



US007368814B1

(12) **United States Patent**
Tully et al.

(10) **Patent No.:** **US 7,368,814 B1**
(45) **Date of Patent:** **May 6, 2008**

(54) **SURFACE MOUNT ADAPTER APPARATUS AND METHODS REGARDING SAME**

(75) Inventors: **Michael J. Tully**, Minneapolis, MN (US); **Ranjit R. Patil**, Eagan, MN (US)

(73) Assignee: **Ironwood Electronics, Inc.**, Eagan, MN (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 426 days.

(21) Appl. No.: **11/088,573**

(22) Filed: **Mar. 24, 2005**

Related U.S. Application Data

(60) Provisional application No. 60/556,983, filed on Mar. 26, 2004.

(51) **Int. Cl.**
H01L 23/12 (2006.01)

(52) **U.S. Cl.** **257/700**; 439/66; 361/760

(58) **Field of Classification Search** 438/257, 438/106-138; 257/700, E23.079; 361/760; 439/66

See application file for complete search history.

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Primary Examiner—Thao X. Le

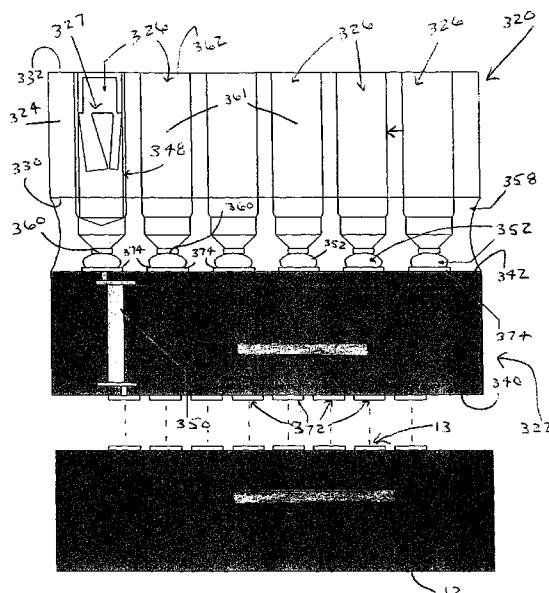
Assistant Examiner—LaTanya Crawford

(74) *Attorney, Agent, or Firm*—Mueting, Raasch & Gebhardt, P.A.

(57) **ABSTRACT**

An adapter apparatus and methods for using in providing such adapter apparatus include providing a high density interconnect board (e.g., having a pattern of contact pads on a first side thereof corresponding to a packaged device, such as a micro lead frame package) and providing an interconnect device. Interconnect elements extend through a substrate of the interconnect device and are electrically connected to conductive pads on a second side of the high density interconnect board.

