

## UPGRADEABLE AND REPAIRABLE SEMICONDUCTOR PACKAGES AND METHODS

### BACKGROUND

5           The present invention, in various embodiments, relates generally to the packaging of electronic components such as integrated circuits, as incorporated in semiconductor devices. Specific embodiments of the present invention include semiconductor device packaging and fabrication devices in which one or more semiconductor packages, each including multiple semiconductor devices within an encapsulant, are operably coupled.

10          Embodiments of the present invention also include methods for repairing and/or replacing one or more inoperable semiconductor devices within a multiple semiconductor device assembly.

### TECHNICAL FIELD

15           The amount of surface area on a carrier substrate that may be saved by stacking semiconductor devices is readily apparent; a stack of semiconductor devices consumes roughly the same amount of "real estate" on a carrier substrate, such as a circuit board, as a single, horizontally oriented semiconductor device or semiconductor device package. In order to conserve the amount of surface area consumed on a carrier substrate by

20          semiconductor devices connected thereto, various types of increased density packages have been developed.

            One of the more popular semiconductor package types is the multi-chip module (MCM). MCMs may be attached to and/or arranged on a substrate using flip-chip attachments, chip-on-board (COB), board-on-chip (BOC) configurations, or otherwise.

25           Flip-chip attachment generally consists of attaching an active surface of a semiconductor die to a substrate with a plurality of conductive bumps therebetween. Each conductive bump aligns and corresponds with respective contact pads on the substrate and the semiconductor die to provide electrical interconnection therebetween. The semiconductor die is bonded to the substrate by reflowing the conductive bumps, after

30          which, an underfill material is typically disposed between the semiconductor die and the substrate for environmental protection and to enhance the attachment of the semiconductor die to the substrate.

Turning to the COB and the BOC configurations, the semiconductor die is directly attached to the surface of a substrate, i.e., printed circuit board, interposer, carrier substrate, with an appropriate adhesive, such as an epoxy or adhesive tape. The die may be oriented either face up or face down (with its active surface and contact pads either up  
5 or down with respect to the circuit board) for wire bonding. A bond wire is then discretely attached to each contact pad on the semiconductor die and extended to a corresponding contact on the substrate.

Unfortunately, existing stacked MCMs are not expandable. For example, if more memory or an additional function is desired, the semiconductor package or the card  
10 carrying one or more semiconductor packages needs to be removed and subsequently replaced with another semiconductor package and/or card that contains more memory or the desired additional function.

Another disadvantage with current multi-die semiconductor packages and arrangements becomes clear when a semiconductor die within such a package fails or  
15 becomes otherwise inoperable. In such an instance, the conventional response to such failure or malfunction is replacement of the entire package.

## BRIEF DESCRIPTION OF DRAWINGS

In the drawings:

20 Fig. 1 is a representation of an embodiment of a semiconductor device package according to the present invention;

Figs. 2 through 6 depict an embodiment of a method for assembling and packaging semiconductor devices;

25 Figs. 7 through 12 illustrate another embodiment of a method for assembling and packaging semiconductor devices;

Fig. 13 shows an embodiment of an assembly including multiple semiconductor device packages;

Fig. 14 depicts another embodiment of an assembly that includes multiple semiconductor device packages;

30 Fig. 15 provides a representation of an embodiment of the manner in which a defective semiconductor device of a semiconductor device package according to an embodiment of the present invention may be effectively replaced; and

Fig. 16 schematically depicts an electronic device including a semiconductor device package with at least one contact pad of a redistribution element exposed through an encapsulant of the package.

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## MODES FOR CARRYING OUT THE INVENTION

With reference to Fig. 1, an embodiment of an upgradeable and/or repairable semiconductor device package 10 of the present invention is shown. As depicted, semiconductor device package 10 may, in some embodiments, be a multi-chip module (MCM) with four semiconductor devices 20a, 20b, 20c, and 20d (which, for the sake of  
10 simplicity, may also be collectively referred to hereinafter as "semiconductor devices 20") in stacked arrangement. The lowermost semiconductor device 20a is secured to a carrier 30. A redistribution element 40 is located over the uppermost semiconductor device 20d. An encapsulant 50 may be located over the redistribution element 40 and may surround lateral edges of semiconductor devices 20 and cover a portion of a  
15 surface 32 of carrier 30. Apertures 53 in the encapsulant 50 expose contact pads 44 of the redistribution element 40, enabling the electrical connection of at least one additional semiconductor device package to semiconductor device package 10 and, thus, facilitating the upgrade and/or repair of semiconductor device package 10.

