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(54) **SEMICONDUCTOR ASSEMBLIES WITH MULTI-LEVEL SUBSTRATES AND ASSOCIATED METHODS OF MANUFACTURING**

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- H05K 3/10** (2006.01)
- H05K 3/34** (2006.01)
- H01L 23/31** (2006.01)
- H01L 23/00** (2006.01)

(52) **U.S. Cl.**

CPC **H05K 3/303** (2013.01); **H01L 23/13** (2013.01); **H01L 23/49816** (2013.01); **H05K 3/10** (2013.01); **H05K 3/34** (2013.01); **H01L 23/3128** (2013.01); **H01L 23/49838** (2013.01); **H01L 24/06** (2013.01); **H01L 24/29** (2013.01); **H01L 24/32** (2013.01); **H01L 24/48** (2013.01);

H01L 24/49 (2013.01); *H01L 24/73* (2013.01); *H01L 2224/04042* (2013.01); *H01L 2224/06156* (2013.01); *H01L 2224/2919* (2013.01); *H01L 2224/32225* (2013.01); *H01L 2224/4824* (2013.01); *H01L 2224/48465* (2013.01); *H01L 2224/49109* (2013.01); *H01L 2224/73215* (2013.01); *H01L 2924/10253* (2013.01); *H01L 2924/1434* (2013.01); *H01L 2924/157* (2013.01); *H01L 2924/15311* (2013.01); *H01L 2924/15787* (2013.01)

(58) **Field of Classification Search**

CPC H01L 24/06; H01L 2224/32225
USPC 257/758
See application file for complete search history.

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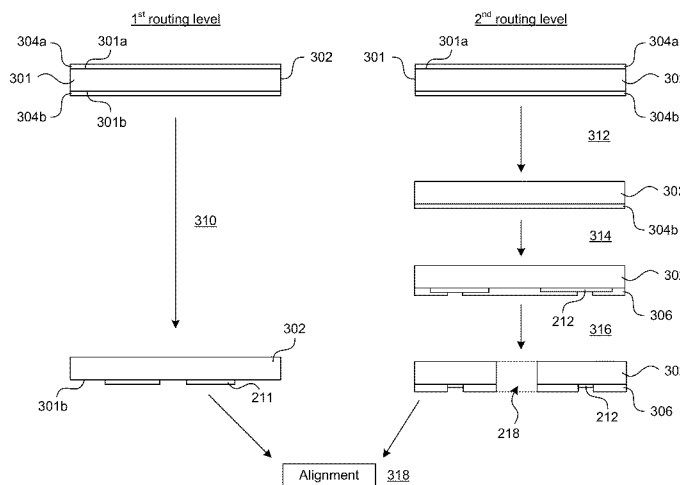
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(57) **ABSTRACT**

Various embodiments of semiconductor assemblies with multi-level substrates and associated methods of manufacturing are described below. In one embodiment, a substrate for carrying a semiconductor die includes a first routing level, a second routing level, and a conductive via between the first and second routing levels. The conductive via has a first end proximate the first routing level and a second end proximate the second routing level. The first routing level includes a terminal and a first trace between the terminal and the first end of the conductive via. The second routing level includes a second trace between the second end of the conductive via and a ball site. The terminal of the first routing level and the ball site of the second routing level are both accessible for electrical connections from the same side of the substrate.

20 Claims, 10 Drawing Sheets



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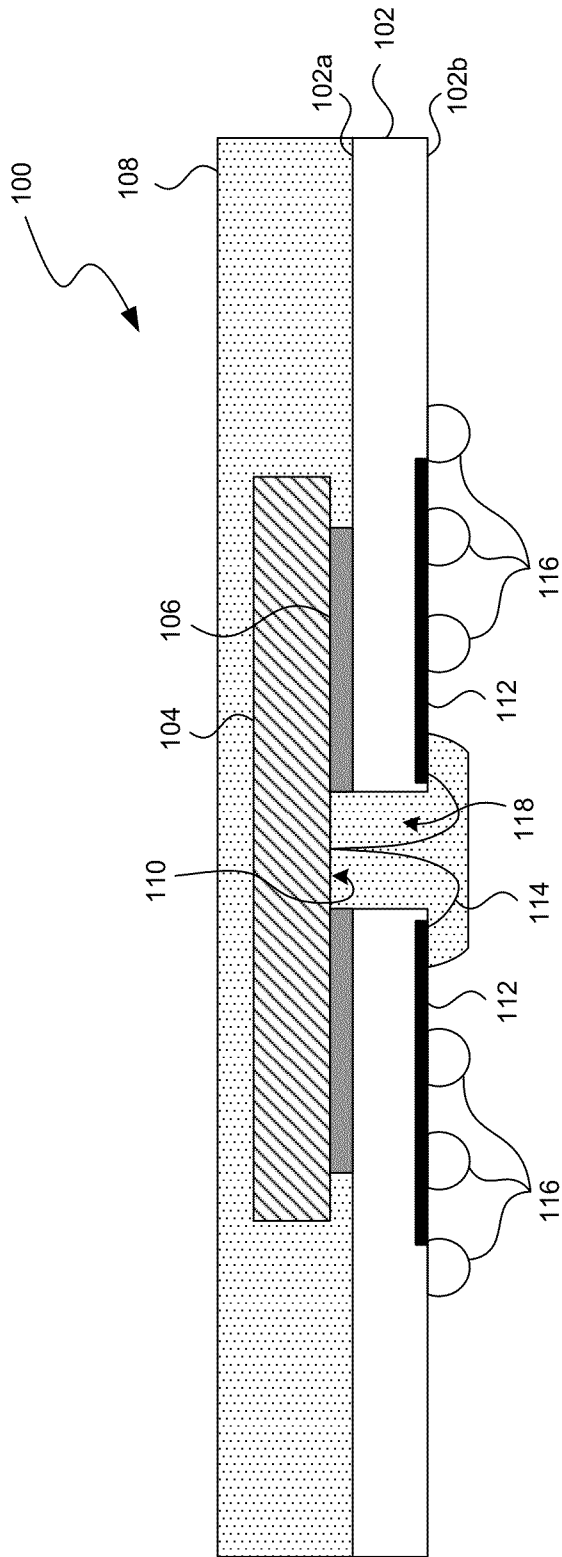