11 Claims, 8 Drawing Sheets



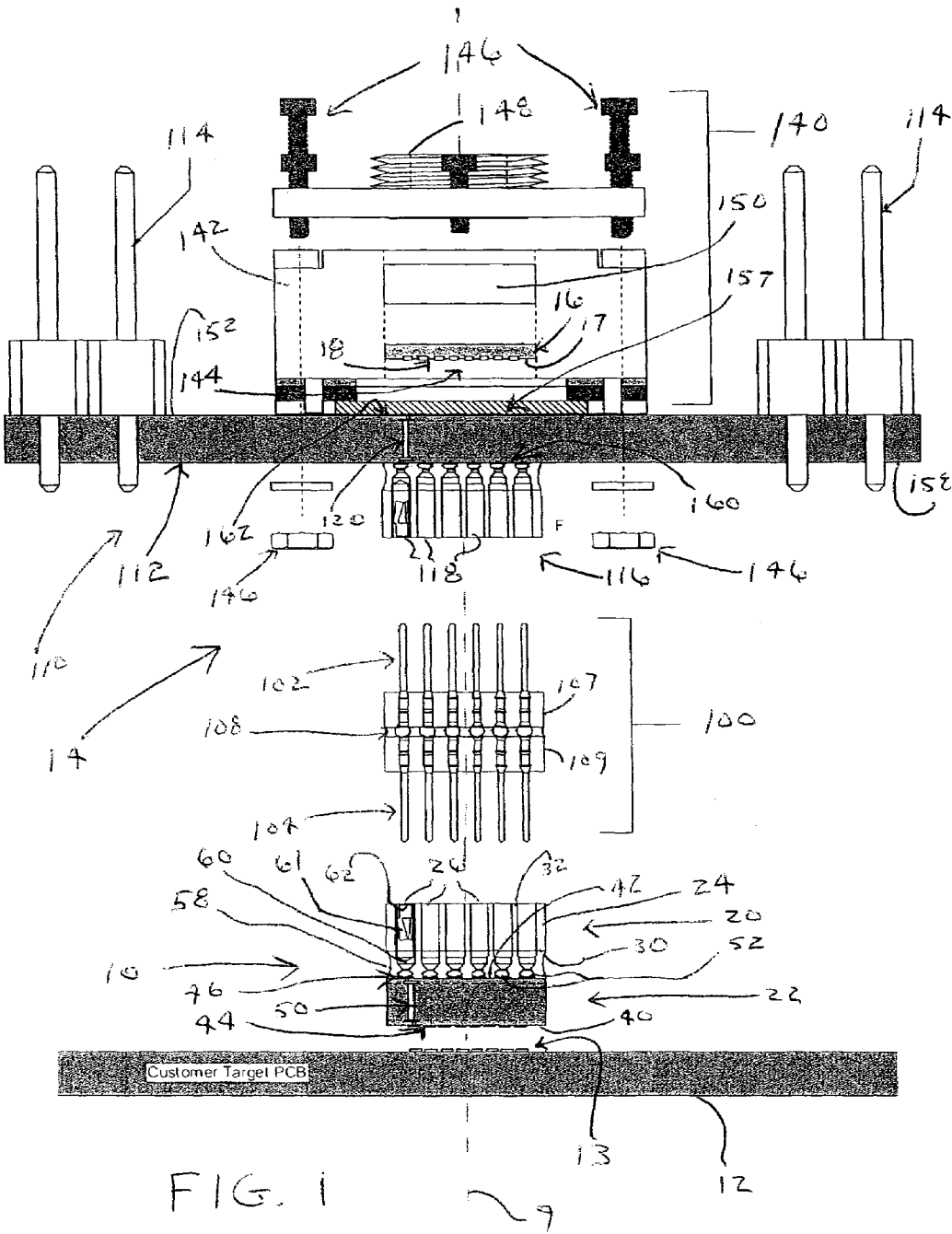


FIG. 1

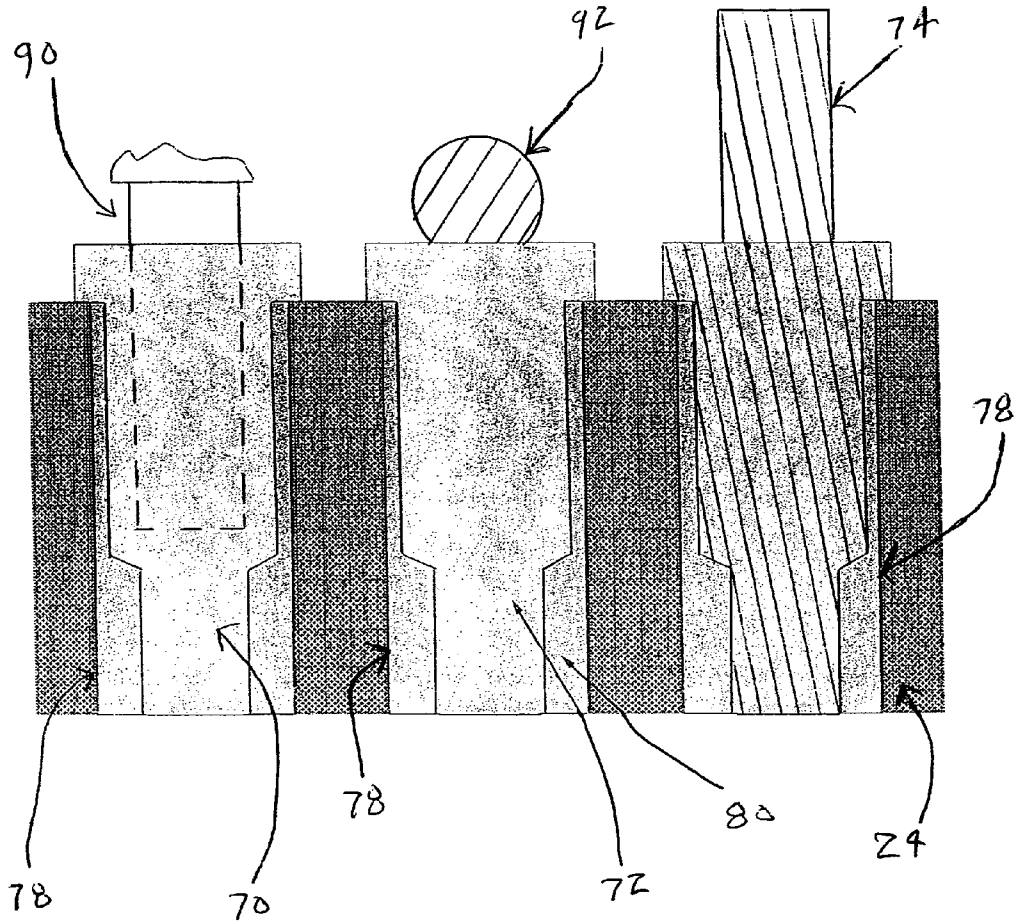


FIG. 2

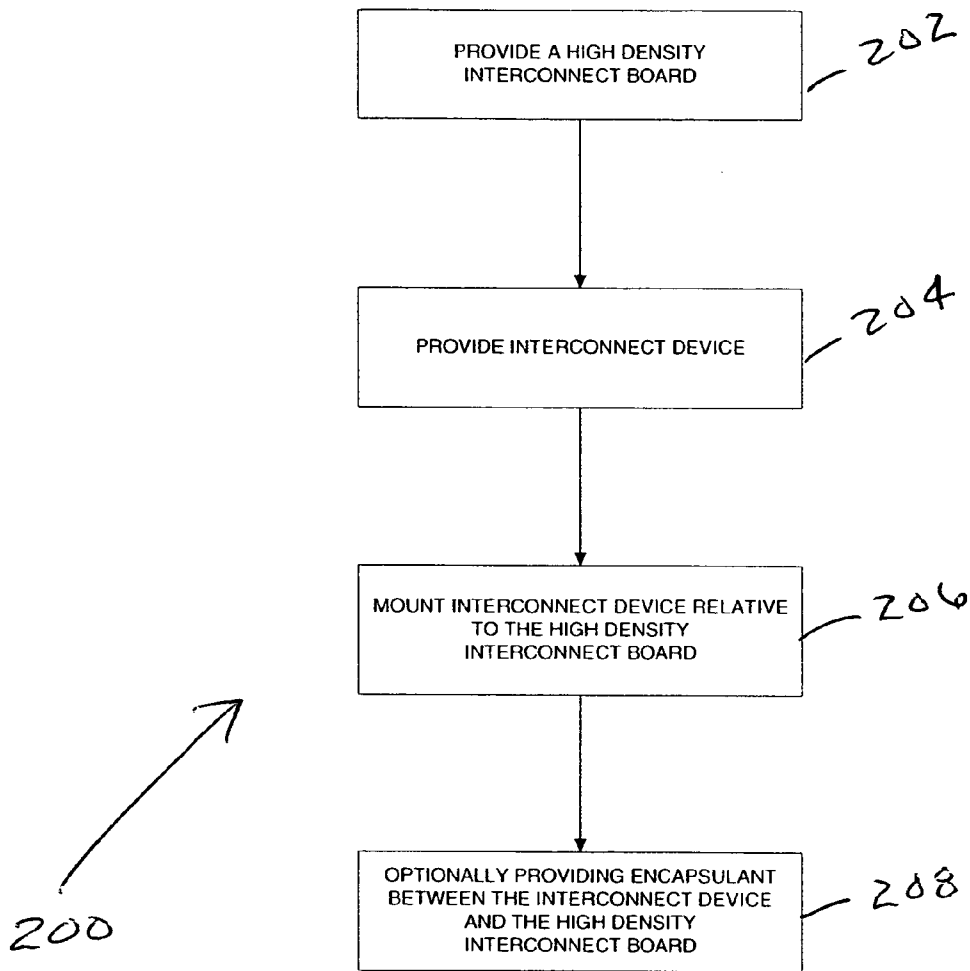


FIG. 3

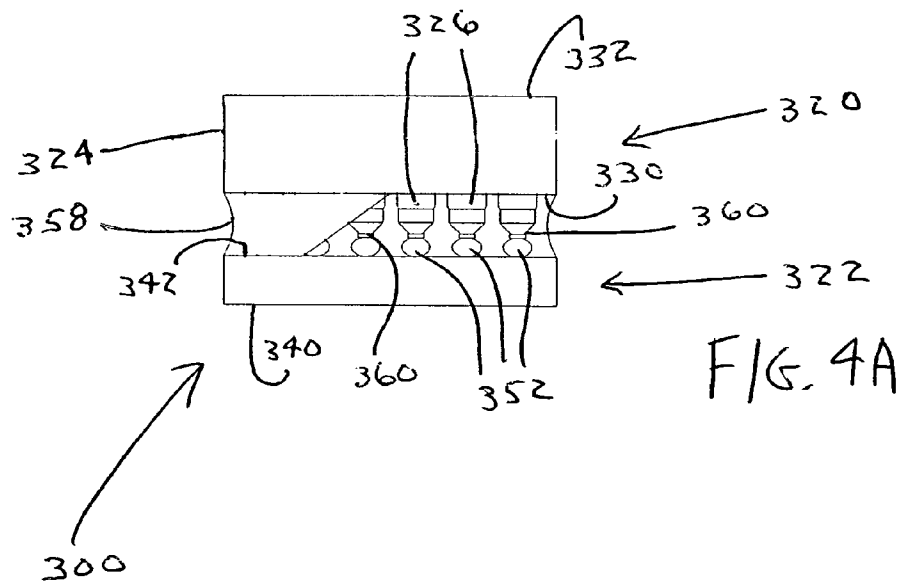
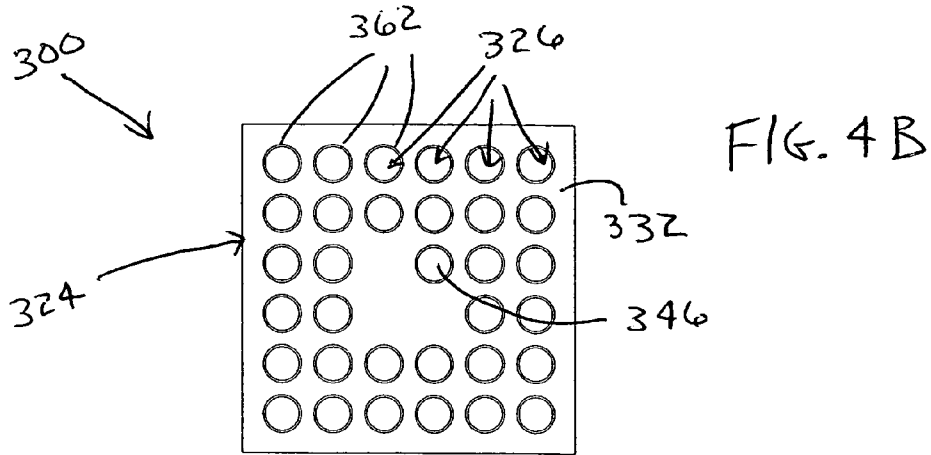