In the illustrated embodiment, carrier 30 is a circuit board. Carrier 30, may,  
20 however, be any other suitable, known element with conductive routes for establishing electrical connections between semiconductor devices 20 and electronic devices (not shown) that are external to semiconductor device package 10. Other embodiments of carriers 30 include, but are not limited to, leads, interposers, and other semiconductor devices (e.g., processors, etc.).

25 In some embodiments, discrete conductive structures 38 may protrude from contacts 37 (e.g., terminals, conductive vias, etc.) on a bottom surface 36 of carrier 30. Discrete conductive structures 38 may, in some embodiments, be arranged in an array (e.g., a grid array, etc.) across surface 36. Discrete conductive structures 38 may comprise any suitable material (e.g., solder, metal, conductive or conductor-filled elastomer, etc.)  
30 formed to have any suitable configuration (e.g., balls, bumps, pins, studs, columns, pillars, etc.).

Semiconductor devices 20 may, in some embodiments, have the same or substantially the same functionality (e.g., memory, processing, etc.) as one another. In a

more specific embodiment, each semiconductor device 20a, 20b, 20c, 20d may be an identical dynamic random access memory (DRAM) device. In another particular embodiment, each semiconductor device 20a, 20b, 20c, 20d may be a NAND flash memory device (e.g., a standard NAND flash memory device, a high speed NAND flash memory device, etc.). Other embodiments of semiconductor device package 10 include one or more semiconductor devices 20a, 20b, 20c, 20d that comprise a different type of device than one or more of the other semiconductor devices 20a, 20b, 20c, 20d and, thus, have different functionalities from one or more of the other semiconductor devices 20a, 20b, 20c, 20d.

10           While there are four semiconductor devices 20 in the illustrated embodiment of semiconductor device package 10, semiconductor device packages with other numbers of semiconductor devices are also within the scope of the present invention. In this regard, some embodiments of semiconductor device packages according to the present invention may have as few as one semiconductor device, while other embodiments may have as many semiconductor devices as remain feasible with available technologies, such as wire bonding, tape-automated bonding or TAB, and the like, for electrically connecting stacked semiconductor devices, and with the number of contacts 34 that may be provided upon a carrier 30 and the number of contact pads 44 that may be provided by a redistribution element 40.

20           Intermediate conductive elements 25 extend between and are conductively coupled to contact pads 24 on a surface 22 (e.g., the active, or upper, surface) of each semiconductor device 20 and corresponding contacts 34 (e.g., contact pads, terminals, leads, etc.) on surface 32 of carrier 30. In this way, each intermediate conductive element 25 electrically connects a contact pad 24 and its corresponding contact 34. Each intermediate conductive element 25 in the embodiment of semiconductor device package 10 shown in Fig. 1 is a bond wire. Semiconductor device packages with other types of intermediate conductive elements, including, but not limited to, conductive traces carried by flexible dielectric film (i.e., TAB connections), leads, and the like.

30           Redistribution element 40 is located on surface 22d of the uppermost semiconductor device 20d in the embodiment shown in Fig. 1. Without limiting the scope of the present invention, redistribution element 40 may, in some embodiments, comprise an interposer (e.g., a silicon-based interposer, a flexible, or "tape," substrate, etc.) that has been adhered to a surface of the uppermost semiconductor device 20d. In other

embodiments, redistribution element 40 may be a redistribution layer (RDL) that has been fabricated on a surface of the uppermost semiconductor device 20d.

Redistribution element 40 includes laterally extending conductive traces (not shown) that lead to contact pads 44 arranged over a surface 42 (e.g., in a grid array, etc.) of redistribution element 40. The arrangement of contact pads 44 on surface 42 may correspond to, or complement, the arrangement of discrete conductive structures of another semiconductor device package, such as the arrangement of discrete conductive structures 38 protruding from the carrier 30 of another semiconductor device (e.g., another semiconductor device package 10 of the present invention) (see, e.g., Fig. 13), that may be assembled with semiconductor device package 10. These and other conductive features of redistribution element 42 may be at least partially electrically isolated from conductive features on surface 22d of semiconductor device 20d by way of dielectric material of redistribution element.

