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TITLE OF THE INVENTION

SOLDER MASKS FOR USE ON CARRIER SUBSTRATES, CARRIER SUBSTRATES AND SEMICONDUCTOR DEVICE ASSEMBLIES INCLUDING SUCH SOLDER MASKS, AND METHODS

BACKGROUND OF THE INVENTION

Field of the Invention

[0001] The present invention relates generally to solder masks for use on carrier substrates and, more particularly, to solder masks that are configured to prevent excess adhesive material from contacting or covering terminals of carrier substrates. In addition, the present invention relates to carrier substrates including such solder masks and to semiconductor device assemblies and packages including the carrier substrates. The present invention also relates to methods for designing solder masks to be used on carrier substrates, to methods for forming solder masks on carrier substrates, and to methods for connecting semiconductor devices to carrier substrates.

Background of Related Art

[0002] Circuit boards and other carrier substrates have long been employed to establish electrical communication between bond pads of semiconductor dice and other electronic components, including those carried by the circuit board and components that are external to the circuit board.

[0003] Conventionally, relatively small circuit boards have been used to package one or more semiconductor dice, which protects the dice and provides a semiconductor device package that includes a standardized connection pattern, regardless of the arrangement of bond pads of each semiconductor device of such a package. These circuit boards are often referred to in the art as "interposers." In the state of the art, the dimensions of interposers are approaching the corresponding dimensions of the semiconductor dice to be secured thereto, with the result being a continuous decrease in the sizes of semiconductor device packages, many of which are so-called "chip-scale packages" exhibiting dimensions that are the same as or only slightly larger than those of the die thereof..

[0004] Nonetheless, when conventional wire bonding processes are used to electrically connect bond pads of a semiconductor die to corresponding contacts, or terminals, of an interposer to which the semiconductor die is back bonded, the terminals of the interposer must be positioned outside of the outer periphery of the semiconductor die. This

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requirement prevents a reduction in the size of these interposers to dimensions that are substantially the same as those of the semiconductor die to be secured thereto and carried thereby.

[0005] Moreover, in order to securely attach a semiconductor die to the circuit board, it is typically desirable that a sufficient amount of adhesive material be used to form a confluent adhesive layer adjacent to the back side of the semiconductor die and a fillet around the entire outer periphery of the semiconductor die. Some excess adhesive material is typically required to adhere the semiconductor die and the circuit board to one another in this manner. When excess adhesive material is used, however, some of the adhesive material may flow outward from the semiconductor die, beyond the desired location for a fillet, and contaminate the connection surfaces of adjacent terminals, which are located at the same elevation as or just above a surface of the circuit board. If the connection surfaces of the terminals become contaminated in this manner, intermediate conductive elements, such as bond wires, may not adhere thereto or form an effective electrical connection, which may ultimately reduce the reliability of the packaged semiconductor device, electrical shorting, and failure of the packaged semiconductor device.

[0006] Larger circuit boards, such as so-called "motherboards" and the substrates of so-called "plug-and-play" devices or cards, may be configured to carry a plurality of semiconductor devices. As with interposers, the trend with such larger circuit boards is also toward ever-decreasing sizes and ever increasing densities. Consequently, contamination of the connection surfaces of terminals by adhesive material is increasingly encountered when semiconductor devices are assembled with larger circuit boards.

[0007] Solder masks are often used on circuit boards to facilitate the formation of solder balls or bumps on selected terminals of the circuit board while protecting other features thereof and preventing solder from wetting and adhering to other features of the circuit board. The solder masks that are used on circuit boards are typically fabricated from photoresists, using known photolithography processes. These solder masks may be left in place while semiconductor devices and other components are secured and electrically connected to the circuit board. Thus, a semiconductor device may be secured to a solder mask which is, in turn, secured to the circuit board to which the semiconductor device is to be electrically connected.

[0008] When conventional solder masks are used on conventional circuit boards, a portion of the adhesive material that secures a semiconductor device to the solder mask may

still flow laterally outward, beyond the outer periphery of the semiconductor device and onto connection surfaces of the adjacent terminals of the circuit board.

[0009] Some solder masks have been configured with recesses to receive some of the excess adhesive material. Nonetheless, these recesses typically do not have great enough volumes to contain all of the excess adhesive material that is forced from beneath a semiconductor device as the semiconductor device is secured to the solder mask and, thus, to the circuit board. Consequently, the terminals of circuit boards are typically spaced a sufficient distance away from the location at which the outer periphery of a semiconductor device to be secured to the circuit board is to be positioned that the connection surfaces thereof will not be contaminated by adhesive material. Such positioning of the terminals undesirably requires that the circuit board include additional real estate, which prevents a reduction in the dimensions of the circuit board.

[0010] The inventors are not aware of any carrier substrates or solder masks therefor that are configured to prevent adhesive material from flowing onto the connection surfaces of the carrier substrate terminals while reducing the dimensions of the carrier substrate.