FIG. 4D

300 →

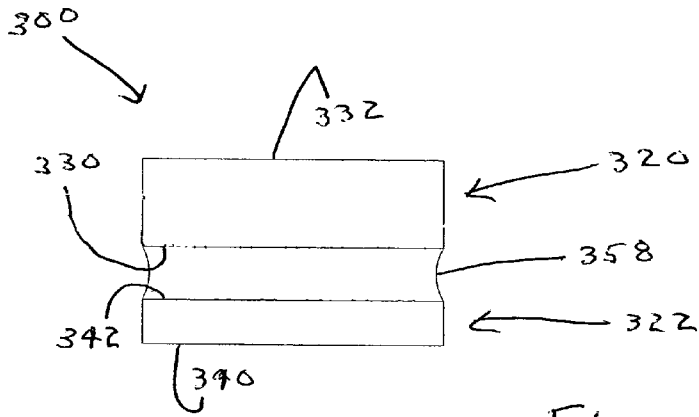
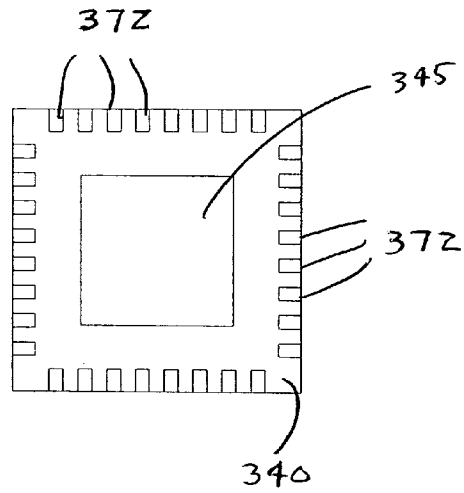
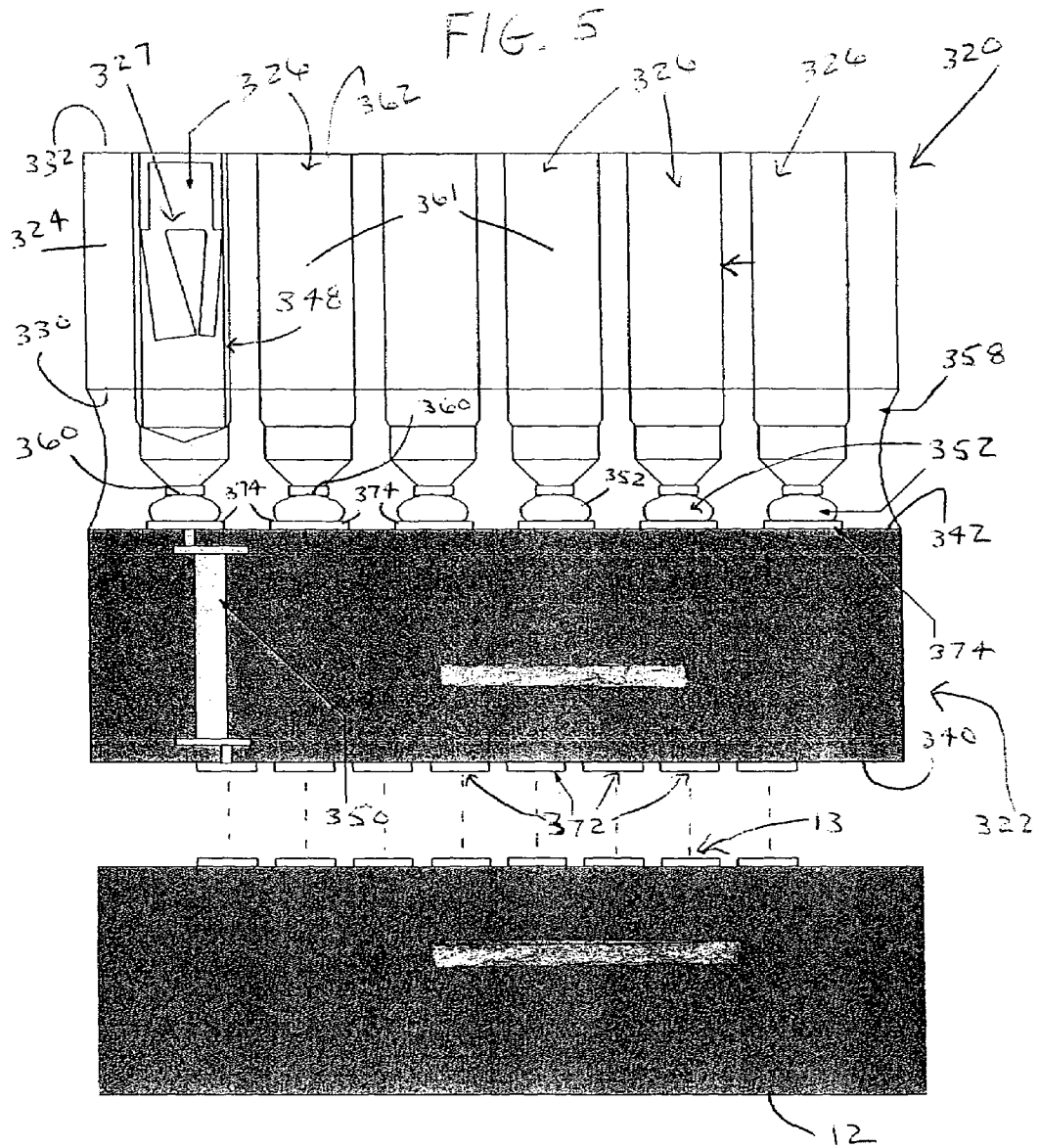
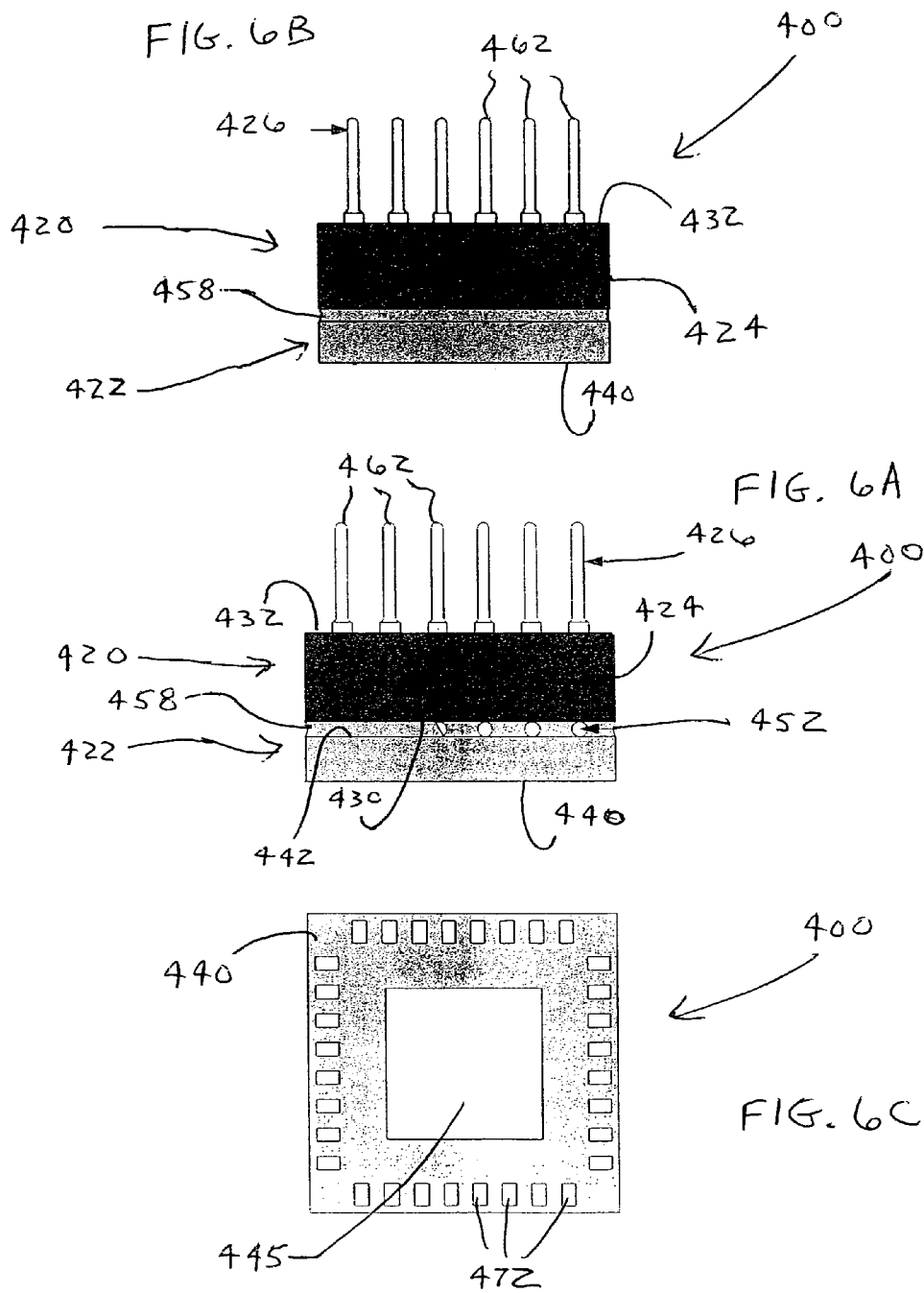
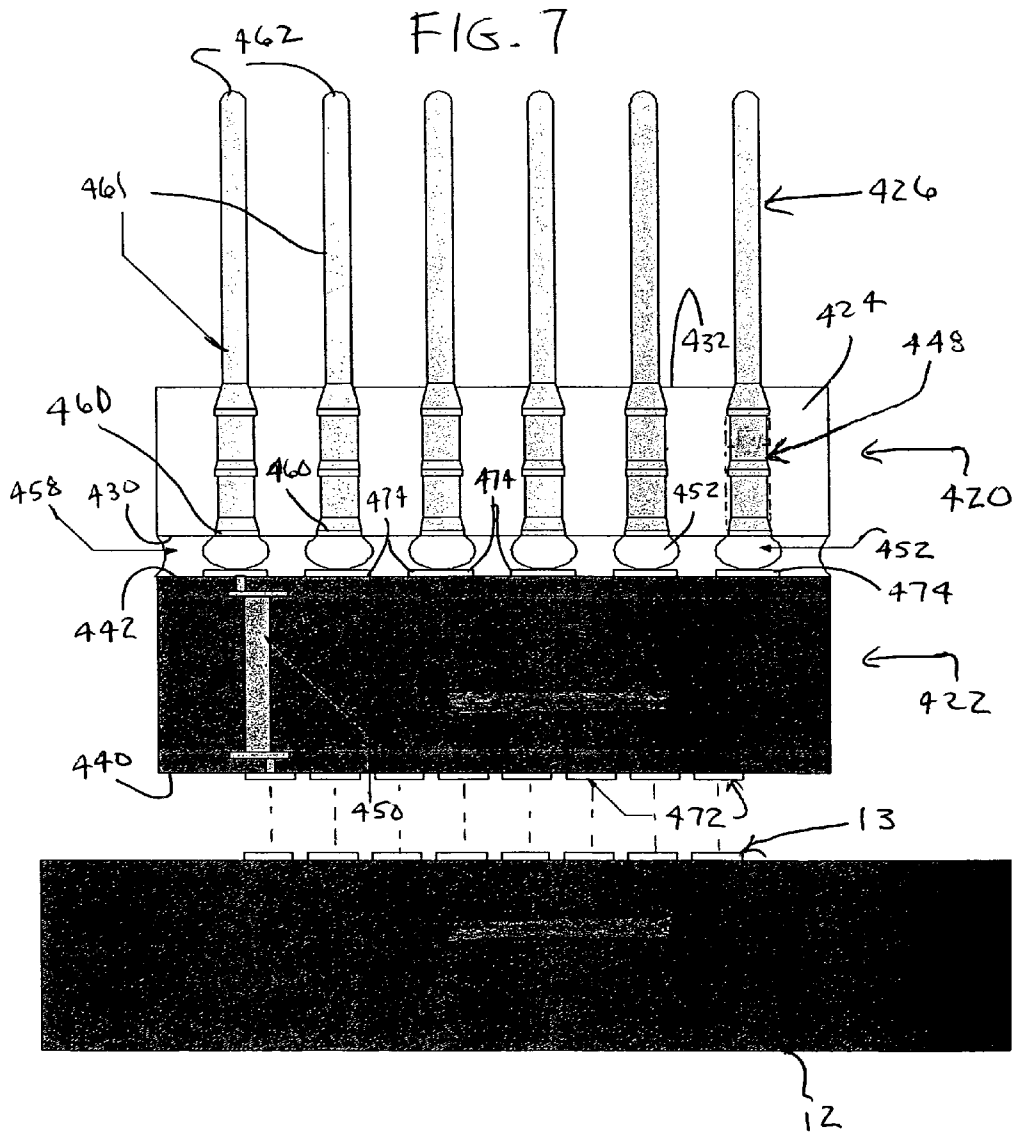