In some embodiments, conductive traces (not shown) communicate with (e.g., are electrically connected to) contact pads 24d of semiconductor device 20d. In other embodiments, conductive traces 43 extend laterally inward (i.e., away from peripheral edges 45 of redistribution element 40) from contact pads 46 located adjacent to one or more peripheral edges 45 of redistribution element 40. Still other embodiments include combinations of these features.

Conductive traces (not shown), contact pads 44, and other conductive features of redistribution element 40 may communicate with each semiconductor device 20 of semiconductor device package 10. In embodiments where conductive traces 43 of redistribution element 40 are electrically connected to contact pads 24d of the uppermost semiconductor device 20d, electrical communication between the underlying semiconductor devices 20a, 20b, and 20c and redistribution element 40 may be established by way of intermediate conductive elements 25, circuitry of carrier 30, and circuitry on (e.g., in the form of a redistribution layer) or within the uppermost semiconductor device 20d.

In embodiments where conductive traces 43 of redistribution element 40 extend laterally inward from contact pads 44, intermediate conductive elements 35 are positioned between and electrically coupled to contact pads 44 and corresponding contacts 34 of carrier 30 to establish communication between redistribution element 40 and one or more semiconductor devices 20. Like intermediate conductive elements 25, intermediate

conductive elements 35 may comprise bond wires, conductive traces carried by flexible dielectric film (*i.e.*, TAB connections), leads, or any other conductive elements suitable for establishing electrical communication between two features that are laterally spaced apart and, optionally, vertically spaced apart from one another.

5           Some embodiments of semiconductor device package 10, such as that depicted in Fig. 1, include encapsulant 50, which may cover a majority of the area of surface 42 of redistribution element 40. In embodiments where encapsulant 50 covers surface 42 of redistribution element 40, contact pads 44 may be exposed through apertures 53 that are formed in and extend through encapsulant 50. In addition to covering portions of  
10 surface 42 of redistribution element 40, encapsulant 50 may also laterally surround semiconductor devices 20, coating and protecting intermediate conductive elements 25 that extend between semiconductor devices 20 and carrier 30, as well as any intermediate conductive elements 35 that extend between carrier 30 and redistribution element 40.

          In addition to exposing contact pads 44, the surfaces of apertures 53 may, in some  
15 embodiments, be coated with conductive liners 54. In some embodiments, each conductive liner 54 may comprise ball-limiting metallurgy (BLM) or under-bump metallurgy (UBM) of a type known in the art. Each conductive liner 54 may be configured to enhance retention (*e.g.*, by adhesion, creation of an interference fit, etc.) of a discrete conductive structure 38 within its corresponding aperture 53, as well enhancing  
20 electrical communication between a discrete conductive structure 38 and its corresponding contact pad 44.

          Encapsulant 50 may comprise any suitable packaging material, such as a quantity of molded material (*e.g.*, a material, such as a plastic or resin, optionally having a filler material therein, suitable for use in transfer molding processes, pot molding processes,  
25 injection molding processes, etc.).

          An embodiment of a method for forming various embodiments of semiconductor device packages 10 of the present invention is shown in Figs. 2 through 6.

          In Fig. 2, at least one semiconductor device 20 is secured and electrically connected to carrier 30. Semiconductor device 20 may be secured to carrier 30 with a  
30 suitable adhesive material or adhesive-coated element of a type known in the art. Communication may be established between contact pads 24 (Fig. 1) of semiconductor device 20 and corresponding contacts 34 (Fig. 1) of carrier (*i.e.*, they may be electrically connected to one another) by forming or placing intermediate conductive elements 25

therebetween. In embodiments where the resulting semiconductor device package 10 is to include more than one semiconductor device 20, one or more additional semiconductor devices 20b, 20c, etc., may be sequentially adhered to an underlying semiconductor device 20a, 20b, etc., and electrically connected to carrier 30 in the same manner.

5           The uppermost semiconductor device 20d includes a redistribution layer 40', which was previously fabricated over a surface 22d of semiconductor device 20d by known processes and communicates with circuitry of semiconductor device 20d or circuitry carried by semiconductor device 20d. In some embodiments, circuitry (*e.g.*, circuit traces 43, Fig. 1) of redistribution layer 40' communicate indirectly with carrier 30  
10 and, thus, with any underlying semiconductor devices 20a, 20b, 20c through intermediate conductive elements 25 that extend between contact pads 24 (Fig. 1) of semiconductor device 20d and corresponding contacts 34 (Fig. 1) of carrier 30. In other embodiments, intermediate conductive elements 35 (*see, e.g.*, Fig. 8) may be formed or placed between contact pads 46' of redistribution layer 40' that are located adjacent to one or more  
15 peripheral edges 21 of semiconductor device 20d and corresponding contacts 34 of carrier 30. This type of arrangement provides for a more direct electrical connection between carrier 30 and circuitry of redistribution element 40'.