FIG. 1A
(Prior Art)

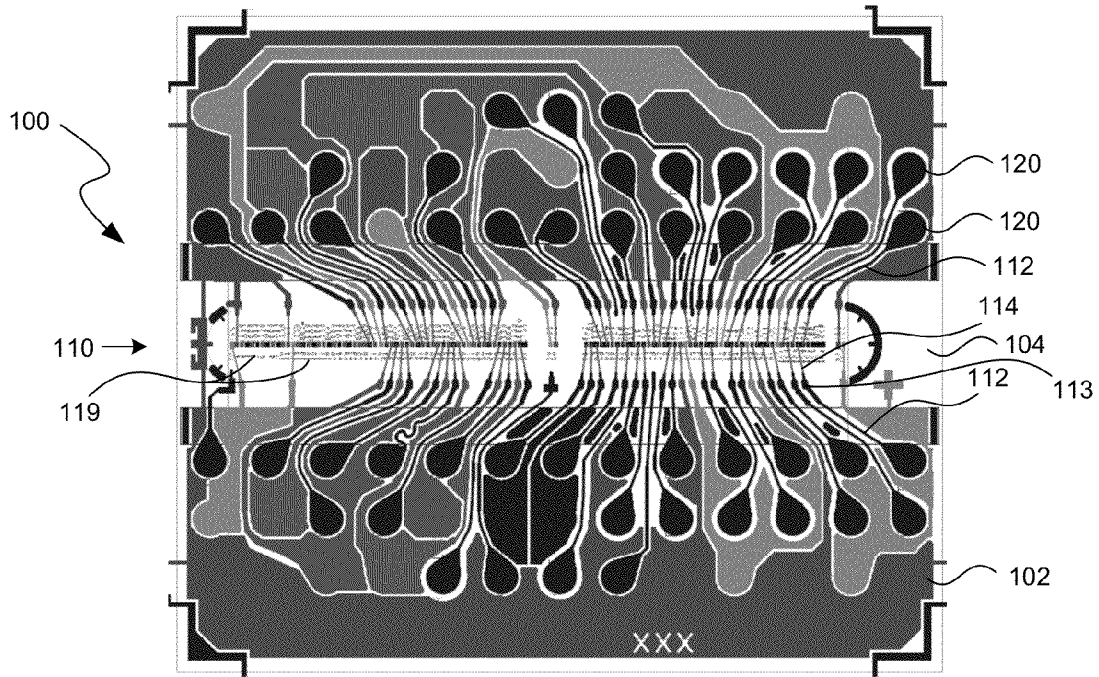


FIG. 1B
(Prior Art)

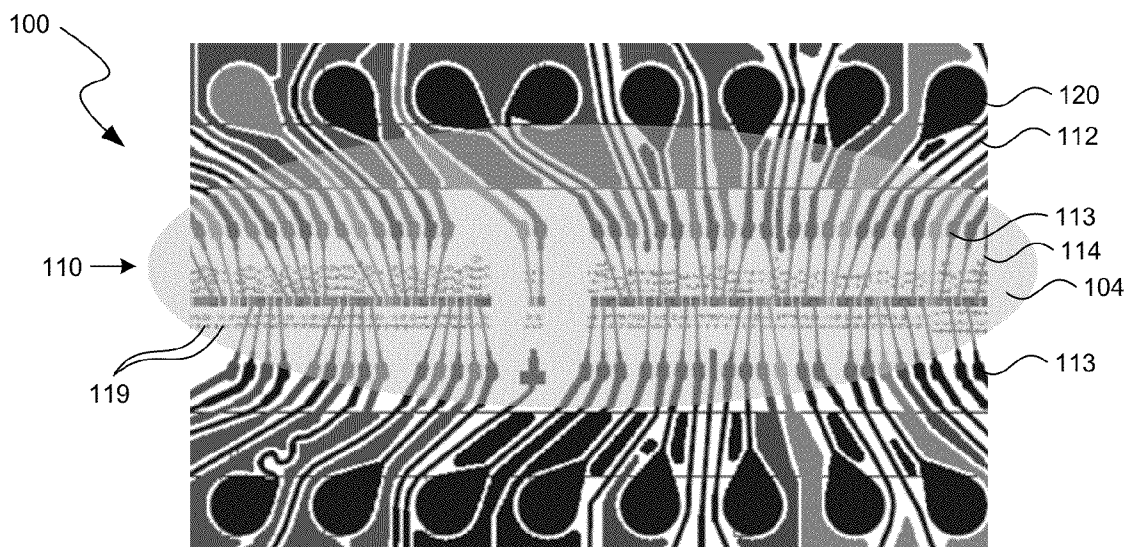


FIG. 1C
(Prior Art)