SUMMARY OF THE INVENTION

[0011] The present invention includes a solder mask for use on a carrier substrate, such as a circuit board. The solder mask is configured to receive adhesive and prevent the same from contacting or otherwise covering connection surfaces of the terminals of the circuit board or other carrier substrate.

[0012] A solder mask according to the present invention includes semiconductor device-securing regions and may include recesses adjacent to the device-securing regions and which are configured to receive adhesive material, dams that are configured to laterally surround terminals of the circuit board, or a combination thereof. If the solder mask includes one or more recesses, or recessed areas, each recess may extend partially through the solder mask or completely therethrough. The collective volume defined between the outer periphery of a semiconductor device positioned upon a particular device-securing region of the solder mask and the solder dams and/or recesses that are adjacent thereto may receive substantially all of the excess adhesive material that is used to secure the semiconductor device to that supporting region. Accordingly, the height at which the supporting region positions a semiconductor device, as well as the depths and lateral dimensions of the recesses, may be configured to provide a volume that will receive excess adhesive.

[0013] In addition, one or more of the solder dams of the solder mask may extend laterally over a peripheral portion of the connection surface of the terminal around which it is positioned. The laterally extending regions of each such solder dam may also provide additional surface area over which adhesive material may spread before spilling over onto the corresponding terminal of the circuit board.

[0014] A circuit board upon which the solder mask is configured to be disposed may include terminals that protrude from, or are raised or elevated relative to, a surface thereof, increasing the volume within which adhesive material may be received. The distance the terminals protrude from the surface of the circuit board may provide a particular, desired volume between their corresponding solder dams and the location at which the outer periphery of a semiconductor device secured over the circuit board will be positioned. As an increased volume of adhesive material may be received between raised terminals and the location at which the outer periphery of a semiconductor device will be positioned, the terminals may be placed closer to their corresponding die-attach location than the terminals of conventional circuit boards and interposers. In addition, the connection surfaces of the terminals may be located at an elevation that is closer to the elevation at which the bond pads or other contacts of a semiconductor device positioned over the circuit board. As a result of one or both of the closer spacing and raised elevation of the raised terminals, the raised terminals of a circuit board that incorporates teachings of the present invention may facilitate the use of shorter intermediate conductive elements between bond pads or other contacts of a semiconductor device and their corresponding terminals of the circuit board.

[0015] As used herein, the term "circuit board" is not limited to particular structures such as conventional FR-4 resin boards, but encompasses any conductor-carrying, substantially planar substrate or other die support member formed of any suitable material, including without limitation conductor-carrying laminates formed of various materials, silicon or glass substrates with deposited (as by photolithography) conductors, ceramic substrates and other suitable conductor carriers as known in the art. Further, the term circuit board includes and encompasses all types of single-die and multi-dice assemblies, such as multi-chip modules (MCMs) including different types of dice or the same die type, the latter being exemplified by single in-line memory modules (SIMMs) or dual in-line memory modules (DIMMs).

[0016] Known techniques, including the use of adhesive material and positioning one or more semiconductor devices over the circuit board and in contact with the adhesive

material, may be used to secure a semiconductor device to a circuit board carrying a solder mask according to the present invention. Upon being brought into contact with the adhesive material, positive pressure exerted by the positioning device and/or gravity may cause adhesive material between a support region of the solder mask on the circuit board and the semiconductor device may cause adhesive material to flow laterally outward, beyond an outer periphery of the support region and/or the semiconductor device. A receptacle formed at least in part by the solder mask will receive adhesive that is forced during placement of the semiconductor device. The volume of each adhesive receptacle, as well as the heights of the solder dams of the solder mask that laterally surround corresponding terminals of the circuit board, prevent adhesive material from contaminating the terminals.

[0017] A semiconductor device assembly incorporating teachings of the present invention includes a circuit board with the solder mask thereon, as well as at least one semiconductor device positioned over and secured to a corresponding support region of the solder mask. Contacts of the semiconductor device may be electrically connected to corresponding terminals of the circuit board by way of intermediate conductive elements, such as leads, bond wires, conductive tape-automated bond (TAB) elements carried by a dielectric film. The semiconductor device assembly may also be partially or fully encapsulated.

[0018] The present invention also includes methods for designing circuit boards and solder masks to be used on circuit boards. The circuit boards, solder masks, or combinations thereof are configured to prevent excess adhesive material from contaminating the connection surfaces of circuit board terminals, while facilitating the placement of circuit board terminals more closely to the location at which the outer periphery of a semiconductor device will be located than the terminals of a conventional circuit board may be placed relative to the location at which the outer periphery of a semiconductor device thereon will be located.

[0019] A method for designing a solder mask in accordance with the present invention includes configuring at least one device-securing region and at least one corresponding recess or a plurality of dams laterally adjacent thereto. Alternatively, a combination of dams and recesses may be configured, with the dams being located adjacent to at least one recess, opposite from the corresponding device-securing region. The heights of the at least one device-securing region and the solder dams that correspond thereto, as well as the depth and lateral dimensions of the at least one corresponding recess, may be configured to provide a desired adhesive receptacle volume.