          Once all of the semiconductor devices 20 are in place upon and electrically connected to carrier 30, an exposed surface 42' of redistribution layer 40' and, optionally,  
20 intermediate conductive elements 25, 35 (Fig. 8) may be covered with a suitable encapsulant 50. Known processes, such as molding (*e.g.*, transfer molding, pot molding, injection molding, etc.) techniques may be used to apply encapsulant material to redistribution layer 40' and, optionally, over intermediate conductive elements 25, 35, to form encapsulant 50.

25           Initially, in embodiments such as that depicted in Fig. 2, encapsulant 50 may completely cover the previously exposed surface 42' of redistribution layer 40'. As shown in Figs. 3 and 4, contact pads 44' that are arranged over surface 42' of redistribution layer 40' may thereafter be exposed through encapsulant 50. Fig. 3 depicts an embodiment in which a mask 60 is formed (*e.g.*, by exposure and development of  
30 photoresist, etc.) over a surface 52 of encapsulant 50 that overlies redistribution layer 40'. Apertures 62 are defined in mask 60 at locations over the contact pads 44' that are to be exposed. The assembly is then exposed to a suitable etchant or solvent, which removes from encapsulant 50 material that has been exposed through apertures 62 of mask 60. The

removal of material from encapsulant 50 may be effected without substantially or completely removing mask 60. Such material removal may continue until apertures 53, through which the desired contact pads 44' have been exposed, have been formed in surface 52 of encapsulant 50.

5           In a variation of the method, apertures 53 may be formed by known laser ablation processes.

          In another variation of the method, apertures 53 may be formed during the formation of encapsulant 50. In one particular embodiment, the mold, or encapsulation, tooling that is used to form encapsulant 50 may include protrusions that align with contact  
10       pads 44' that are to be exposed and define apertures 53 over these contact pads 44'. These protrusions may be lined with a somewhat compressible film mold assist material, such as a polytetrafluoroethylene (PTFE), a perfluoroalkoxy (PFA), or a fluorinated ethylene propylene (FEP) to prevent the formation of "flash," a thin layer of encapsulant material, over contact pads 44'.

15           In embodiments of the method where apertures 53 are formed without chemically removing (*e.g.*, etching, dissolving, etc.) material from encapsulant 50, mask 60 may be subsequently formed, as shown in Fig. 4.

          With apertures 53 formed and mask 60 (still) in place over surface 52, apertures 53 and the contact pads 44' exposed therethrough may be coated with a conductive lining 54.  
20       In one embodiment, conductive lining 54 may be formed by depositing (*e.g.*, by known physical vapor deposition (PVD) processes, known chemical vapor deposition (CVD) processes, etc.) conductive material over mask 60 and onto surfaces of apertures 53. The deposited conductive material may form a complete conductive lining 54 over the surfaces of each aperture 53, or it may form a seed layer for subsequent plating (*e.g.*, electrolytic  
25       plating, electroless plating, immersion plating, etc.) processes, which complete the conductive lining 54.

          Once conductive linings 54 have been formed in apertures 53, conductive material may, in some embodiments, be removed from other locations of encapsulant 50 (*i.e.*, from above surface 52) as mask 60 is removed. This removal of conductive material may be  
30       accomplished by known lift-off techniques, in which the structure is exposed to a suitable chemical (*e.g.*, a resist strip in embodiments where mask 60 has been formed from a photoresist, an etchant in embodiments where mask 60 is formed from another material), and results in the structure shown in Fig. 5.

As Fig. 6 shows discrete conductive structures 38 may be applied to contacts 37 on a bottom surface 36 of carrier 30 by known processes. In embodiments where discrete conductive structures 38 are formed from solder or another metal or metal alloy, they may be formed by screen printing metallic paste onto contacts 37 and reflowing the same.

5 Alternatively, they may be formed by use of a bath of molten metal or by employing a wave of molten metal. In other embodiments, discrete conductive structures 38 may be formed by placing conductive material or securing preformed conductive structures to contacts 37.