FIG. 4C







SURFACE MOUNT ADAPTER APPARATUS AND METHODS REGARDING SAME

CROSS-REFERENCE TO RELATED APPLICATION

This application claims the benefit of U.S. Provisional Application Ser. No. 60/556,983 filed 26 Mar. 2004, which is incorporated herein by reference in its entirety.

BACKGROUND OF THE INVENTION

The present invention relates generally to adapters for use with packaged devices or other adapter apparatus (e.g., micro lead frame (MLF) devices, chip scale packages (CSP), ball grid array (BGA) packages, land grid array (LGA) or other surface mount devices, male pin adapters, female socket adapter apparatus, etc.).

Certain types of integrated circuit packages are becoming increasingly popular due to their occupancy area efficiency. In other words, they occupy less area on a target board on which they are mounted while providing a high density of contact terminals. For example, one such high density package type is a MLF device.

Generally, such packages contain an integrated circuit having its die bond pads electrically connected to respective conductive surface mount pads that are distributed in a particular configuration on the bottom surface of the package. A target printed circuit board typically has formed on its surface a corresponding configuration of conductive pads which align with the configuration of surface mount pads of the package for electrically mounting the package on the target board. The target board typically includes other conductive traces and elements which lead from the conductive pads used for mounting the package to other circuitry on the target board for connecting various components mounted thereon.

A MLF package is a type of chip scale package (CSP). The die area is a minimum of 80% of the total package area (i.e., the area of the substrate the die is encapsulated in). Further, generally, an MLF package has physical characteristics similar to LGAs, quad flat packages (QFPs), and leadless chip carrier (LCC) type integrated circuit (IC) packages. The MLF package is a leadless design. The interface to the target board is a set of solder pads (e.g., 8-104 pads) on a bottom surface of the package similar to a LGA package. The pads are typically arranged on the perimeter of the package similar to a QFP or LCC type package. MLF packages are generally square or rectangular shaped and have pads along two or four sides of the package on the bottom surface. The pitch between the pads is typically 0.5 mm or less.

Typically, to mount such a package (e.g., MLF package) to a target board, the package is positioned with the configuration of surface mount pads corresponding to the conductive pads on the target board. One or more solder techniques are used (e.g., placement of solder and subsequent heat treatment) to fuse the surface mount pads to the conductive pads of the target board.

Such area efficient packaging (e.g., MLF packages) provide a high density of terminals at a very low cost. Also, this packaging provides for limited lead lengths. Limited lead lengths may reduce the risk of damage to such leads of the package, may provide for higher speed product, etc.

Generally, circuit boards, and/or components mounted thereon, are tested by designers as the circuit boards are being developed. For example, for a designer to test a circuit

board and/or a package mounted thereon, the designer must first electrically connect the package to the target circuit board. As described above, this generally includes mounting the package on the target board using a soldering technique to fuse the surface mount pads to the conductive pads of the target board. Therefore, the package may be prevented from being used again.

It is desirable for various reasons to use package adapters for mounting the packages and reuse such packages after testing. For example, such packages may be relatively expensive. Further, for example, once attached, the leads of the package and/or the connection between the surface mount pads of the package and the conductive pads of the target board are not accessible for testing. In addition, it is often difficult to rework the circuit board with packages soldered thereon.

Various adapters which are used for electrically connecting a package to a target printed circuit board are known. For example, U.S. Pat. No. 6,007,348 to Murphy, issued 28 Dec. 1999, entitled "Solder Sphere Terminal," and U.S. Pat. No. 6,325,280 to Murphy, issued 4 Dec. 2001, entitled "Solder Sphere Terminal," describe several adapter apparatus for use in mounting ball grid array packages. For example, as described therein, various intercoupling components are provided. In one of such components, an insulative support member includes a plurality of terminal elements positioned within holes extending through the insulative support member. The terminal elements are sized to be press-fit within the holes of the insulative support member.

To gain access to the signals on a target board through an ICs land pattern (e.g., configuration of surface mount pads), it is generally necessary to attach an adapter to the IC's land pattern. Ideally, the adapter is employed such that each signal is brought out individually to a probe point or some other interface which can be connected to with test clips, cables, connectors, etc. Connecting individual wires to an ICs solder pads (e.g., pads of a MLF device) is impossible in most cases due to density concerns and would be extremely time consuming work by a technician (e.g., such work would need to be done with specialized equipment under a microscope). Further, due the density of the pads and the size of the package (e.g., MLF packages or other chip scale packages), various available adapters (e.g., ball grid array type adapters or those similar thereto) are inadequate to achieve access to the signals.

SUMMARY OF THE INVENTION

According to the present invention, an apparatus, a system or a method provides a user with one or more features for use in gaining access to signals on target boards for probing, testing, or other interconnection purposes, mounting packaged devices, or providing other functionality that should be apparent from the description provided herein. For example, one embodiment of a surface mount adapter apparatus (e.g., an MLF foot) according to the present invention allows interconnection to a surface mount land pattern on a target board through an adapter which emulates the package (e.g., a MLF package). The adapter apparatus may be used for emulation of any surface mount or chip scale package. The adapter apparatus may be easily and quickly soldered to the land pattern using the same techniques employed to solder the actual package (e.g., MLF package).

A surface mount adapter apparatus according to one exemplary embodiment of the present invention includes a high density interconnect board and an interconnect device. The high density interconnect board has first and second

sides, and further includes a first plurality of conductive pads configured on the first side of the high density interconnect board electrically connected (e.g., using blind and buried vias) with a second plurality of conductive pads configured on the second side of the high density interconnect board. The first plurality of conductive pads are configured for connection to a pattern of conductive pads of a target board (i.e., the pattern of the conductive pads of the target board are configured to receive a packaged device, such as a micro lead frame package or any other chip scale package).

