74 create a ball grid array. It will be appreciated that structures and features equivalent to those discussed above, in connection with FIGS. 1 to 3, may be included in embodiments similar to that of FIG. 4, and insofar as there are common features, the prior discussion of such common features applies here as well. This discussion accordingly will focus on the additional features of FIG. 4.

[0028] Lead shaft 70 runs from a side 61 of the semiconductor assembly 60 towards inner bond end 82 directed towards the center of the assembly 60. Inner bond end 82 is directly

thermocompressively bonded to a bond pad 84 located on the longitudinal axis or centerline L of semiconductor chip 62.

[0029] FIG. 5 depicts the lead 68 of FIG. 4, allowing inner bond end 82 to be seen in greater detail. Inner bond end 82 may feature a contact pad 90 located at the underside of the inner bond end 82 of shaft 70. Contact pad 90 is configured for bonding to a bond pad 84 when subjected to an appropriate thermocompressive effect. To enhance the ability of the contact pad 90 in forming the bond, inner bond end 82 may desirably include an area of increased flexibility adjacent and outboard from contact pad 90. Undercut 92 is located on the chip side of the shaft 70, adjacent to contact pad 90. Undercut 92 comprises a thinner section or smaller cross-section segment of the shaft 70. The shaft 70 may be formed with undercut 92 in place. Alternatively, undercut 92 may be formed by etching or grinding material from a segment of the shaft 70.

[0030] This thinner section of shaft 70 formed by the undercut 92 increases the flexibility of the shaft 70 at the inner bond end 82 in directions perpendicular to the axis of the shaft 70 as depicted by arrow 94. Inner bond end 82 and specifically contact pad 90 of shaft 70 thus may be easily moved downwards toward the bond pad 84 in order to facilitate forming the thermocompressive bond therewith. It will be appreciated that the thermocompressive bond between contact pad 90 and bond pad 84 may be formed by any suitable means known now, or in the future, to those skilled in the art. It is also contemplated that a conductive or conductor-filled adhesive may be used to form an electrical and mechanical connection between contact pads 90 and bond pads 84. Likewise, a Z-axis anisotropic conductive film may be disposed therebetween.

[0031] In accordance with the description provided, the present invention includes methods of forming semiconductor assemblies that include leads-over-chip leadframes with substantially one-length leads forming a grid array through offset positioning. Similarly, the present invention includes methods of forming semiconductor assemblies which include leadframes forming an upset grid array that are thermocompressively bonded to a semiconductor chip.

[0032] It will be appreciated that the foregoing leadframes, semiconductor assemblies, and methods of forming assemblies result in structures with advantages over the prior art. Such assemblies include a molded package with inherent sealing and protection, are reinforced by a number of similar-length leads creating a stronger package, include a grid array that can feature a BGA, SLICC or similar structure, may include leads allowing for improved thermocompression bonding, and allow for the semiconductor chip to be mounted in a LOC fashion. The grid array

may be positioned to form an assembly that is only slightly larger than the semiconductor chip. Since a leadframe is used in forming the assembly, no expensive retooling of fabrication equipment is required.

[0033] It is apparent that details of the apparatus and methods herein described can be varied considerably without departing from the concept and scope of the invention. The claims alone define the scope of the invention as conceived and as described herein.

CLAIMS

What is claimed is:

1. A method of forming a semiconductor package comprising:

providing a semiconductor chip comprising at least a first electrical contact pad and at least a second electrical contact pad disposed on an active surface thereof;

providing a leadframe comprising at least a first lead and at least a second lead originating at a first side of said leadframe in a first plane and having substantially similar lengths, said at least a first lead comprising at least a first array offset between inner and outer ends thereof comprising a segment of said at least a first lead that protrudes from said first plane to a second plane, and said at least a second lead comprising at least a second array offset between inner and outer ends thereof comprising a segment of said at least a second lead that protrudes from said first plane to said second plane;

attaching said leadframe to said active surface of said semiconductor chip;

electrically connecting said at least a first lead to said at least a first electrical contact pad and said at least a second lead to said at least a second electrical contact pad;

placing said leadframe and semiconductor chip into a mold cavity with at least a portion of said at least a first array offset and said at least a second array offset in contact with an interior surface of said mold cavity; and

introducing a molding compound into said mold cavity to encapsulate said at least a first lead and said at least a second lead and said active surface of said semiconductor chip.