Another embodiment of a process for assembling a semiconductor device  
10 package 10 (Fig. 1) according to an embodiment of the present invention is shown in Figs. 7 through 12.

As depicted by Fig. 7, one or more semiconductor devices 20a, 20b, 20c are secured in place over and electrically connected to carrier 30. A lowermost semiconductor device 20a may be secured to carrier 30 with a suitable adhesive material  
15 or adhesive-coated element of a type known in the art. Communication may be established between contact pads 24 (Fig. 1) of each semiconductor device 20a, 20b, 20c and corresponding contacts 34 (Fig. 1) of carrier 30 (*i.e.*, they may be electrically connected to one another) by forming or placing intermediate conductive elements 25 therebetween.

20 In embodiments where the resulting semiconductor device package 10 is to include more than one semiconductor device 20, an uppermost semiconductor device 20d is positioned over and secured to another semiconductor device 20c. An interposer 40" may then be positioned over and secured to a surface 22d of the uppermost semiconductor device 20d.

25 In some embodiments, such as that shown in Fig. 8, interposer 40" is positioned over semiconductor device 20d before contact pads 24d (Fig. 1) of semiconductor device 20d are electrically connected to corresponding contacts 34 (Fig. 1) of carrier 30. In these embodiments, intermediate conductive elements 25 may then be formed or placed and electrically coupled between contact pads 24d and their corresponding contacts 34. In  
30 addition, as Fig. 8 also shows, contact pads 46 at or near one or more peripheral edges 45" of interposer 40" may be electrically connected to corresponding contacts 34 of carrier 30 by forming or placing and electrically coupling intermediate conductive elements 35 therebetween.

With continued reference to Fig. 8, an encapsulant 50 may be formed over an exposed surface 42" of interposer 40". Additionally, encapsulant 50 may laterally surround semiconductor devices 20, as well as portions of intermediate conductive elements 25, 35 that extend laterally therefrom. Encapsulant 50 may be formed by known processes, including, without limitation, known molding processes. Encapsulant 50 may, at first, completely cover the previously exposed surface 42" of interposer 40".

Thereafter, as shown in Figs. 9 and 10, contact pads 44" that are arranged over surface 42" of interposer 40" may be exposed through encapsulant 50. As shown in Fig. 9, a mask 60 may be formed (e.g., by exposure and development of photoresist, etc.) over a surface 52 of encapsulant 50 that overlies interposer 40". Apertures 62 are defined in mask 60 at locations over the contact pads 44" that are to be exposed. The assembly is then exposed to a suitable solvent or etchant, which removes from encapsulant 50 material that has been exposed through apertures 62 of mask 60. The material of encapsulant 50 may, in some embodiments, be removed without substantially or completely removing mask 60. Material may be removed through mask 60 until apertures 53, through which the desired contact pads 44" have been exposed, have been formed in surface 52 of encapsulant 50.

In another embodiment, apertures 53 may be defined without the use of a mask. Such an embodiment includes the use of known laser ablation techniques to remove material from encapsulant 50 and to expose one or more contact pads 44" therethrough.

In other embodiments, apertures 53 may be formed as encapsulant 50 is formed. In one such embodiment, the mold, or encapsulation, tooling that is used to form encapsulant 50 may include protrusions that align with contact pads 44" that are to be exposed and define apertures 53 over these contact pads 44". These protrusions may be lined with a somewhat compressible film mold assist material, such as a polytetrafluoroethylene (PTFE), a perfluoroalkoxy (PFA), or a fluorinated ethylene propylene (FEP) to prevent the formation of "flash," a thin layer of encapsulant material, over contact pads 44".

In any event, as shown in Fig. 10, a mask 60 may be present on a surface 52 of an encapsulant 50 in which apertures 53 are recessed. With apertures 53 formed and mask 60 in place over surface 52, a conductive lining 54 may be formed over surfaces of apertures 53 and on the contact pads 44" exposed therethrough, as illustrated by Fig. 11. Known processes, including deposition processes (e.g., PVD, CVD, etc.) and/or known

plating processes (*e.g.*, electrolytic plating, electroless plating, immersion plating, etc.) may be used to form a conductive lining 54 within each aperture 53.

As the processes that are used to form each conductive lining 54 may also leave conductive material over other areas of surface 52, the conductive material may be removed from these areas. In some embodiments, the removal of conductive material from above surface 52 may be effected by known lift-off techniques, in which mask 60 (Fig. 10) is exposed to a suitable chemical (*e.g.*, a resist strip in embodiments where mask 60 has been formed from a photoresist, an etchant in embodiments where mask 60 is formed from another material).