[0020] Additionally, the present invention includes a method for designing a circuit board to minimize contamination of the terminals thereof by excess adhesive. Such a method includes configuring terminals of the circuit board to protrude from a surface of the circuit board a distance that will provide a desired adhesive receptacle volume laterally between the terminals and a corresponding semiconductor device once the semiconductor device has been secured to the circuit board, while facilitating the connection of intermediate conductive elements to the terminals after the semiconductor device has been secured to the circuit board.

[0021] Other features and advantages of the present invention will become apparent to those of ordinary skill in the art through consideration of the ensuing description, the accompanying drawings, and the appended claims.

BRIEF DESCRIPTION OF THE DRAWINGS

[0022] In the drawings, which depict various aspects of exemplary embodiments of the present invention:

[0023] FIG. 1 is a top view of an exemplary circuit board according to the present invention, which includes terminals that protrude from at least one surface thereof;

[0024] FIG. 2 is a cross-section taken along line 2—2 of FIG. 1;

[0025] FIG. 3 is a cross-sectional representation of another exemplary circuit board which includes a raised die-attach location;

[0026] FIG. 4 is a top view of a circuit board with each recessed area thereof being positioned adjacent to a portion of the periphery of a die-attach location thereof;

[0027] FIG. 5 is a top view of an exemplary solder mask according to the present invention;

[0028] FIG. 6 is a top view of another exemplary solder mask of the present invention, each recessed area of which is located adjacent to only a portion of the periphery of a device-securing region thereof;

[0029] FIG. 7 is a top view of an exemplary circuit board assembly of the present invention which includes a circuit board and a solder mask;

[0030] FIG. 8 is a cross-section taken along line 8—8 of FIG. 7;

[0031] FIG. 9 is a top view of the circuit board assembly of FIG. 7 with a semiconductor device secured and electrically connected thereto; and

[0032] FIG. 10 is cross-section taken along line 10—10 of FIG. 9.

DETAILED DESCRIPTION

[0033] With reference to FIGs. 1 and 2, an exemplary embodiment of a circuit board 10 is depicted which incorporates teachings of the present invention. The depicted circuit board 10 includes a substantially planar substrate 12 with a plurality of die-attach locations 20 on at least one surface 14 thereof. Terminals 26 that correspond to each die-attach location 20 are positioned laterally adjacent thereto, adjacent to a periphery 22 of area of surface 14 that will be occupied by a semiconductor device (not shown in FIG. 1 or FIG. 2) that will be secured to the corresponding die-attach location 20. Circuit board 10 may also include at least one recessed area 24 located at least partially between each die-attach location 20 and at least some of its corresponding terminals 26.

[0034] Substrate 12 of circuit board 10 may be formed from one or more layers of any suitable material (*e.g.*, FR-4 resin). In addition to terminals 26, a plurality of conductive traces 28 that communicate with terminals 26 may be carried upon one or both surfaces 14 and 16 of circuit board 10, or internally thereby, if substrate 12 comprises a multi-layer laminate structure. As is well known in the art, conductive traces 28 are arranged in such a way as to establish communication between the leads of contacts (not shown in FIG. 1 or FIG. 2) of one or more of the semiconductor devices (also not shown in FIG. 1 or FIG. 2) that are electrically connected thereto and other components, such as the peripheral componentry of a computer, other semiconductor devices, or the like, which may be carried by circuit board 10 or external thereto. To establish communication between the leads or contacts of a semiconductor device that has been secured to circuit board 10 and componentry external to circuit board 10, conductive traces 28 may extend to connective elements 30 of circuit board 10, such as so-called "plug-and-play" type connectors, secondary terminals, conductive pins, or the like.

[0035] Although it is currently preferred that conductive traces 28 do not extend across a surface 14, 16 of circuit board 10 in the area of a die-attach location 20, circuit boards 10 that include die-attach locations 20 with circuit traces 28 extending thereacross are also within the scope of the present invention.

[0036] Each die-attach location 20 of circuit board 10 is an area over which a semiconductor device is to be physically secured. By way of example only, bare semiconductor devices, packaged semiconductor devices, or multi-chip assemblies may be secured over each die-attach location 20. Die-attach locations 20 may reside in substantially

the same plane as their corresponding surface 14, 16, as shown in FIGs. 1 and 2, or they may be raised somewhat relative to their corresponding surface 14, 16 and, thus, reside in a different plane than that surface 14, 16, as depicted in FIG. 3.

[0037] Terminals 26 of circuit board 10 are arranged on a surface 14, 16 thereof in such a way as to facilitate the placement of intermediate conductive elements (not shown in FIG. 1 or FIG. 2), such as leads, bond wires, or conductive tape-automated bonding (TAB) elements comprising conductive traces carried upon a flexible dielectric substrate, in desired orientations between each terminal 26 and its corresponding bond pad of an adjacent semiconductor device (not shown in FIG. 1 or FIG. 2). Each terminal 26 of circuit board 10 includes a connection surface 27 to which the corresponding intermediate conductive element is secured to establish electrical communication between that terminal 26 and its corresponding bond pad.