The interconnect device of the surface mount adapter apparatus includes a substrate having first and second sides and a plurality of interconnect elements extending through the substrate. Each of the plurality of interconnect elements includes at least a first end and a second end. The interconnect device is electrically connected (e.g., a reflowed solder connection, conductive epoxy, etc.) to the high density interconnect board with the second side of the high density interconnect board adjacent the first side of the interconnect device. The first end of each of one or more of the plurality of interconnect elements is electrically connected to one of the second plurality of conductive pads on the second side of the high density interconnect board. The high density interconnect board and the interconnect device are configured to have a footprint substantially the same as the packaged device (e.g., a micro lead frame package or any other chip scale package).

In one embodiment of the surface mount adapter apparatus, one or more of the plurality of interconnect elements (e.g., female socket pins, male terminal pins, or conductive elements comprising two ends configured to receive solder material on at least one of the ends) extending through the substrate of the interconnect device may be press-fit into a corresponding opening defined through the substrate of the interconnect device, or in another embodiment, one or more of the plurality of interconnect elements may be mounted within a corresponding opening defined through the substrate of the interconnect device using a curable material.

In another embodiment of the surface mount adapter apparatus, the first plurality of conductive pads of the high density interconnect board are electrically connected with the second plurality of conductive pads of the high density interconnect board using blind and buried micro-vias.

In yet another embodiment of the surface mount adapter apparatus, an encapsulant may be provided between the second side of the high density interconnect board and the first side of the interconnect device.

Still further, a carrier adapter may be configured for connection via the second ends of the plurality of interconnect elements to the surface mount adapter apparatus. The carrier adapter is used to connect a micro lead frame package or any other chip scale package to the surface mount adapter apparatus.

A method for use in forming a surface mount adapter apparatus is also provided according to the present invention. The method includes providing a high density interconnect board having first and second sides. The high density interconnect board further includes a first plurality of conductive pads configured on the first side of the high density interconnect board electrically connected (e.g., using blind and buried vias) with a second plurality of conductive pads configured on the second side of the high density interconnect board. The first plurality of conductive pads are configured for connection to a pattern of conductive pads of a target board with the pattern of the conductive pads of the target board configured to receive a packaged device (i.e., the pattern of the conductive pads of the target board are

configured to receive a packaged device, such as a micro lead frame package or any other chip scale package).

The method further includes providing an interconnect device including a substrate having first and second sides and a plurality of interconnect elements (e.g., female socket pins, male terminal pins, or conductive elements comprising two ends configured to receive solder material on at least one of the ends) extending through the substrate. Each of the plurality of interconnect elements includes at least a first end and a second end. The second side of the high density interconnect board is positioned adjacent the first side of the interconnect device and the first end of each of one or more of the plurality of interconnect elements is electrically connected (e.g., a reflowed solder connection, conductive epoxy, etc.) to one of the second plurality of conductive pads on the second side of the high density interconnect board.

In one embodiment of the method, an encapsulant is provided between the second side of the high density interconnect board and the first side of the interconnect device.

In another embodiment of the method, the method further includes mounting the surface mount adapter apparatus to the target board by connecting the first plurality of conductive pads of the high density interconnect board to the pattern of conductive pads of the target board. A carrier adapter is connected to the surface mount adapter apparatus using the second ends of the interconnect elements (i.e., the carrier adapter being configured for use with the packaged device).

In another embodiment of the method, electrically connecting the first end of each of one or more of the plurality of interconnect elements to one of the second plurality of conductive pads on the second side of the high density interconnect board includes placing solder material on the second plurality of conductive pads on the second side of the high density interconnect board. The second side of the high density interconnect board is positioned adjacent the first side of the interconnect device with the first end of the plurality of interconnect elements in contact with the second plurality of conductive pads on the second side of the high density interconnect board. Thereafter, at least the solder material is thermally treated to connect the first ends of the plurality of interconnect elements to the second plurality of conductive pads on the second side of the high density interconnect board. Further, the method may include providing an encapsulant between the second side of the high density interconnect board and the first side of the interconnect device and surrounding the connection of the first ends of the plurality of interconnect elements to the second plurality of conductive pads on the second side of the high density interconnect board.

The above summary of the present invention is not intended to describe each embodiment or every implementation of the present invention. Advantages, together with a more complete understanding of the invention, will become apparent and appreciated by referring to the following detailed description and claims taken in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a generalized illustrative diagram of one exemplary embodiment of a surface mount adapter apparatus (e.g., including a high density interconnect board and an interconnect device) according to the present invention for use with a carrier adapter to mount a packaged device (e.g., MLF package) relative to a target board.

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FIG. 2 is a generalized diagrammatic view of a portion of an interconnect device of a surface mount adapter apparatus such as shown in FIG. 1 including a plurality of interconnect elements for use in illustrating various types of conductive interconnect elements that may be mounted in openings 5 formed through a substrate of the interconnect device.

FIG. 3 is a block diagram showing one generalized embodiment of a method for providing a surface mount adapter apparatus such as that shown generally in FIG. 1.

FIGS. 4A-4D show a partial cut-away side view, a top view, a side view, and a bottom view, respectively, of one exemplary embodiment of a surface mount adapter apparatus according to the present invention. 10

FIG. 5 shows a more detailed diagrammatic cross-sectional view of the surface mount adapter apparatus shown in FIGS. 4A-4D as well as a target board to which it can be mounted. 15

FIGS. 6A-6C show a partial cut-away side view, a side view, and a bottom view, respectively, of one exemplary alternate embodiment of a surface mount adapter apparatus according to the present invention. 20

FIG. 7 shows a more detailed diagrammatic cross-sectional view of the surface mount adapter apparatus shown in FIGS. 6A-6C as well as a target board to which it can be mounted. 25

DETAILED DESCRIPTION OF THE EMBODIMENTS

The present invention shall generally be described with reference to FIGS. 1-3. A more detailed description of one or more various embodiments of the present invention shall then be described with reference to FIGS. 4-7. It will be apparent to one skilled in the art that elements from one embodiment may be used in combination with elements of the other embodiments, and that the present invention is not limited to the specific embodiments described. Further, it will be recognized that the embodiments of the present invention described herein will include many elements that are not necessarily shown to scale. Further, it will be recognized that the size and shape of various elements herein may be modified without departing from the scope of the present invention, although one or more shapes and sizes may be advantageous over others. 30

FIG. 1 shows a generalized diagrammatic view of a surface mount adapter apparatus 10 mountable on an exemplary target board 12 and configured for receiving a carrier adapter 14, and/or portions thereof. The carrier adapter 14 is used to connect a packaged device 16 (e.g., an MLF device and/or any other chip scale package) having a plurality of conductive pads 18 on a surface (e.g., bottom surface 17) thereof. 35

The surface mount adapter apparatus 10 includes a high density interconnect board 22 and an interconnect device 20. The high density interconnect board 22 includes a first side 40 and a second side 42 opposite the first side 40. The high density interconnect board 22 further includes a first plurality of conductive pads 44 configured on the first side 40 of the high density interconnect board 22 electrically connected with a second plurality of conductive pads 46 configured on the second side 42 of the high density interconnect board 22. The first plurality of conductive pads 44 are configured for connection to a pattern of conductive pads 13 of the target board 12. 40

The pattern of conductive pads 13 on the target board 12 are configured to receive a packaged device 16 thereon. For example, the pattern of conductive pads 13 may be config-

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ured for mounting various types of packaged devices, including, but not limited to, for example, surface mount devices, such as ball grid array packages, land grid array (LGA) packages, micro-lead frame (MLF) devices, column grid array packages, non-solder ball packages, other packaged devices with surface mount pads, etc. One will recognize that the surface mount adapter apparatus 10 will be different depending on the type of packaged device 16 being mounted (e.g., the surface mount apparatus 10 including a different conductive pad configuration and/or other different electrical connections used therein). 5

Preferably, according to the present invention, the surface mount adapter apparatus 10 is used to mount MLF devices and/or any other chip scale packages. As described in the Background of the Invention section, a chip scale package is a package that has a die area that is a minimum of 80% of the total package area (e.g., the area of the substrate the die is encapsulated in). Further, in one embodiment, the pitch between the pads of an MLF package mounted according to the present invention is typically about 0.8 mm or less. In yet another embodiment, the pitch between the pads of an MLF package mounted according to the present invention is typically about 0.5 mm or less. 10

The interconnect device 20 of the surface mount adapter apparatus 10 comprises a substrate 24 having a first side 30 and a second side 32 opposite thereof. A plurality of interconnect elements 26 extend through the substrate 24. Each of the plurality of interconnect elements 26 include a body 61 extending between a first end 60 and a second end 62. 15