The structure that results from these processes, an embodiment of which is depicted in Fig. 12, may be further processed by the addition of discrete conductive structures 38 to contacts 37 on a bottom surface 36 of carrier 30. Discrete conductive structures 38 may be formed on or secured to contacts 37 by a variety of processes that are known in the art. In embodiments where discrete conductive structures 38 are formed from solder or another metal or metal alloy, they may be formed by screen printing metallic paste onto contacts 37 and reflowing the same. Alternatively, they may be formed by use of a bath of molten metal or by employing a wave of molten metal. In other embodiments, discrete conductive structures 38 may be formed by placing conductive material or securing preformed conductive structures to contacts 37.

A semiconductor device package 10 that incorporates teachings of the present invention may be used for a variety of purposes. Various embodiments of the manner in which one more semiconductor device packages 10 may be utilized are described in reference to Figs. 13 through 15.

In the embodiment depicted by Fig. 13, two or more semiconductor device packages 10a, 10b, 10c, etc., (which are also collectively referred to hereinafter, for the sake of simplicity, as "semiconductor device packages 10") according to embodiments of the present invention (four are shown) are interconnected to one another. All of the semiconductor device packages 10 may have the same functionality (*e.g.*, DRAM, NAND flash memory, etc.), or they may combine different functionalities (*e.g.*, multiple types of memory, one or more types of memory and processing capabilities, etc.).

Semiconductor device packages 10 may be assembled simply by inserting discrete conductive structures 38 that protrude from the base 12 of one package 10 (*e.g.*, semiconductor device package 10d) into corresponding apertures 53 of another

package 10 (e.g., semiconductor device package 10c), with each discrete conductive structure 38 contacting the contact pad 44 (Fig. 1) and/or any conductive lining 54 (Fig. 1) with its corresponding aperture 53. In some embodiments, electrical contact between a discrete conductive structure 38 and its corresponding contact pad 44 and/or conductive lining 54 may be established and maintained by reflowing the material from which the discrete conductive structure 38 is formed. In other embodiments, electrical contact may be established and maintained by way of a mechanical interaction, such as with an interference fit or by simply forcing, or physically biasing, the interconnected packages 10 toward one another and maintaining that physical bias.

10        Assembly of semiconductor device packages 10 in the manner shown in and described with reference to Fig. 13 may be employed as a final process in the packaging of semiconductor devices, or it may be used post-production to upgrade the functionality of (e.g., expand an existing functionality of or add functionality to) previously installed semiconductor devices (e.g., by repair technicians, consumers, etc.).

15        Figs. 14 and 15 illustrate an embodiment of a technique for repairing a semiconductor device package 10 that includes one or more defective semiconductor devices 20. As shown in Fig. 14, a repair package 10R, which includes at least one replacement device 20R, is assembled with a defective semiconductor device package 10. More specifically, discrete conductive structures 38R that protrude from a base 12R of repair package 10R are inserted into corresponding apertures 53 of the defective semiconductor device package 10, electrically contacting contact pads 44 (Fig. 1) and/or conductive liners 54 (Fig. 1) within those apertures 53. Discrete conductive structures 38R of repair package 10R protrude from locations that will align with a group of chip select pads 44 that correspond to the defective semiconductor device 20, as shown in Fig. 15. In the illustrated embodiment, replacement package 10R is intended to replace semiconductor device 20a ("chip 0"). Accordingly, each of the discrete conductive structures 38R that protrudes from base 12R of replacement package 10R is positioned to align with an aperture 53 that exposes a contact pad 44a (of "chip set 0," or "CS0") that corresponds to semiconductor device 20a. If another semiconductor device 20 of semiconductor device package 10 were defective, discrete conductive structures 38R would instead protrude locations that align with contact pads 44 (e.g., CS1, CS2, CS3, etc.) that correspond to that defective semiconductor device 20.

Turning now to Fig. 16, an electronic device 200, such as a computer, controller, cellular telephone, portable digital music player, digital camera, or the like is depicted. Electronic device 200 includes a circuit board 210 to which at least one semiconductor device package 10 according to embodiments of the present invention is electrically  
5 connected. In the illustrated embodiment, electronic device 200 includes two semiconductor device packages 10 that are electrically connected to each other.