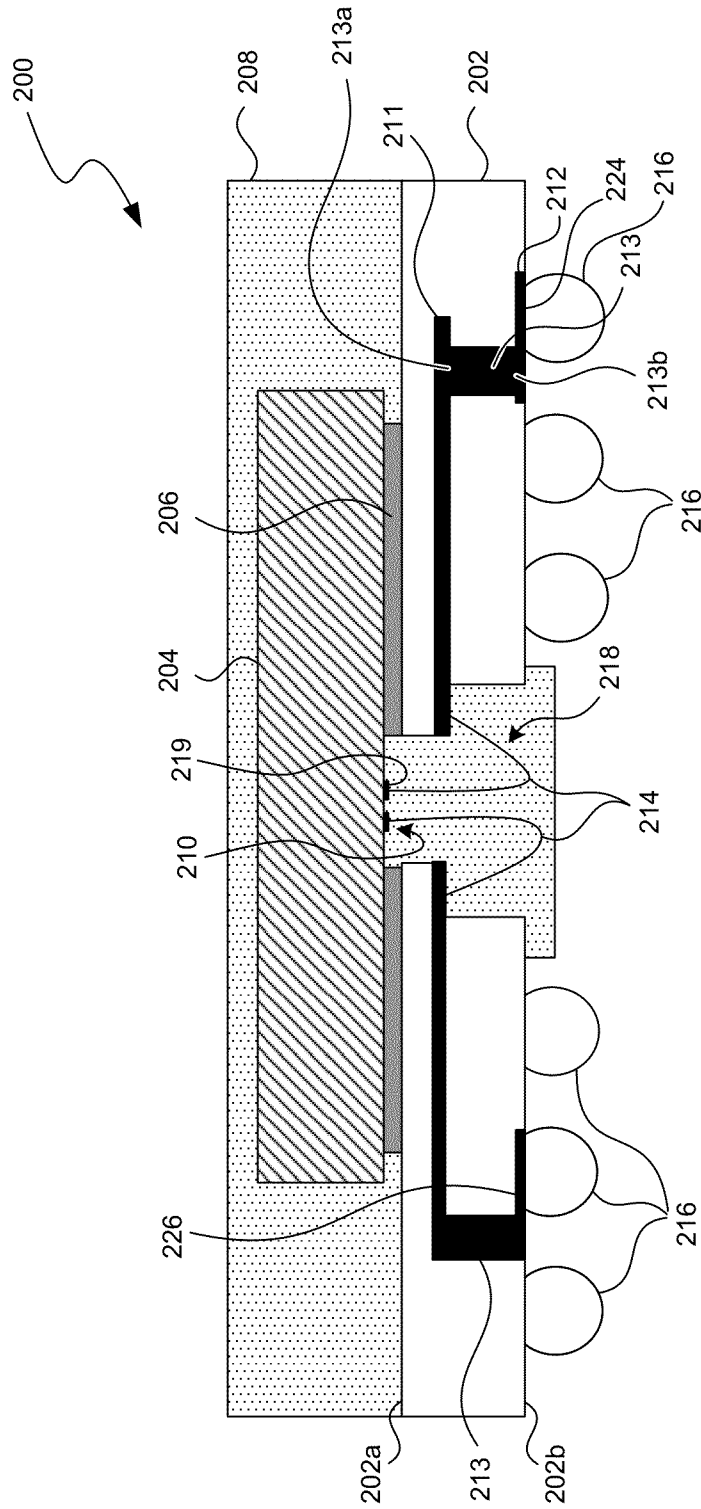


FIG. 2A

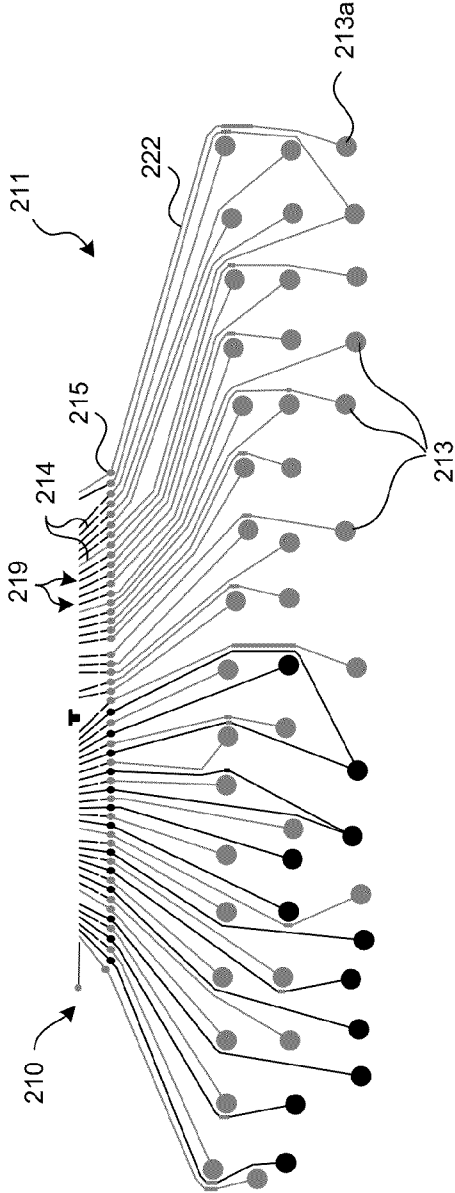


FIG. 2B

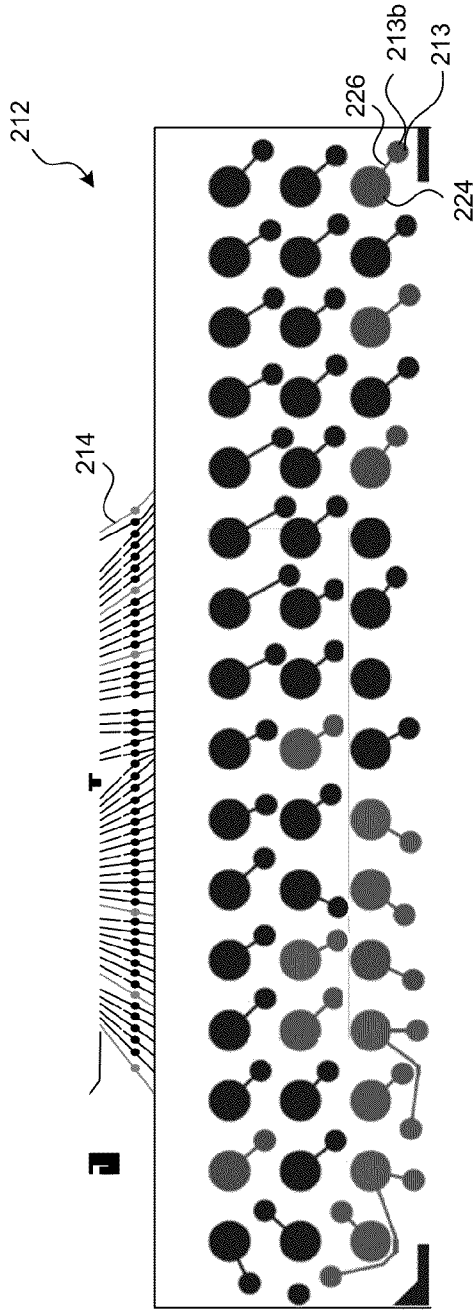


FIG. 2C

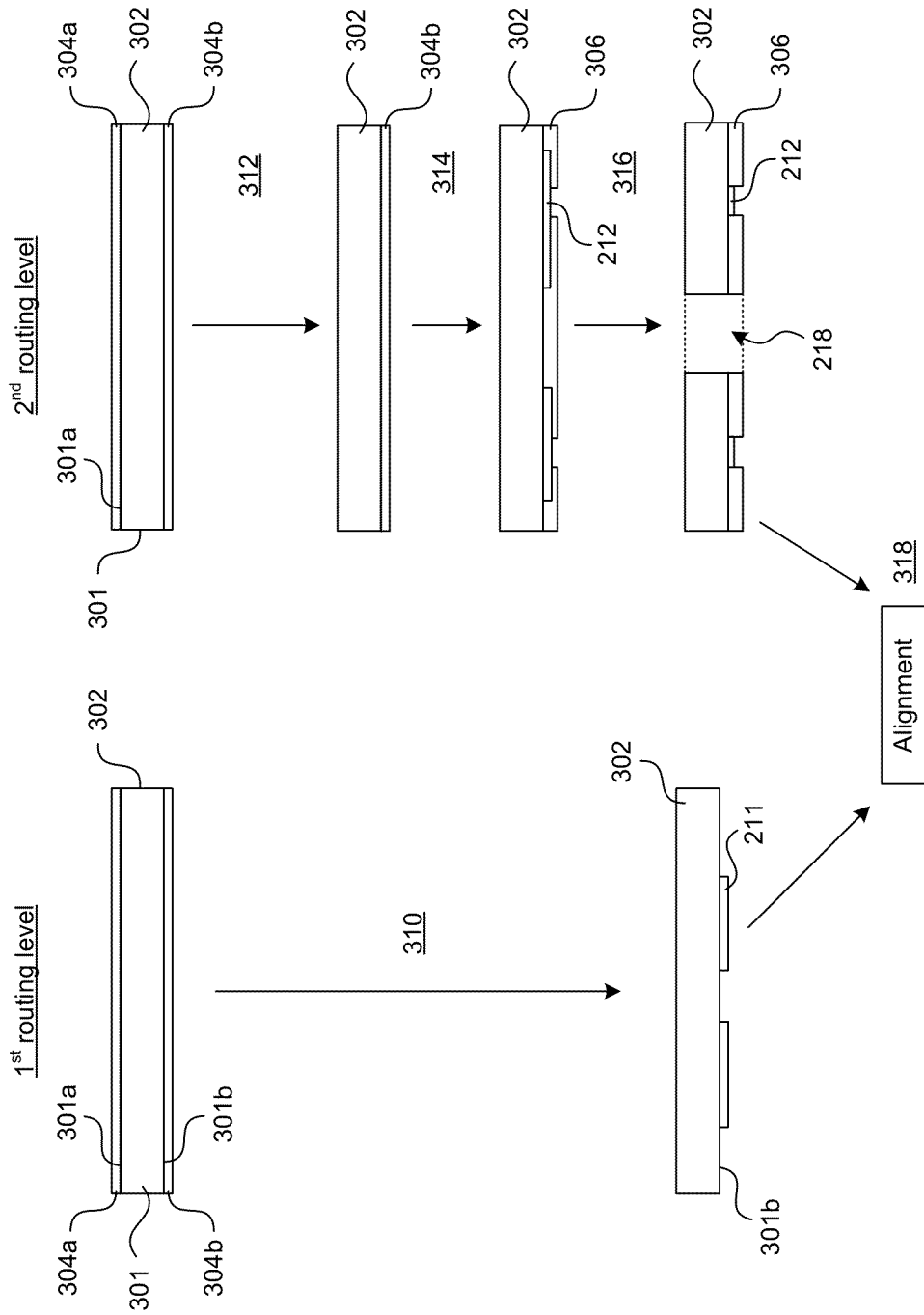


FIG. 3A

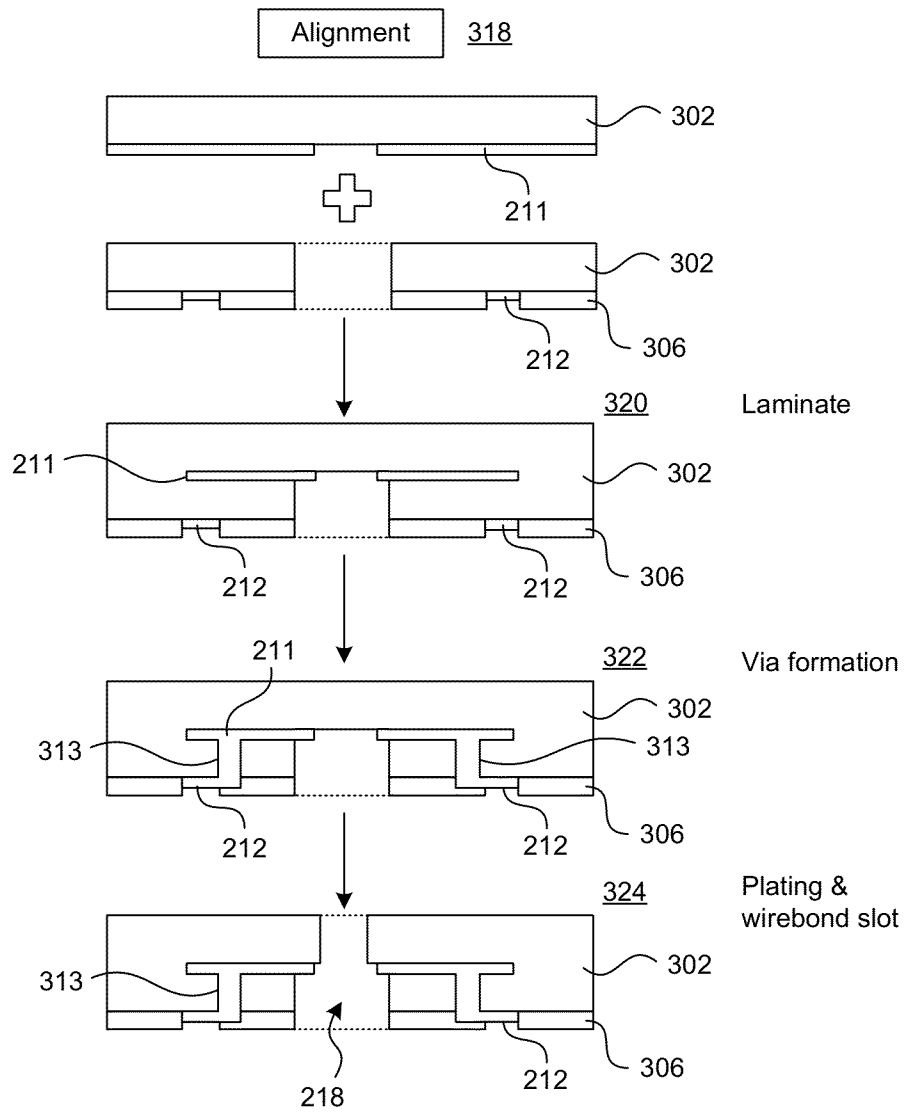


FIG. 3B

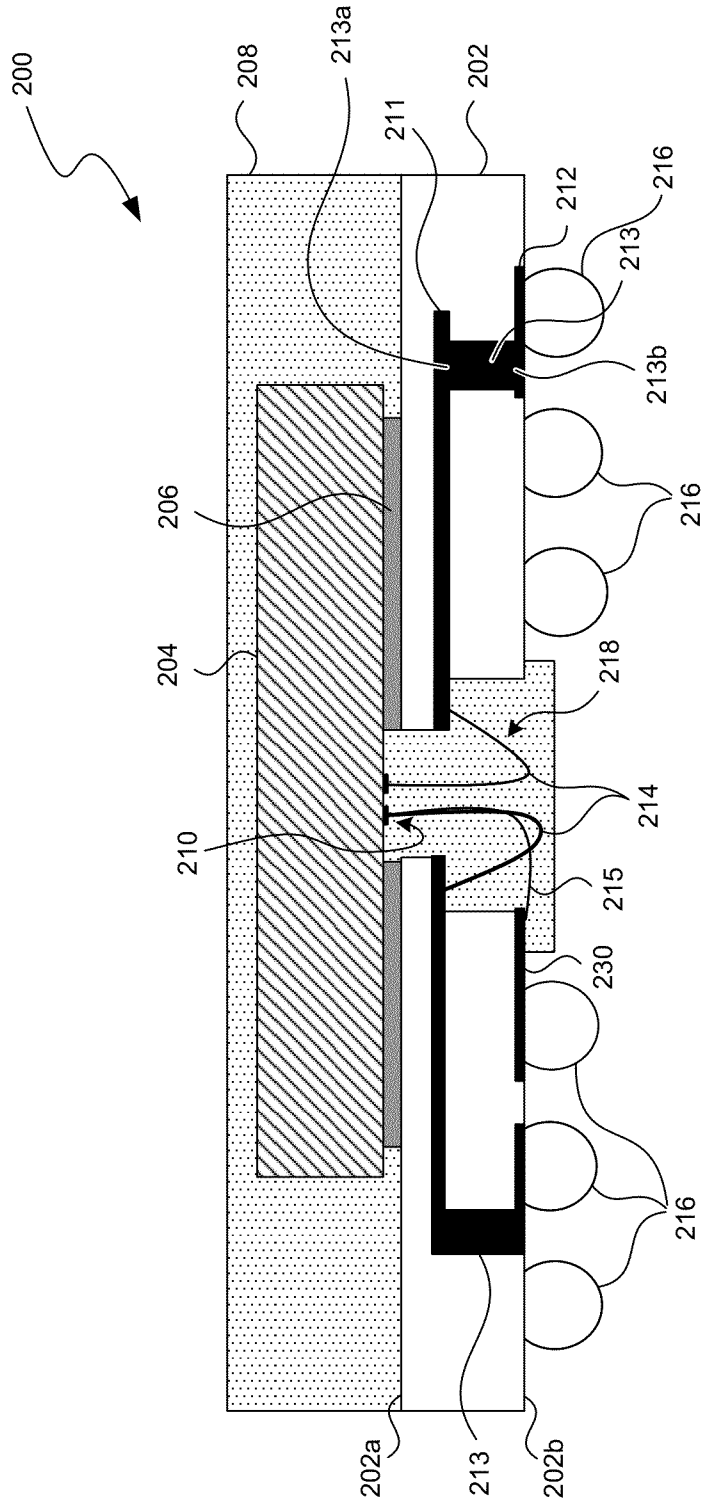


FIG. 4A

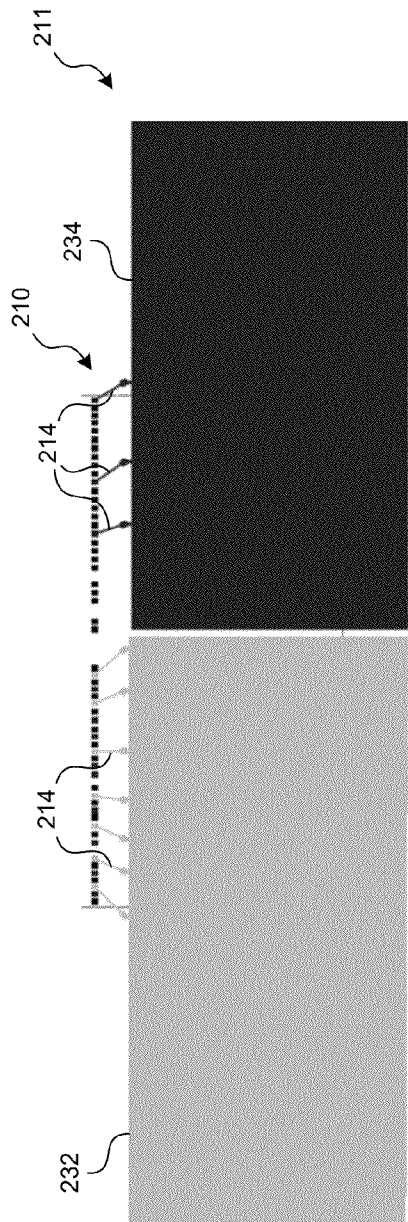


FIG. 4B

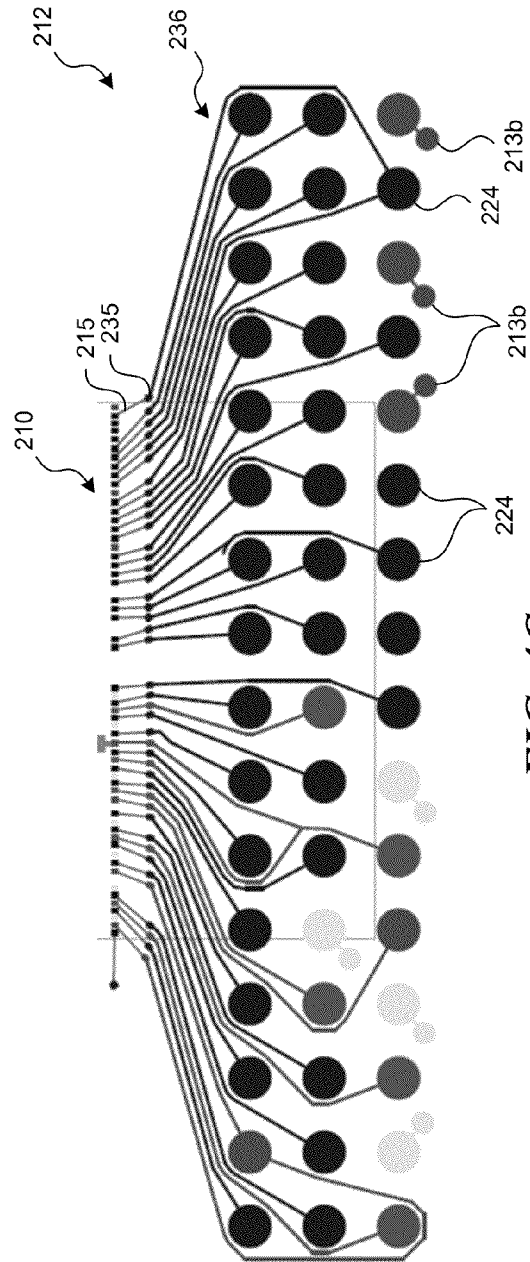


FIG. 4C