The interconnect device 20 is electrically connected to the high density interconnect board 22 with the second side 42 of the high density interconnect board 22 adjacent the first side 30 of the interconnect device 20. Preferably, the sides are orthogonal to axis 9, which axis 9 is generally orthogonal to target board 12 (e.g., the carrier adapter 14, surface mount adapter apparatus 10, and components thereof, extending along axis 9). The first end 60 of each of one or more plurality of interconnect elements 26 are electrically connected to one of the second plurality of conductive pads 46 on the second side 42 of the high density interconnect board 22. 20

With the interconnect device 20 electrically connected to the high density interconnect board 22, the surface mount adapter apparatus 10 may be mounted (e.g., by electrically connecting the conductive pads 44 on the first side of the high density interconnect board 22 to the conductive pads 13 of the target board 12) to the target board 12. As mounted, the surface mount adapter apparatus 10 may receive one or more portions of the carrier adapter 14 for use in mounting packaged device 16. For further structural integrity and isolation of the conductive interconnect elements 26, an encapsulant 58 is provided between the second side 42 of the high density interconnect board 22 and the first side 30 of the interconnect device 20. 25

The high density interconnect board 22 and the interconnect device 20 are configured to have a footprint substantially the same as the packaged device 16. As used herein, the term "footprint" refers to the surface area of the target board occupied by the packaged device 16 and/or the surface mount adapter apparatus 10. For example, a square packaged device having a length and width of 5.25 mm will have a footprint of $(5.25 \text{ mm})^2$. 30

As used herein, the term "substantially the same" used in conjunction with the term footprint shall refer to dimensional characteristics within $\pm 10\%$. For example, if a packaged device having a footprint of $(5.25 \text{ mm})^2$ is being mounted using the surface mount adapter apparatus 10, 35

according to the present invention, the high density interconnect board **22** and the interconnect device **20** shall be configured to have a footprint of $(5.25 \text{ mm})^2 \pm 10\%$.

One will recognize that the footprint of the surface mount adapter apparatus **10** may vary based on the application of the adapter apparatus **10**. For example, the surface mount adapter apparatus **10** may be configured to mount more than one packaged device. As such, as used herein, when the term “packaged device” is used, it may refer to more than one package. Likewise, when a singular term is used for one or more other components herein, such components may include more than one.

The high density interconnect board **22** may be any suitable high density interconnect board for providing the interconnection between conductive pads **44** on the first side **40** (e.g., which generally have the same configuration as the conductive pads **18** of the packaged device **16** to be mounted using the surface mount adapter apparatus **10**) and the conductive pads **46** on the second side **42** of the high density interconnect board **22**. Such conductive pads **46** will generally take a different configuration than the conductive pads **44** on the first side of the high density interconnect board **22**. In other words, the conductive pads **46** will be distributed differently on the second side **42** of the high density interconnect board **22** than the conductive pads **44** on the first side of the high density interconnect board **22**. Such distribution of the conductive pads **46** allow for connection to the conductive elements **26** of the interconnect device **20**.

In one embodiment, the high density interconnect board **22** may be a multi-layered printed circuit board which uses blind and buried vias **50** (only a single via shown for simplicity), such as, for example, blind and buried microvias, to connect the conductive pads **44** and conductive pads **46** on opposite sides of the printed circuit board. Blind vias are generally vias having a connection to the surface of a printed circuit board, but not going through all the layers thereof. Further, buried vias go through one or more layers of the printed circuit board, but without connection to the surface thereof. This is in contrast to normal vias which generally go through all the layers of the printed circuit board. Further, generally, micro-vias (e.g., small plated holes) are holes that are about 5 mils or less in diameter and about 5 mils or less in depth. Typically, micro-vias are created using lasers (e.g., to control depth) as opposed to mechanical drills.

Generally, the high density interconnect board **22** is formed of any suitable insulative materials (e.g., polyimide materials). Preferably, the high density interconnect board **22** is formed of a high temperature material (e.g., a material that is suitable for use in temperatures that exceed 125°C . or that exceed PCB assembly reflow temperatures, such as materials that are exposed to temperatures that exceed 200°C . for a time period of 10 seconds to 30 seconds). For example, the high density interconnect board may be formed of one or more materials such as FR4/G10, Kapton, or Rogers R04350.

The substrate **24** of the interconnect device **20** also may be formed of any suitable insulative materials (e.g., polyimide materials). Preferably, the substrate **24** is formed of a high temperature material (e.g., a material that is suitable for use in temperatures that exceed 125°C . or that exceed PCB assembly reflow temperatures, such as materials that are exposed to temperatures that exceed 200°C . for a time period of 10 seconds to 30 seconds). For example, the substrate **24** may be formed of one or more materials such as FR4/G10, Kapton, or Rogers R04350.

Openings in the substrate **24** are defined in which the interconnect elements **26** are mounted. The interconnect elements **26** may be mounted in the openings defined in substrate **24** by any suitable technique. For example, the interconnect elements **26** may be press-fit within the defined openings in the substrate **24**. Further, the conductive elements **26** may be mounted within the defined openings of the substrate **24** using a curable material, such as described in U.S. patent application Ser. No. 11/069,102, entitled, “Adapter apparatus with conductive elements mounted using curable material and methods regarding same,” filed 1 March 2005, which is incorporated by reference herein.

The mounting of the interconnect elements **26** within the defined openings in the substrate **24** is performed such that the first end **60** of the interconnect elements **26** are accessible at the first side **30** of the interconnect device **20**. Likewise, the second ends **62** of the interconnect elements **26** are accessible at the second side **32** of the interconnect device **20** when the interconnect elements **26** are mounted within the openings defined in substrate **24**.

The conductive interconnect elements **26**, as shown in FIG. 1, include female socket pins mounted in corresponding openings defined through the substrate **24**. However, as shown in FIG. 2, the interconnect elements may include any type of terminal configuration mounted with openings **78** of the substrate **24**. For example, as shown in FIG. 2, the conductive interconnect elements may include a female socket pin **70** (e.g., like that shown in FIG. 1) for mating with a male terminal pin **90**, or may include a male terminal pin **74** (e.g., like that shown in FIGS. 6-7) for mating with a female socket. In addition, the conductive interconnect element may even include a conductive element that has both first and second ends configured to receive solder material **92** on at least one or both of the ends (e.g., solder material on both ends, solder material on one end and a solder film on another, etc.), as shown by conductive element **72** in FIG. 2. For example, the conductive interconnect element **72** may be a conductive plug (e.g., an element that does not include either a female contact or a male contact at either end) mounted in opening **78** (e.g., using a curable material **80** or press fit therein) that has solder material attached to one or both of the respective ends thereof. However, the conductive interconnect elements may have other solder materials provided thereon, or may not require any solder material on the ends at all. In other words, the type of conductive element mounted in the openings defined in substrate **24** according to the present invention will depend upon the particular application to be accomplished with the surface mount adapter apparatus **10**.

For example, as shown in FIG. 1, and not to be considered limiting to the present invention, the surface mount adapter apparatus **10** is employed as a MLF surface mount emulator foot adapter to mount a packaged device **16** (e.g., a MLF package) to target board **12**. Target board **12** includes the pattern of contact elements or pads **13** corresponding to the configuration of contact pads **18** on lower surface **17** of MLF device **16**. The MLF device **16** is received within carrier adapter **14** which may be pluggable onto surface mount adapter apparatus **10**.

Although carrier adapter **14** may include one of any number of different configurations (e.g., carrier adapter assemblies including a test/probe structure), FIG. 1 provides one exemplary embodiment of such a carrier adapter. The carrier adapter **14** shown in FIG. 1 includes a socket apparatus **140** (e.g., a high speed MLF socket such as a GHz socket that receives a MLF package) and a test/probe assembly **110**.

The test/probe assembly **110** includes a probing board **112** which routes female socket connector **116** on the bottom of the test/probe assembly **110** to pads **162** on the upper surface **152** corresponding to the pads **18** on the lower surface **17** of the packaged device **16** (e.g., a MLF device). The conductive pads **162** on the probing board **112** also route to test points **114** on the perimeter of the probing board **112**.

The female socket connector **116** includes a plurality of female socket elements **118** generally corresponding to the socket configuration or conductive interconnect elements **26** of the interconnect device **20** of the surface mount adapter apparatus **10**. The conductive female socket elements **118** of the female socket connector **116** are electrically connected to the contact pads **160** on the lower surface **158** of probing board **112** which are routed (e.g., via conductive traces, vias, etc.) shown generally by numeral **120** to the conductive pads **162** corresponding to the contact pads **18** of the packaged device **16**.