In summary, the present invention includes embodiments of semiconductor device packages with one or more semiconductor devices that are borne by and electrically connected to a carrier. In embodiments that include more than one semiconductor device,  
10 the semiconductor devices may be stacked one on another. In addition to the carrier and one or more semiconductor devices, a semiconductor device package of the present invention includes a redistribution element atop an uppermost semiconductor device. The redistribution element communicates with one or more (*e.g.*, all) semiconductor devices of the package. Contact pads that are arranged in an array over a surface of the redistribution  
15 element enable the connection of one or more additional semiconductor device packages to the package. The contact pads may be exposed through apertures formed in an encapsulant, which apertures may facilitate alignment of corresponding discrete conductive structures that protrude from an additional semiconductor device package with the appropriate contact pads of the redistribution element. This arrangement facilitates  
20 repair of and upgrades to packages, or multi-chip modules, that include a plurality of semiconductor devices, without requiring that the entire package be discarded and that any operable semiconductor devices thereof, or data stored thereby, be needlessly wasted. The present invention also includes methods for assembling and packaging semiconductor devices, as well as methods for assembling multiple packages, including methods for  
25 replacing the functionality of one or more defective semiconductor devices of a package according to embodiments of the present invention.

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 embodiments. Similarly, other embodiments of the invention may be  
30 devised which lie within the scope of the present invention. Features from different embodiments 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

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as disclosed herein which fall within the meaning and scope of the claims are to be embraced thereby.

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CLAIMS

What is claimed:

1. A semiconductor device package, comprising:  
a carrier with at least one contact on a first surface thereof;  
5 at least one semiconductor device on the first surface of the substrate, the semiconductor device including an active surface bearing at least one contact pad;  
a redistribution element including at least one contact pad and located over the active surface of the at least one semiconductor device;  
at least one intermediate conductive element electrically connecting the at least one  
10 contact pad of the carrier and the at least one contact pad of the at least one semiconductor device; and  
a molded encapsulant located at least over the redistribution element and including at least one aperture through which the at least one contact pad of the redistribution element is individually exposed, at least electrically.  
15
2. The semiconductor device package of claim 1, further comprising at least another intermediate conductive element establishing communication between at least one contact of the carrier and at least one contact pad of the redistribution element.
- 20 3. The semiconductor device package of claim 2, wherein the at least another intermediate conductive element extends between the at least one contact of the carrier and a contact pad of the at least one semiconductor device, with the contact pad of the at least one semiconductor device in communication with the at least one contact pad of the redistribution element.  
25
4. The semiconductor device package of claim 2, wherein the at least another intermediate conductive element extends between the at least one contact of the carrier and at least one peripheral contact pad of the redistribution element, with the at least one peripheral contact pad of the redistribution element in communication with the at least one  
30 contact pad of the redistribution element.

5. The semiconductor device package of claim 1, wherein at least one aperture is configured to receive a discrete conductive structure protruding from another semiconductor device.

5           6. The semiconductor device package of claim 1, further comprising:  
a conductive lining on at least one of a surface of the at least one aperture and the at least  
one contact pad that is individually exposed, at least electrically, through the at  
least one aperture.

10           7. The semiconductor device package of claim 1, further comprising a  
plurality of semiconductor devices, including the at least one semiconductor device, in  
stacked arrangement.

15           8. The semiconductor device package of claim 7, wherein the redistribution  
element includes a plurality of chip select groups of contact pads, each chip select group  
comprising a plurality of contact pads corresponding to one semiconductor device of the  
plurality of semiconductor devices.

20           9. The semiconductor device package of claim 1, wherein the redistribution  
element comprises at least one of a redistribution layer and an interposer.