[0038] At least some terminals 26 of circuit board 10 protrude from the surface 14, 16 upon which they are carried. Each such terminal 26 may protrude above its corresponding surface 14, 16 by a distance D_T that will prevent excess adhesive material (not shown in FIG. 1 or FIG. 2), which may be used for securing a semiconductor device to its corresponding die-attach location 20, from flowing onto and, thus, contaminating connection surface 27 of that terminal 26. In addition, connection surface 27 of each protruding terminal 26 may be positioned at an elevation above its corresponding surface 14, 16 that facilitates the connection of one or more intermediate conductive elements thereto. The raised height of each connection surface 27, as well as the possibly closer positioning of each terminal 26 relative to is corresponding die-attach location 20, may facilitate the use of shorter intermediate conductive elements between each terminal 26 and its corresponding bond pad or other contact of a semiconductor device as the semiconductor device is secured and electrically connected to circuit board 10.

[0039] Terminals 26 of circuit board 10 may be fabricated by any suitable, known technique. By way of example only, an electrolytic process that employs known dry film techniques and copper filling or plating may be used to form terminals 26. Also, each terminal 26 may be plated with a material, such as gold or another so-called "noble metal", nickel, or a combination of different plating layers, that may enhance the adhesion and electrical connection characteristics of an intermediate conductive element thereto. Such plating may also be effected by known processes, such as by electrolytic, electroless, or immersion plating techniques.

[0040] If circuit board 10 also includes one or more recessed areas 24, each recessed area 24 may be sized and configured to receive at least some of the excess adhesive material that is forced outwardly from a die-attach location 20 of circuit board 10 as a semiconductor device is secured in position thereover. Each recessed area 24 may substantially laterally surround its corresponding die-attach location 20, as depicted in FIGs. 1 and 2. Alternatively, as shown in FIG. 4, one or more discrete recessed areas 24' may be positioned laterally around only portions of a corresponding die-attach location 20. Further, each recessed area 24 may extend into its corresponding die-attach location 20 so as to overlap periphery 22 and to extend at least partially beneath a semiconductor device when the semiconductor device is secured into position over that die-attach location 20 (*see* FIG. 10). Recessed areas 24 may also laterally extend substantially to a periphery of each terminal 26 that corresponds to the corresponding die-attach location 20, thereby effectively increasing the height of each such terminal 26 for purposes of preventing excess adhesive material from flowing onto and contaminating connection surface 27 thereof.

[0041] Turning now to FIG. 5, an exemplary embodiment of a solder mask 30 for use on a surface of a circuit board, such as circuit board 10 of FIGs. 1 and 2, is illustrated. Solder mask 30 includes a plurality of dams 46 that are configured to laterally surround corresponding terminals (*e.g.*, terminals 26 of circuit board 10, shown in FIGs. 1 and 2) of the circuit board. As shown in FIG. 5, solder mask 30 may also include a plurality of device-securing regions 40 to which semiconductor devices may be secured. Also, if solder mask 30 includes one or more device-securing regions 40, it may also include at least one recessed area 44 adjacent to each device-securing region 40.

[0042] Solder mask 30 is configured to prevent solder or another electrically conductive joint-forming material (*e.g.*, a conductive elastomer, conductor-filled epoxy, etc.) (not shown) from contacting various features of a circuit board. Thus, solder mask 30 prevents such conductive joint-forming materials from damaging the circuit board, as well as from wetting and, thus, adhering to and potentially causing electrical shorting between electrically conductive features of the circuit board or structures carried thereby, such as conductive traces of the circuit board, connective elements of the circuit board, and devices that have already been secured to the circuit board, as well as other terminals of the circuit board to which bond wires or conductive TAB elements are to be subsequently secured.

[0043] Each dam 46 of solder mask 30 contacts at least a portion of a periphery of a corresponding terminal of the circuit board (*e.g.*, a terminal 26 of circuit board 10) so as to

prevent solder from flowing between that dam 46 and its corresponding, adjacent terminal 26. Also, the distance D_D (FIG. 8) each dam 46 protrudes above a laterally adjacent location of solder mask 30 prevents excess quantities of the adhesive material (not shown in FIG. 5) which is used to secure a semiconductor device (not shown in FIG. 5) to the circuit board over which solder mask 30 is positioned from flowing onto and, thus, from contaminating its corresponding terminals.

[0044] As depicted in FIG. 10, each dam 46 may include a laterally extending ledge 47 which is configured to extend over a peripheral edge of the connection surface of its corresponding terminal (*e.g.*, connection surface 27 of terminal 26). Ledge 47 may be configured to further prevent excess adhesive material from flowing onto and contaminating the connection surface without impeding connection of an intermediate conductive element thereto. Thus, the height H of ledge 47 relative to the connection surface 27 of the adjacent terminal 26 may be small enough, and the area and shape of the connection surface 27 that is exposed through or laterally beyond ledge 47 may be large enough, to permit connection equipment (*e.g.*, a wire bonding capillary) to access the connection surface.