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SEMICONDUCTOR ASSEMBLIES WITH MULTI-LEVEL SUBSTRATES AND ASSOCIATED METHODS OF MANUFACTURING

CROSS-REFERENCE TO RELATED APPLICATION

This application is a divisional of U.S. application Ser. No. 13/206,321 filed Aug. 9, 2011, now U.S. Pat. No. 8,637,987, which is incorporated herein by reference.

TECHNICAL FIELD

The present disclosure is related to semiconductor assemblies with multi-level substrates and associated methods of manufacturing.

BACKGROUND

Board-on-chip (“BOC”) techniques have been used for packaging high speed memory components. FIG. 1A is a cross-sectional view of a BOC semiconductor assembly in accordance with the prior art. As shown in FIG. 1A, the semiconductor assembly 100 includes a substrate 102, a semiconductor die 104 attached to the substrate 102 with an adhesive 106, and an encapsulant 108 encapsulating the semiconductor die 104 and at least a portion of the substrate 102. The substrate 102 includes a first side 102a proximate the semiconductor die 104, a second side 102b opposite the first side 102a, and an opening 118 between the first and second sides 102a and 102b. The opening 118 exposes a connection region 110 on the semiconductor die 104. A plurality of traces 112 are located on the second side 102b of the substrate 102 and are electrically connected to the connection region 110 via a plurality of wirebonds 114. A plurality of electrical couplers 116 (e.g., solder balls) are attached to ball sites on the substrate 102.