10. A multi-package assembly, comprising:  
a first semiconductor device package, including:  
a carrier;  
at least one semiconductor device on and electrically coupled to the carrier;  
5 a redistribution element on the at least one semiconductor device, with a plurality  
of contact pads arranged over a surface of the redistribution element;  
a molded encapsulant covering a surface of the redistribution element, contact  
pads of the plurality being individually exposed, at least electrically,  
through an aperture in the molded encapsulant; and  
10 a second semiconductor device package, including:  
a carrier including a base with a plurality of discrete conductive structures  
protruding therefrom, each discrete conductive structure contacting a  
corresponding contact pad of the plurality of contact pads of the  
redistribution element of the first semiconductor device package; and  
15 at least one semiconductor device electrically coupled to the carrier.
11. The multi-package assembly of claim 10, wherein the second  
semiconductor device package expands an existing functionality of the first semiconductor  
device package, adds another functionality to a functionality of the first semiconductor  
device package, or replaces at least one defective semiconductor device of the first  
20 semiconductor device package.
12. The multi-package assembly of claim 10, wherein the second  
semiconductor device package further includes:  
a redistribution element on the at least one semiconductor device, with a plurality  
25 of contact pads arranged over a surface of the redistribution element; and  
a molded encapsulant covering a surface of the redistribution element, contact  
pads of the plurality being individually exposed, at least electrically,  
through an aperture in the molded encapsulant.

13. A method for packaging at least one semiconductor device, comprising:  
electrically connecting at least one semiconductor device to a first surface of a carrier, the  
at least one semiconductor device including an active surface and at least one  
contact pad on the active surface;
- 5 disposing a redistribution element on the at least one semiconductor device;  
electrically connecting the redistribution element to at least one of the carrier and the at  
least one semiconductor device;  
applying an encapsulant to a surface of the redistribution element; and  
defining at least one aperture through the encapsulant to individually expose at least one  
10 contact pad of the redistribution element through the encapsulant.
14. The method of claim 13, wherein electrically connecting at least one  
semiconductor device includes stacking and electrically connecting a plurality of  
semiconductor devices to the carrier.
- 15 15. The method of claim 13, wherein disposing the redistribution element  
comprises at least one of fabricating a redistribution layer on a surface of the at least one  
semiconductor device and securing an interposer to the surface of the at least one  
semiconductor device.
- 20 16. The method of claim 13, wherein electrically connecting the at least one  
redistribution element comprises forming or positioning at least one intermediate  
conductive element between a contact pad of the redistribution element and a  
corresponding contact of the carrier.
- 25 17. The method of claim 13, wherein electrically connecting the at least one  
redistribution element comprises forming or positioning at least one intermediate  
conductive element between a contact pad of the at least one semiconductor device and a  
corresponding contact of the carrier.
- 30 18. The method of claim 13, wherein defining at least one aperture through  
the encapsulant to expose the at least one contact pad of the redistribution element is  
effected while applying the encapsulant to the surface of the redistribution element.

19. The method of claim 13, wherein defining at least one aperture through the encapsulant to expose the at least one contact pad of the redistribution element is effected after encapsulant has been applied to the surface of the redistribution element.

5           20. The method of claim 13, further comprising:  
fabricating at least one conductive liner in at least one aperture formed through the encapsulant.

21. A method of electrically connecting a plurality of semiconductor  
10 packages, comprising:  
aligning each discrete conductive structure protruding from a base of a semiconductor package with a corresponding contact pad of a redistribution element of another semiconductor device package including a plurality of semiconductor devices, each corresponding contact pad individually exposed, at least electrically, through  
15 an encapsulant of the another semiconductor device package;  
inserting the each discrete conductive structure into a corresponding aperture formed in a surface of the encapsulant, into electrical communication with the corresponding contact pad; and  
maintaining electrical contact between the at least one discrete conductive structure and  
20 the at least one contact pad.

22. The method of claim 21, wherein aligning comprises aligning a replacement semiconductor device package including at least one semiconductor device that replaces at least one defective semiconductor device of the another semiconductor device package.

23. The method of claim 21, wherein aligning comprises aligning a semiconductor device package including at least one semiconductor device that adds new functionality to a functionality of the another semiconductor device package or that enhances an existing functionality of the another semiconductor device package.

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24. An electronic device, comprising:

at least one circuit board;

at least one semiconductor device package including a carrier electrically connected to

the at least one circuit board, a plurality of semiconductor devices in stacked

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arrangement on the carrier, a redistribution element over the plurality of

semiconductor device and including an array of contact pads, and an encapsulant

through which an array of apertures are formed to enable an upgrade to the at

least one semiconductor device package, each aperture corresponding individually

to a contact pad of the array of contact pads, each contact pad of the array of

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contact pads being at least electrically exposed through the aperture

corresponding individually to the contact pad.

25. The electronic device of claim 24, further comprising:

at least another semiconductor device including a plurality of discrete conductive

structures protruding from a base thereof, the plurality of discrete conductive

structures extending through the encapsulant of the at least one semiconductor

device package and contacting corresponding contact pads of the array.