[0045] As shown in FIG. 5, each dam 46 is configured to surround the entire periphery of its corresponding terminal. Also, each dam 46 includes a ledge 47 (FIG. 10) that extends over the entire peripheral edge of the connection surface of its corresponding terminal.

[0046] Each device-securing region 40 of solder mask 30 is positionable over a corresponding die-attach location of the circuit board (*e.g.*, a die-attach location 20 of circuit board 10) over which solder mask 30 is to be positioned. Dams 46 of solder mask 30 that correspond to a particular device-securing region 40 may be positioned laterally adjacent to that device-securing region 40.

[0047] Each device-securing region 40 of solder mask 30 is configured to receive a semiconductor device, such as a bare semiconductor device, a packaged semiconductor device, or a multi-chip assembly, and to have the semiconductor device secured thereto. By way of example only, an adhesive material, such as a suitable epoxy, thermoset resin, or pressure-sensitive adhesive, may be used to secure a semiconductor device to a device-securing region 40 of solder mask 30. If the adhesive material is in a liquid or semisolid state as the semiconductor device is positioned over device-securing region 40, some of the adhesive material may be forced from between the semiconductor device and device-securing

region 40, laterally beyond an outer periphery of the semiconductor device, and toward dams 46 and their corresponding terminals of the circuit board that underlies solder mask 30.

[0048] To further reduce the likelihood that such excess adhesive material will flow over dams 46 and contaminate the connection surfaces of their corresponding terminals, one or more recessed areas 44 may be provided between each device-securing region 40 and at least some of its corresponding dams 46. Each recessed area 44 may have dimensions that are configured to receive substantially all of the excess adhesive material that is forced from between a semiconductor device and the adjacent device-securing region 40 when the semiconductor device is secured to device-securing region 40.

[0049] As shown in FIG. 5, a single recessed area 44 laterally surrounds an outer periphery 42 of each device-securing region 40. Alternatively, as depicted in FIG. 6, one or more recessed areas 44□may be positioned adjacent to only portions of an outer periphery 42 of a corresponding device-securing region 40 of solder mask 30. In either event, as shown in FIG. 10, one or more recessed areas 44 may extend beneath the location at which an outer periphery of a semiconductor device will be positioned when the semiconductor device is secured to device-securing region 40.

[0050] Solder mask 30 may comprise a preformed element that is configured to be aligned relative to, positioned over, and secured (*e.g.*, with an adhesive material) to a complementary circuit board. Alternatively, solder mask 30 may be formed on the circuit board.

[0051] A variety of known, suitable processes may be employed to form solder mask 30 either separately from or on a circuit board. By way of example only, known photolithography techniques, which include the use of a liquid photoresist material, a pattern on a reticle to be copied to a layer of the photoresist material, radiation of a suitable wavelength for exposing selected regions of the layer of photoresist material through the reticle, and resist-developing chemicals that are appropriate for use with the photoresist material. Dry film photoresist materials are also known and suitable for use in the present invention. As another example, stereolithographic techniques may be used to form solder mask 30 from one or more layers of a photocurable polymer by selectively exposing regions of each layer of photocurable polymer, one layer at a time, to cure the selectively exposed regions.

[0052] Turning now to FIGs. 7 and 8, an example of a circuit board assembly 1 is depicted which includes a circuit board 10″ and a solder mask 30″ that incorporate teachings of the present invention.

[0053] As shown, circuit board 10″ includes a substrate 12″ with a single die-attach location 20″ on a substantially planar surface 14″ thereof. A plurality of terminals 26″ are positioned around and adjacent to a periphery 23″ of die-attach location 20″. Each of terminals 26″ protrudes from surface 14″ to substantially the same elevation relative to (*e.g.*, over) surface 14″.

[0054] Solder mask 30″, which substantially covers surface 14″, includes a single device-securing region 42″ that is aligned with and positioned over at least a portion of die-attach location 20″ of circuit board 10″. In addition, dams 46″ of solder mask 30″ are aligned with and positioned laterally around corresponding terminals 26″ of circuit board 10″. As shown, dams 46″ may substantially laterally surround terminals 26″, with only connection surface 27″ of each terminal 26″ or a portion thereof being exposed through each dam 46″. A recessed area 44″ is positioned between each peripheral edge 43″ of device-securing region 42″ and dams 46″ that are located adjacent to that peripheral edge 43″. Thus, each recessed area 44″ is positioned over circuit board 10″ so as to extend laterally from a die-attach location 20″ thereof to terminals 26″ that correspond to that die-attach location 20″.

[0055] In FIGs. 9 and 10, assembly and electrical connection of semiconductor devices 50 with a strip 2 comprising a plurality of unsevered circuit board assemblies 1 are described.