FIG. 1B is a bottom view of the semiconductor assembly 100 of FIG. 1A, and FIG. 1C is an enlarged view of a portion of the semiconductor assembly 100 shown in FIG. 1B. As shown in FIGS. 1B and 1C, the semiconductor die 104 can include a plurality of bond sites 119 in the connection region 110. The individual bond sites 119 are coupled to corresponding terminals 113 of the individual traces 112 on the semiconductor substrate 102 via the wirebonds 114. As is clearly shown in FIGS. 1B and 1C, the plurality of traces 112 fan out from the terminals 113 to contact corresponding ball pads 120.

Over the course of time, manufacturers have made dies smaller and smaller to meet user demands. As the semiconductor dies 104 have become smaller, the number of ball pads 120 and the traces 112 required on the substrate 102 has increased such that the large ball pads 120 can interfere with routes of the traces 112. One conventional solution for dealing with this problem is to use aggressive design rules and wire bond profiles to decrease the sizes of all features on both the semiconductor die 102 and the substrate 104. However, such a conventional technique is still limited due to the number of ball pads 120 that are typically required.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1A illustrates a BOC semiconductor assembly in accordance with the prior art.

FIG. 1B is a bottom view of the BOC semiconductor assembly of FIG. 1A.

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FIG. 1C is an enlarged view of the BOC shown in FIG. 1B.

FIG. 2A illustrates a BOC semiconductor assembly with a multi-level substrate in accordance with embodiments of the present technology.

FIGS. 2B and 2C are plan views of first and second substrate levels, respectively, of the multi-level substrate shown in FIG. 2A.

FIGS. 3A and 3B illustrate a process of forming the multi-level substrate shown in FIG. 2A, in accordance with embodiments of the technology.

FIG. 4A illustrates a BOC semiconductor assembly with a multi-level substrate in accordance with additional embodiments of the present technology.

FIGS. 4B and 4C are plan views of first and second substrate levels of the multi-level substrate shown in FIG. 4A.

FIGS. 5 and 6 illustrate BOC semiconductor assemblies with a multi-level substrate in accordance with further embodiments of the present technology.

DETAILED DESCRIPTION

Various embodiments of semiconductor assemblies with multi-level substrates and associated methods of manufacturing are described below. Typical semiconductor assemblies or packages include microelectronic circuits or components, thin-film recording heads, data storage elements, microfluidic devices, and other components manufactured on microelectronic substrates. Substrates can include semiconductor pieces (e.g., doped silicon wafers or gallium arsenide wafers), non-conductive pieces (e.g., various ceramic substrates), or conductive pieces. A person skilled in the relevant art will also understand that the technology may have additional embodiments, and that the technology may be practiced without several of the details of the embodiments described below with reference to FIGS. 2A-6.

FIG. 2A illustrates a BOC semiconductor assembly 200 with a multi-level substrate 202 configured in accordance with embodiments of the present technology. As shown in FIG. 2A, the semiconductor assembly 200 can include the multi-level substrate 202, a semiconductor die 204 attached to the substrate 202 with an adhesive 206, and an encapsulant 208 encapsulating the semiconductor die 204 and at least a portion of the substrate 202. The semiconductor die 204 can include a memory die, a processor, and/or other suitable types of dies. The encapsulant 208 can include an epoxy and/or other suitable compositions. Even though a particular arrangement of the foregoing components is shown in FIG. 2A for illustration purposes, in other embodiments, the semiconductor die 204 may also be attached to the substrate 202 in a flip-chip configuration and/or other suitable configurations.

In the illustrated embodiment, the substrate 202 can include a first side 202a proximate the semiconductor die 204, a second side 202b opposite the first side 202a, and an opening 218 extending through the substrate 202 from the first side 202a to the second side 202b. The opening 218 exposes a connection region 210 on the semiconductor die 204. The connection region includes bond sites 219 that are connected internally to structures within the semiconductor die 204. In other embodiments, the opening 218 may be omitted, for example, if the semiconductor die 204 is coupled to the substrate 202 in a flip-chip configuration.

As shown in FIG. 2A, the substrate 202 includes a first routing level 211, a second routing level 212, and conductive vias 213 between the first and second routing levels 211 and 212. The individual first and second routing levels 211 and 212 can be in generally parallel planes, and can include a trace, a plate, and/or other suitable routing structures. Indi-

vidual conductive vias **213** can include a first end **213a** in contact with the first routing level **211** and a second end **213b** in contact with the second routing level **212**. In the illustrated embodiment, a plurality of wirebonds **214** electrically connect individual bond sites **219** at the connection area **210** of the semiconductor die **204** to the first routing level **211**. In other embodiments, at least some of the wirebonds **214** can also be connected to the second routing level **212**, as described in more detail below with reference to FIG. 4A. In further embodiments, the substrate **202** may include three, four, or any other suitable number of routing levels in configurations generally similar to or different from that shown in FIG. 2A, depending upon the embodiment. In any of these embodiments, the second ends **213b** of the individual vias **213** can be electrically connected to individual ball sites **224** via connectors **226**. The ball sites **224** can be configured as a ball grid array to receive a plurality of electrical couplers **216** (e.g., solder balls) as shown in FIG. 2A.