The socket **140** is mounted to the probing board **112** using mounting hardware **146**. One will recognize that any such hardware may be used to provide such mounting and that any suitable socket may be employed. The socket **140** defines a cavity **144** within a body **142** of the socket **140** for receiving the packaged device **16** adjacent a pattern of conductive elements **157** (e.g., a conductive elastomer) for providing electrical connection between the packaged device **16** and the conductive pads **162** on probing board **112**. A screw **148** for contacting compression plate **150** and providing a force upon packaged device **16** to provide for effective contact between the conductive pads **18** of the packaged device **16** and the conductive elements **157** is also provided.

The carrier adapter **14** further includes a male-to-male interface connector **100** for coupling the female socket connector **116** to the female socket or interconnect elements **26** of the interconnect device **20**. The male/male interface connector **100** includes a first set of male pins **102** configured for mounting within female socket connector **116** and a second set of male pins **104** configured for pluggable connection to interconnect elements **26** of interconnect device **20**. The male pins **102** and **104** are inserted or mounted within substrates **107**, **109**, respectively, and electrically connected to one another, for example, by a reflowed solder connection **108** (e.g., reflowed solder balls or spheres). One skilled in the art will recognize from the description herein that the male/male connector may be provided in one or more various configurations (e.g., a double-ended male pin inserted in a single substrate).

In other words, as the surface mount adapter apparatus **10** includes female socket pins as the interconnect elements **26**, a male pin adapter **100** is used for mounting the carrier adapter **14**. However, if the adapter apparatus **10** included a plurality of male terminal pins, such as male terminal pins **426** shown in FIGS. 6-7, a female adapter, such as female socket connector **116**, may be employed for use in mounting the carrier adapter as opposed to the male pin adapter **100**.

It will be recognized that any carrier adapter apparatus may be used in combination with the surface mount adapter apparatus **10** for mounting one or more packaged devices. The exemplary configuration of carrier adapter **14** is not to be taken as limiting on the configuration thereof. In other words, any number of carrier adapter configurations may be employed according to the present invention.

In one embodiment of the surface mount adapter apparatus **10**, the foot adapter allows interconnection to the surface mount land pattern **13** on the target board **12** through the adapter apparatus **10** that emulates a MLF package (or, for

example, any other surface mount or chip scale packages). The MLF foot adapter apparatus **10** is easily and quickly soldered to the land pattern using the same techniques employed to solder the actual MLF package **16**. The MLF foot adapter apparatus **10** includes the surface mount pads **44** on the target board side and a set of interconnect pins **26** on the opposite side. The interconnect pins **26** on the top of the foot adapter **10** can interconnect to various assemblies with a connector of the opposite sex. Generally, each MLF pad **44** on the bottom of the high density interconnect device **22** is routed to a single interconnect element **26** accessible at the top of the MLF foot adapter apparatus **10**.

Further, in one embodiment of the foot adapter apparatus **10**, the high density interconnect board **22** (e.g., with blind and buried micro vias) routes from the interconnect elements **26** to the bottom pads **44** which connect to the target board **12**. The interconnect device **20**, or high density receptacle, is connected (e.g., reflowed or connected using a conductive epoxy) to the top of the high density interconnect board **22**. Generally, the footprint of the interconnect device is smaller than the package (e.g., the MLF package it is emulating) so that the high density interconnect board **22** can maintain a size substantially the same as the package intended for the target board pattern of conductive elements **13**. The interconnect elements **26** (e.g., receptacle pins) are retained in the substrate **24** to keep them on the same centers as their corresponding soldering pads **46** on the high density interconnect board **22**. As previously described, encapsulant **58** may be used between the high density interconnect board **22** and the interconnect device **20** to keep contaminants out of the interface between the interconnect elements **26** and the conductive pads **46** on the high density interconnect board **22**.

One will recognize that any number of designed adapters may be connected to the interconnect elements **26** when the foot adapter **10** is used (e.g., a carrier adapter as further described herein, a carrier assembly that has a socket on top for receiving the actual MLF package and a set of male pins on the bottom which would plug onto the foot, a foot with female pins extending through the substrate, etc.).

Further, the interconnect elements **26** (e.g., receptacles) could be probed with high density flying lead-type probes, or any other suitable testing devices. The conductive interconnect elements **26**, as generally shown in FIG. 1, as well as any other conductive interconnect elements which may be mounted in openings defined through substrate **24** (e.g., see conductive elements of FIG. 2), may be formed of any suitable conductive material. For example, such conductive elements may be formed of brass alloy, gold, nickel, beryllium, or copper alloy. Yet further, various types of contact structures may be employed, as well as various different material types for such contact structures as would be known in the art.

FIG. 3 provides a block diagram of a method **200** for providing a surface mount adapter apparatus **10** such as that shown generally in FIG. 1. The method **200** includes providing a high density interconnect board **22** (block **202**), such as that described with reference to FIG. 1. For example, the high density interconnect board **22** may be a printed circuit board that connects a first plurality of conductive pads **44** configured on a first side **40** of the high density interconnect board **22** with a second plurality of conductive pads **46** configured on a second opposite side **42** of the high density interconnect board **22** using blind and buried vias **50** (e.g., micro-vias).

The method **200** further includes providing an interconnect device **20** (block **204**), such as that shown generally in

FIG. 1. For example, the interconnect device **20** may include a substrate **24** having first and second sides **30**, **32** and a plurality of interconnect elements **26** extending through the substrate **24**. Each of the plurality of interconnect elements **26** include at least a first and second end **60**, **62**. The second side **42** of the high density interconnect board **22** is positioned adjacent the first side **30** of the interconnect device **20**. The first end **60** of each of one or more of the plurality of interconnect elements **26** are then electrically connected to a corresponding pad of the second plurality of conductive pads **46** on the second side **42** of the high density interconnect board **22** to mount the interconnect device **20** relative to the high density interconnect board **22** (block **206**).

Such electrical connection may be performed using any suitable technique. For example, the electrical connection between the first ends **60** of the interconnect elements **26** and the conductive pads **46** on the second side **42** of the high density interconnect board **22** may be performed using a conductive epoxy, may be performed using a reflowed solder connection, may be performed using a reflowed solder ball configuration, etc.

In one embodiment of the present invention, solder material (e.g., solder balls **52**) are positioned on conductive pads **46** of the high density interconnect board **22**. The interconnect device **20** is then positioned such that the interconnect elements **26** thereof are positioned on the solder material **52**. Thereafter, the solder material is reflowed to provide the connection between the interconnect device **20** and the high density interconnect board **22**.

Further, as shown in FIG. 3, the method **200** may optionally include providing an encapsulant **58** between the interconnect device **20** and the high density interconnect board **22** (block **208**). Any suitable method of providing such an encapsulant between the components may be used. For example, in one embodiment, an epoxy is provided using a syringe. The epoxy is provided to the volume between the interconnect device **20** and the high density interconnect board **22** and about the interconnections between the conductive interconnect elements **26** and conductive pads **46** on the high density interconnect board **22**. Any suitable device, such as a flexible scraper, may be used to remove any excess encapsulant **58**.

Solder material **52** may include any suitable type of solder material generally known in the art. For example, the solder material **52** may include solder balls (as shown in FIG. 1), solder films, solder spheres, partial solder spheres, solder columns, or any other suitable size and shape of solder material. Further, for example, the solder material may include eutectic **63/37** SnPb solder balls or solder spheres, solder paste, or may be formed of lead free solder alloys such as SAC305 (Sn,Ag3.0,Cu0.5).

The encapsulant **58** may include any suitable curable material that provides insulative and structural functionality. For example, such curable material may include UV-curable material or heat-curable material (e.g., epoxy materials), or any other curable materials (e.g., acrylic materials). Further, for example, the curable material may be formed of an epoxy, such as DP-270, DP-100, DP-110, R1133, etc. Generally, thermal characteristics of the cured encapsulant is preferably like those of the substrate materials used for the interconnect device **20** and the high density interconnect board **22** (e.g., similar thermal expansion coefficients).

After the surface mount adapter apparatus **10** is provided according to, for example, method **200** as shown in FIG. 3, the surface mount adapter apparatus **10** may be mounted to the target board **12** by connecting the first plurality of conductive pads **44** to the pattern of conductive pads **13** of

the target board **12**. For example, such an electrical connection may be provided using a solder connection. Alternatively, such an electrical connection may be provided by a conductive epoxy or any other suitable conductive connection material.

With the surface mount adapter apparatus **10** mounted on the target board **12**, a carrier adapter, such as carrier adapter **14**, may be removably connected to the surface mount adapter apparatus **10** using the second ends **62** of the interconnect elements **26**. In such a fashion, the carrier adapter **14** may receive a packaged device, such as a MLF device, and mounting of the MLF device relative to the target board **12** is accomplished.