[0056] Semiconductor device 50 may comprise a bare semiconductor die, as depicted, or a packaged semiconductor device. Also, semiconductor device 50 may comprise a single semiconductor die or a multi-chip assembly. A quantity of a suitable adhesive material 60, such as a two-stage epoxy, a thermoset resin, or a pressure-sensitive adhesive material, may be applied to one or both of a bottom surface 52 of a semiconductor device 50 (*i.e.*, the back side of the depicted semiconductor die) and a device-securing region 42″ of solder mask 30″. As a semiconductor device 50 is positioned adjacent to (*e g.*, over) its corresponding device-securing region 42″, some adhesive material 60 therebetween may be forced beyond an outer periphery 54 of semiconductor device 50, toward dams 46″ of solder mask 30″ and their corresponding terminals 26″ of circuit board 10″. This excess adhesive material 60 is received within recessed areas 44″, as well as between outer periphery 54 of semiconductor

device 50 and dams 46″ of solder mask 30″ that are positioned adjacent to associated terminals 26″ of circuit board 10″. The volume defined by recessed areas 44″, outer periphery 54 of semiconductor device 50, and dams 46″ of solder mask 30″ is preferably sufficient to receive substantially all of the excess adhesive material 60 forced from between semiconductor device 50 and device-securing region 42″ of solder mask 30″. Thus, this collective volume preferably prevents adhesive material 60 from flowing onto exposed portions of connection surfaces 27″ of adjacent terminals 26″.

[0057] Any combination of raised terminals 26, 26″ and dams 46, 46″, recessed areas 24 of a circuit board 10, and recessed areas 44, 44″ of a solder mask 30, 30″ of the present invention may prevent adhesive material 60 from contaminating connection surfaces 27, 27″ of terminals 26, 26″. Accordingly, each of these features of the present invention facilitates the placement of terminals 26, 26″ in closer proximity to their corresponding die-attach location 20, 20″ than the terminals of conventional circuit boards may be positioned relative to their corresponding die-attach locations.

[0058] Once a semiconductor device 50 has been positioned and properly oriented relative to the appropriate locations of circuit board 10″ and solder mask 30″, adhesive material 60, if a curable material, may be partially or substantially cured, as appropriate for the type of adhesive material 60 used, to securely maintain the position of semiconductor device 50 on device-securing region 44″. In addition, intermediate conductive elements 70, such as the bond wires that are shown, leads, or conductive TAB elements carried by a dielectric film, may be positioned or formed between bond pads 56 of semiconductor device 50 and their corresponding terminals 26″ of circuit board 10″.

[0059] Following the placement or formation of intermediate conductive elements 70 between bond pads 56 of semiconductor device 50 and their corresponding terminals 26″ of circuit board 10″, semiconductor device 50, intermediate conductive elements 70, and, optionally, circuit board 10″ may be fully or partially encapsulated, as known in the art. By way of example only, a so-called "glob top" type encapsulant material 80 may be disposed on semiconductor device 50 and intermediate conductive elements 70 (FIG. 8). Alternatively, semiconductor device 50, intermediate conductive elements 70, and at least adjacent portions of circuit board 10″ may be encapsulated in a molded package.

[0060] Although the foregoing description contains many specifics, these should not be construed as limiting the scope of the present invention, but merely as providing illustrations of some of the presently preferred embodiments. Similarly, other embodiments of the invention may be devised which do not depart from the spirit or scope of the present invention. Moreover, features from different embodiments of the invention may be employed in combination. The scope of the invention is, therefore, indicated and limited only by the appended claims and their legal equivalents, rather than by the foregoing description. All additions, deletions, and modifications to the invention, as disclosed herein, which fall within the meaning and scope of the claims are to be embraced thereby.

CLAIMS

What is claimed is:

1. A solder mask for use on a carrier substrate, comprising:

at least one device-securing region;

at least one recessed area located laterally adjacent to said at least one device-securing region; and

at least one dam adjacent to said at least one recessed area and configured to be positioned laterally adjacent to at least a portion of a terminal of the carrier substrate, said at least one dam being located at least the same elevation as said at least one device-securing region.

2. The solder mask of claim 1, wherein said at least one dam is configured to extend laterally over at least a peripheral edge portion of a connection surface of the terminal.

3. The solder mask of claim 1, wherein said at least one dam is at a higher elevation than said at least one device-securing region.

4. The solder mask of claim 1, wherein said at least one recessed area extends substantially laterally around said at least one device-securing region.

5. The solder mask of claim 1, wherein said at least one recessed area extends substantially laterally adjacent to only a portion of a periphery of said at least one device-securing region.

6. The solder mask of claim 1, wherein said at least one recessed area is configured to receive excess adhesive material forced from between a semiconductor device and said at least one device-securing region.

7. The solder mask of claim 1, wherein said at least one dam has a height configured to prevent excess adhesive material forced from between a semiconductor device and said at least one device-securing region from contaminating a connection surface of the terminal.