2. The method according to claim 1, wherein attaching said leadframe to said semiconductor chip comprises bonding said leadframe to said semiconductor chip with an adhesive element.

3. The method according to claim 1, wherein electrically connecting said at least a first lead to said at least a first electrical contact pad and said at least a second lead to said at least a second electrical contact pad comprises wirebonding or thermocompression bonding.

4. The method according to claim 1, further comprising disposing a volume of an electrically conductive material upon said at least a portion of each of said at least a first array offset and said at least a second array offset to form discrete conductive elements.

5. The method according to claim 4, further comprising removing any molding compound flash from said at least a portion of each of said at least a first array offset and said at least a second array offset prior to disposing said volume of said electrically conductive material thereon.

6. The method according to claim 4, wherein disposing said volume of an electrically conductive material upon said at least a portion of said each of said at least a first array offset and said at least a second array offset comprises disposing a solder, a conductive epoxy, or a conductive-filled epoxy.

7. The method according to claim 6, wherein said electrically conductive material is solder and further comprising flowing said solder to form a solder ball on said at least a portion of said at least a first array offset and said at least a second array offset.

8. The method according to claim 1, wherein providing a leadframe further comprises providing a substantially planar leadframe comprising at least a first lead and at least a second lead of substantially similar length, and bending said at least a first lead to form said at least a first array offset.

9. The method according to claim 8, wherein providing a leadframe further comprises bending said at least a second lead to form said at least a second array offset.

10. A method of forming a semiconductor package comprising:

providing a semiconductor chip comprising at least a first electrical contact pad on an active surface thereof;

providing a leadframe comprising at least a first lead comprising a lead shaft and a bonding end, said bonding end comprising a bonding pad located at an end of said lead shaft, said bonding pad configured for attachment to said at least a first electrical contact pad on said semiconductor chip by a thermocompression bond, said lead shaft comprising a first array offset comprising a section of said lead shaft that protrudes out of a first plane of said leadframe to a second plane and then returns from said second plane to said first plane;

attaching said semiconductor chip to said leadframe;

thermocompressively bonding said bond pad of said at least a first lead to said at least a first electrical contact pad of said semiconductor chip;

placing said attached leadframe and semiconductor chip into a mold cavity; and

injecting a molding compound into said mold cavity to encapsulate said at least a first lead and said active surface of said semiconductor chip.

11. The method according to claim 10, wherein placing said attached leadframe and semiconductor chip into a mold cavity comprises placing said attached leadframe and semiconductor chip such that at least a portion of said at least a first array offset is in contact with a surface of said mold cavity.

12. The method according to claim 10, wherein injecting a molding compound into said mold cavity comprises injecting a molding compound to encapsulate said attached leadframe and semiconductive chip while leaving said at least a portion of said first array offset accessible.

13. The method according to claim 12, further comprising disposing an electrically conductive compound upon said at least a portion of said first array offset that is accessible.

14. The method according to claim 13, further comprising cleaning said at least a portion of said first array offset that is accessible prior to disposing an electrically conductive compound thereon.

15. The method according to claim 13, wherein disposing an electrically conductive compound upon said at least a portion of said first array offset that is accessible comprises disposing solder upon said at least a portion of said first array offset.

16. The method according to claim 15, further comprising flowing said solder to form a solder ball on said at least a portion of said first array offset.

17. The method according to claim 10, wherein thermocompressively bonding the bond pad of said at least first lead to said at least first electrical contact pad comprises flexing the lead shaft towards the semiconductor chip.

18. The method according to claim 17, wherein flexing said lead shaft comprises flexing said lead shaft at an undercut formed in a first surface thereof.

19. The method according to claim 10, wherein attaching said semiconductor chip to said leadframe comprises bonding said leadframe to said semiconductor chip with an adhesive.