FIGS. 4A-4D show a partial cut-away side view, a top view, a side view, and a bottom view, respectively, of one exemplary embodiment of a surface mount adapter apparatus **300** including female socket pins according to the present invention. FIG. 5 shows a more detailed diagrammatic cross-sectional view of the surface mount adapter apparatus **300** shown in FIGS. 4A-4D, as well as a target board **12** including a pattern of conductive pads **13** configured thereon for receiving a packaged device (e.g., a MLF device). The surface mount adapter apparatus **300** includes interconnect device **320** and a high density interconnect board **322**.

The high density interconnect board **322** includes a first side **340** including a plurality of conductive pads **372** configured thereon to correspond to the pattern of conductive pads **13** on target board **12** (e.g., the same configuration as conductive pads of a packaged device which was to be mounted on the pattern of conductive pads **13** of the target board **12**). The conductive pads **372** on the lower surface or first side **340** of the high density interconnect board **322** are connected or routed to conductive pads **374** on the second side **342** of the high density interconnect board **322** by blind and buried vias as generally represented by single via **350** (see FIG. 5). One will recognize that such routing by blind and buried vias (e.g., micro-vias) is known in the art and will not be described in any further detail herein. The ground pad **345** is also routed to a female socket terminal pin **346**, as well as the other conductive pads **372**.

The interconnect device **320** which is electrically connected to the high density interconnect board **322** (e.g., which also provides a mechanical coupling therebetween) includes a substrate **324** having a first side **330** and an opposite second side **332**. A plurality of openings **348** are defined through the substrate **324** from first side **330** to the second side **332** thereof.

The interconnect device **320** further includes a plurality of female socket terminal pins **326**. Each female socket terminal pin **326** includes a body member **361** that extends from a first end **360** to a second end **362**. The second end **362** at the second side **332** of the interconnect device **320** is accessible for receiving a mating male pin or any other suitable interconnect or connector apparatus, or testing device. The first end **360** of the female socket terminal pin **326** is electrically connected to a corresponding conductive pad **374** on the second surface **342** of the high density interconnect board **322**.

As shown in FIG. 5, such an electrical connection is accomplished with a reflowed solder connection **352**. For example, such a connection may be made by positioning solder spheres between the conductive pads **374** and first end **360** of female socket terminal pins **326** followed by subsequent reflow (e.g., thermal treatment).

Each of the female socket terminal pins **326** may include a receptacle clip **327** that accepts and mates with a terminal

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male pin. Further, an encapsulant **358** is provided between the interconnect device **320** and the high density interconnect board **322** (e.g., between the second side **342** of the high density interconnect board **322** and the first side **330** of the interconnect device **320**).

FIGS. **6A-6C** show a partial cut-away side view, a side view, and a bottom view, respectively, of one exemplary embodiment of a surface mount adapter apparatus **400** including male terminal pins **426** according to the present invention. FIG. **7** shows a more detailed diagrammatic cross-sectional view of the surface mount adapter apparatus **400** shown in FIGS. **6A-6C**, as well as a target board **12** including a pattern of conductive pads **13** configured thereon for receiving a packaged device (e.g., a MLF device). The surface mount adapter apparatus **400** includes interconnect device **420** and a high density interconnect board **422**.

The high density interconnect board **422** includes a first side **440** including a plurality of conductive pads **472** configured thereon to correspond to the pattern of conductive pads **13** on target board **12** (e.g., the same configuration as conductive pads of a packaged device which was to be mounted on the pattern of conductive pads **13** of the target board **12**). The conductive pads **472** on the lower surface or first side **440** of the high density interconnect board **422** are connected or routed to conductive pads **474** on the second side **442** of the high density interconnect board **422** by blind and buried vias as generally represented by single via **450** (see FIG. **7**). One will recognize that such routing by blind and buried vias (e.g., micro-vias) is known in the art and will not be described in any further detail herein. The ground pad **445**, as well as the other conductive pads **472**, are routed to male terminal pins **426**.

The interconnect device **420** which is electrically connected to the high density interconnect board **422** includes a substrate **424** having a first side **430** and an opposite second side **432**. A plurality of openings **448** are defined through the substrate **424** from first side **430** to the second side **432** thereof.

The interconnect device **420** further includes a plurality of male terminal pins **426**. Each male terminal pin **426** includes a body member **461** that extends from a first end **460** to a second end **462**. The second end **462** at the second side **432** of the interconnect device **420** is accessible for mating with a female receptacle or any other suitable interconnect or connector apparatus, or testing device. The first end **460** of the male terminal pin **426** is electrically connected to a corresponding conductive pad **474** on the second surface **442** of the high density interconnect board **422**.

As shown in FIG. **7**, such an electrical connection is accomplished with a reflowed solder connection **452**. For example, such a connection may be made by positioning solder spheres between the conductive pads **474** and first end **460** of male terminal pins **426** followed by subsequent reflow (e.g., thermal treatment). Further, an encapsulant **458** is provided between the interconnect device **420** and the high density interconnect board **422** (e.g., between the second side **442** of the high density interconnect board **422** and the first side **430** of the interconnect device **420**).

All patents, patent documents, and references cited herein are incorporated in their entirety as if each were incorporated separately. This invention has been described with reference to illustrative embodiments and is not meant to be construed in a limiting sense. As described previously, one skilled in the art will recognize that other various illustrative applications may use the techniques as described herein to take advantage of the beneficial characteristics of the apparatus and methods described herein. Various modifications

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of the illustrative embodiments, as well as additional embodiments of the invention, will be apparent to persons skilled in the art upon reference to this description.

What is claimed is:

1. A surface mount adapter apparatus comprising:

a high density interconnect board comprising first and second sides, wherein the high density interconnect board further comprises a first plurality of conductive pads configured on the first side of the high density interconnect board electrically connected using blind and buried vias with a second plurality of conductive pads configured on the second side of the high density interconnect board, wherein the first plurality of conductive pads are configured for connection to a pattern of conductive pads of a target board, the pattern of the conductive pads of the target board configured to receive a packaged device; and

an interconnect device comprising a substrate having first and second sides and a plurality of interconnect elements extending through the substrate, wherein each of the plurality of interconnect elements comprises at least a first end and a second end, wherein the interconnect device is electrically connected to the high density interconnect board with the second side of the high density interconnect board adjacent the first side of the interconnect device, the first end of each of one or more of the plurality of interconnect elements being electrically connected to one of the second plurality of conductive pads on the second side of the high density interconnect board, wherein the high density interconnect board and the interconnect device are configured to have a footprint substantially the same as the packaged device.

2. The adapter apparatus of claim 1, wherein each of one or more of the plurality of interconnect elements extending through the substrate are press-fit into a corresponding opening defined through the substrate of the interconnect device.

3. The adapter apparatus of claim 1, wherein each of one or more of the plurality of interconnect elements extending through the substrate are mounted within a corresponding opening defined through the substrate of the interconnect device using a curable material.

4. The adapter apparatus of claim 1, wherein the first end of each of one or more of the plurality of interconnect elements is electrically connected to one of the second plurality of conductive pads on the second side of the high density interconnect board by a reflowed solder connection.

5. The adapter apparatus of claim 1, wherein at least one of the plurality of interconnect elements comprises a female socket pin, a male terminal pin, or a conductive element comprising two ends configured to receive solder material on at least one of the ends.

6. The adapter apparatus of claim 5, wherein at least one of the plurality of interconnect elements comprises a female socket pin.

7. The adapter apparatus of claim 1, wherein the first plurality of conductive pads configured on a first side of the high density interconnect board are configured for connection to a pattern of conductive pads of a target board, the pattern of conductive pads of the target board configured to receive a micro lead frame package or any other chip scale package.

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8. The adapter apparatus of claim 1, wherein the first plurality of conductive pads of the high density interconnect board are electrically connected with the second plurality of conductive pads of the high density interconnect board using blind and buried micro-vias.

9. The adapter apparatus of claim 8, wherein the first plurality of conductive pads configured on a first side of the high density interconnect board are configured for connection to a pattern of conductive pads of a target board, the pattern of conductive pads of the target board configured to receive a micro lead frame package or any other chip scale package.

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10. The adapter apparatus of claim 1, wherein an encapsulant is provided between the second side of the high density interconnect board and the first side of the interconnect device.

5 11. The adapter apparatus of claim 1, wherein a carrier adapter is configured for connection via the second ends of the plurality of interconnect elements to the surface mount adapter apparatus, wherein the carrier adapter is used to connect a micro lead frame package or any other chip scale package to the surface mount adapter apparatus.

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