8. The solder mask of claim 1, wherein said at least one device-securing region is configured to receive only a portion of a bottom surface of a semiconductor device positioned thereon.

9. A connection element for carrying at least one semiconductor device, comprising:

a substantially planar substrate including:

at least one terminal protruding from a surface of said substantially planar substrate; and

at least one die-attach location; and

a solder mask on said surface of said substantially planar substrate, said solder mask including:

at least one device-securing region positioned over at least a portion of said at least one die-attach location of said substantially planar substrate; and

at least one dam located between said at least one recessed area and said at least one terminal, said at least one dam having a height that at least a distance said at least one terminal protrudes from said surface of said substantially planar substrate.

10. The connection element of claim 9, wherein said at least one dam of said solder mask extends over at least a peripheral edge portion of a connection surface of said terminal of said substantially planar substrate.

11. The connection element of claim 10, wherein said at least one dam of said solder mask is located at a higher elevation than said at least one device-securing region of said substantially planar substrate.

12. The connection element of claim 11, wherein said at least one terminal protrudes from said surface of said substantially planar substrate to a higher elevation than said at least one device-securing region of said substantially planar substrate.

13. The connection element of claim 9, wherein said at least one terminal protrudes from said surface of said substantially planar surface a sufficient distance to

prevent said connection surface thereof from being contaminated with excess adhesive material forced from between said at least one device-securing region and a semiconductor device upon securing of the semiconductor device to said at least one device-securing region.

14. The connection element of claim 9, wherein said substantially planar substrate further includes:

at least one recessed area between said at least one device-securing region and said at least one terminal.

15. The connection element of claim 14, wherein said at least one recessed area substantially laterally surrounds said at least one device-securing region.

16. The connection element of claim 14, wherein said at least one recessed area is located laterally adjacent to only a portion of a periphery of said at least one device-securing region.

17. The connection element of claim 9, wherein said solder mask further includes:

at least one recessed area located laterally adjacent to at least a portion of said at least one device-securing region.

18. The connection element of claim 17, wherein said at least one recessed area is configured to receive excess adhesive material forced from between a semiconductor device and said at least one device-securing region upon securing the semiconductor device to said at least one device-securing region.

19. The connection element of claim 17, wherein said recessed area substantially laterally surrounds said at least one device-securing region.

20. The connection element of claim 17, wherein said recessed area is positioned laterally adjacent to only a portion of a periphery of said at least one device-securing region.

21. The connection element of claim 9, wherein said at least one dam has a height configured to prevent excess adhesive material forced from between a semiconductor device

and said at least one device-securing region from contaminating a connection surface of the terminal.

22. The connection element of claim 9, wherein said at least one dam is configured to extend laterally over at least a peripheral edge portion of a connection surface of the terminal.

23. A semiconductor device assembly, comprising:

a carrier substrate including:

a substantially planar substrate;

at least one die-attach location on a surface of said substantially planar substrate; and

at least one terminal protruding from said surface of said substantially planar substrate;

a solder mask on said carrier substrate, including:

at least one device-securing region positioned at least partially over said at least one die-attach location of said carrier substrate; and

at least one dam positioned adjacent to a peripheral edge of said at least one terminal of said carrier substrate; and

at least one semiconductor device secured to said device-securing region of said solder mask with adhesive material, excess adhesive material located between a peripheral edge of said at least one semiconductor device and said at least one dam, a connection surface of said at least one terminal of said carrier substrate substantially uncontaminated by said excess adhesive material.

24. The semiconductor device assembly of claim 23, wherein at least one of said carrier substrate and said solder mask includes at least one recessed area for receiving at least some of said excess adhesive material.

25. The semiconductor device assembly of claim 24, wherein said at least one recessed area substantially laterally surrounds said at least one device-securing region.

26. The semiconductor device assembly of claim 24, wherein said at least one recessed area is located laterally adjacent to only a portion of a periphery of said at least one device-securing region.

27. The semiconductor device assembly of claim 23, wherein said at least one dam includes a top portion that extends laterally over a peripheral edge portion of said at least one terminal.

28. The semiconductor device assembly of claim 23, wherein an intermediate conductive element electrically connects at least one bond pad of said at least one semiconductor device to said at least one terminal.

29. The semiconductor device assembly of claim 28, further comprising:
an encapsulant material covering at least said intermediate conductive element and at least a portion of said at least one semiconductor device.

30. A method for forming a semiconductor device assembly, comprising:
providing a carrier substrate including at least one die-attach location and at least one terminal adjacent to said die-attach location; and
providing a solder mask on said carrier substrate, said solder mask including at least one securing region positioned over at least a portion of said at least one die-attach location, at least one recessed area adjacent to said at least one device-securing region, and at least one dam adjacent to said at least one recessed area, opposite from said at least one device-securing region, said at least one dam contacting at least a portion of a peripheral edge of said at least one terminal.

31. The method of claim 30, further comprising:
applying adhesive material to at least one of said at least one device-securing region of said solder mask and a bottom surface of at least one semiconductor device to be secured to said at least one device-securing region.

32. The method of claim 31, further comprising:

positioning said at least one semiconductor device to said at least one device-securing region, said adhesive material located between said bottom surface and said at least one device-securing region securing said at least one semiconductor device to said at least one device-securing region.

33. The method of claim 32, wherein said positioning comprises applying force to at least one of said at least one semiconductor device and said carrier substrate.

34. The method of claim 32, wherein said positioning comprises forcing said adhesive material to spread between said bottom surface of said at least one semiconductor device and said at least one device-securing region.

35. The method of claim 34, wherein said positioning comprises causing excess adhesive material to flow laterally beyond at least one of at peripheral edge of said at least one semiconductor device and an periphery of said at least one device-securing region.

36. The method of claim 35, further comprising:
receiving said excess adhesive material within said at least one recessed area.

37. The method of claim 35, wherein said at least one dam prevents said excess adhesive material from contaminating a connection surface of said at least one terminal.

38. The method of claim 30, wherein said providing said solder mask comprises providing a solder mask with said at least one dam comprising a laterally extending portion configured to cover at least portion of a peripheral edge of a connection surface of said at least one terminal.

39. The method of claim 30, wherein said providing said solder mask comprises providing said carrier substrate with said solder mask already secured thereto.

40. The method of claim 30, wherein said providing said solder mask includes securing a preformed solder mask to said surface of said substantially planar substrate.

41. The method of claim 30, wherein said providing said solder mask includes forming said solder mask on said surface of said substantially planar substrate.

42. The method of claim 41, wherein said forming is effected stereolithographically.

43. The method of claim 41, wherein said forming comprises forming a plurality of at least partially superimposed, contiguous, mutually adhered material layers.

44. A method for designing solder mask for use on a carrier substrate, comprising:
configuring at least one device-securing region to have a semiconductor device secured thereto; and
configuring a plurality of raised dams to be positioned adjacent to and in contact with peripheries of terminals of the carrier substrate.

45. The method of claim 44, further comprising:
configuring at least one recessed area between at least a portion of a periphery of said device-securing region and at least one of said plurality of raised dams.

46. A method for designing a solder mask for use on a carrier substrate, comprising:
configuring at least one device-securing region to have a semiconductor device secured thereto; and
configuring at least one recessed area adjacent to said at least one device-securing region.

47. The method of claim 46, further comprising:
configuring a plurality of raised dams adjacent to said at least one recessed area, opposite from said at least one device-securing region.

48. A method for designing a solder mask to be used on a carrier substrate, comprising:
configuring at least one device-securing region of the solder mask to be located over at least a portion of a die-attach location of the carrier substrate;

configuring at least one recessed area laterally adjacent to said at least one device-securing region; and

configuring at least one dam adjacent to said at least one recessed area, opposite from said at least one device-securing region, to be located laterally adjacent to and contact a peripheral edge of a terminal protruding from a surface of the carrier substrate, and to have a have a height at least as great as a height of said at least one device-securing region.

49. The method of claim 48, wherein said configuring said at least one dam comprises configuring said at least one dam to include a laterally extending ledge positionable over at least a portion of a peripheral edge of a connection surface of the terminal.

50. The method of claim 48, wherein said configuring said at least one dam comprises configuring said at least one dam to have a height that exceeds said height of said at least one device-securing region.

51. The method of claim 50, wherein said configuring said at least one dam comprises configuring said at least one dam to be located at an elevation which is substantially the same or less than an elevation of an active surface of a semiconductor device to be positioned on said device-securing region.

52. A method for designing a carrier substrate, comprising:

configuring a substantially planar substrate to include at least one die-attach location; and

configuring at least one terminal adjacent to said at least one die-attach location and to protrude a sufficient distance from said substantially planar substrate to prevent excess adhesive material forced from between a semiconductor device and said die-attach location from contaminating a connection surface of said at least one terminal.

53. The method of claim 52, further comprising:

configuring an adhesive-receiving area between said at least one die-attach location and said terminal.

54. The method of claim 53, wherein said configuring said adhesive-receiving area comprises configuring at least one recess.

55. The method of claim 54, wherein said configuring at least one recess comprises configuring said at least one recess to substantially laterally surround said at least one die-attach location.

56. The method of claim 54, wherein said configuring at least one recess comprises configuring said at least one recess to be located adjacent to only a portion of said at least one die-attach location.

57. The method of claim 52, wherein said configuring said at least one terminal comprises configuring said at least one terminal to have a height that is at least as great as an elevation at which a bottom surface of the semiconductor device will be supported above said surface of said substantially planar substrate.

58. The method of claim 57, wherein said configuring said at least one terminal comprises configuring said at least one terminal to have a height that is, at most, substantially the same as an elevation at which a top surface of the semiconductor device will be located upon securing the semiconductor device relative to said substantially planar substrate.