FIGS. 2B and 2C are bottom views of the first and second routing levels **211** and **212**, respectively. As shown in FIG. 2B, the individual wirebonds **214** are electrically coupled between a terminal **215** of the individual trace **222** on the first routing level **211** and corresponding bond sites **219** in the connection region **210**. The individual traces **222** fan out from the terminals **215** to connect with the first ends **213a** of the conductive vias **213**. As shown in FIG. 2C, the second routing level **212** includes the second ends **213b** of the individual vias **213**, which are electrically connected to corresponding ball sites **224** with corresponding connectors **226**, as discussed above with reference to FIG. 2A. The bond sites **219** (FIG. 2B) and the ball sites **224** (FIG. 2A) can be accessible from the same side (e.g., the same major surface) of the substrate **202**, as shown in FIG. 2A. As a result, and with continued reference to FIG. 2A, the wire bonds **214** and electrical couplers **216** (e.g., solder balls) can readily be connected to the substrate **202** from the same side of the substrate **202**.

As shown in FIGS. 2B and 2C, the first routing level **211** of the substrate **202** has a plurality of traces **222** that fan out to form a target pattern of the first ends **213a** of the conductive vias **213**. The illustrated first routing level **211** does not include any ball sites. As a result, the traces **222** can fan out without hindrance from the ball sites **224** because the ball sites **224** are on the second routing level **212** which is in a different plane than the plane containing the traces **222**. In other words, the traces **222** on the first routing level **211** can pass under or over any number of ball sites **224** without interference from the ball sites **224** because the ball sites **224** are on the second routing level **212**. As a result, embodiments of the substrate **202** can accommodate a large number of traces **222** and ball sites **224** even though the semiconductor die **204** has a small size.

FIGS. 3A and 3B illustrate a process of forming the multi-level substrate **202** in FIG. 2A in accordance with embodiments of the technology. As shown in FIG. 3A, the process for forming the first routing level **211** and the second routing level **212** are shown side by side for illustration purposes. In certain embodiments these processing stages may be performed concurrently. In other embodiments these operating stages may be performed at least partially in series.

As shown in FIG. 3A, separate pieces or elements of a substrate material **302** are used to form the first and second routing levels, respectively. The substrate material **302** includes a generally non-conductive core **301** with a first conductive material **304a** (e.g. copper) on a first side **301a** and a second conductive material **304b** on a second side **301b**. An initial stage **310** of forming the first routing level **211** can include stripping the first conductive material **304a** from the

first side **301a** of the non-conductive core **301**. Subsequently, the second conductive material **304b** may be patterned and selectively removed from the second side **301b** of the non-conductive core **301**, forming the first routing level **211**.

Preparing the second routing level **202** can include stripping the first conductive material **304a** from the first side **301a** of a separate non-conductive core **301** (stage **312**) and patterning and selectively removing the second conductive material **304b** to form a targeted pattern for the second routing level **212** (stage **314**). As shown in FIG. 3A, a solder mask **306** is formed over the second routing level **212** at stage **316**. In other embodiments the solder mask **306** may be omitted. Stage **316** can include removing a portion of the solder mask **306** and the generally non-conductive core **301** to form a portion of the opening **218** in the substrate **202**. The formed first and second routing levels **211** and **212** can then be generally aligned at stage **318**.

As shown in FIG. 3B, the first routing level **211** and the second routing level **212** can be laminated together at stage **320**. Conductive vias **313** between the first and second routing levels **211** and **212** can be subsequently formed at stage **322** using through-substrate via forming techniques and/or other suitable techniques. Subsequently, the non-conductive core **301** of the first routing level **211** can be selectively removed to form another portion of the opening **218** in the substrate **202** at stage **324**. Subsequently, the semiconductor die **204** (FIG. 2A) can be attached to the substrate **202** and subsequently encapsulated with encapsulant **218** according to conventional techniques for BOC packaging.

Even though the wirebonds **214** are shown in FIG. 2A as extending between the connection region **210** of the semiconductor die **204** and the first routing level **211**, in other embodiments the second routing level **212** can also include contact areas electrically coupled to the connection region **210** of the semiconductor die **204**. For example, as shown in FIG. 4A, the second routing level **212** can include at least one contact area **230** electrically coupled to the connection region **210** of the semiconductor die **204** via a wirebond **215**.

As shown in FIG. 4B, the first routing level **211** is shown divided into a first signal plane **232** and a second signal plane **234** in a side-by-side arrangement. The individual first and second signal planes **232** and **234** are electrically coupled to the connection region **210** with the wirebonds **214**. In certain embodiments, at least one of the first and second signal planes **232**, **234** can include a power plane, a ground plane, and/or other suitable signal planes that are electrically common to multiple terminals of the die **204** (FIG. 4A). As shown in FIG. 4C, the second routing level **212** can include a plurality of traces **236** that fan out from a plurality of terminals **235** into a plurality of ball sites **224**. The individual terminals **235** are electrically connected to the connection region **210** via the wirebonds **215**. The first and second routing levels **211** and **212** are connected with the conductive vias **213**, in a manner generally similar to that discussed above with reference to FIGS. 2A-2C.

FIGS. 5 and 6 are cross-sectional views of BOC semiconductor assemblies **500** and **600**, respectively, configured in accordance with additional embodiments of the present technology. Embodiments of the semiconductor assemblies **500** and **600** can be generally similar to those shown in FIGS. 2A and 4A, respectively, except that the semiconductor assemblies **500** and **600** individually include a conductive material **240** between the substrate **202** and the semiconductor die **204**. The conductive material **240** can include a metal plate, a metal alloy plate, and/or other suitable materials and/or structures with sufficient thermal conductivity to conduct heat from the semiconductor die **202**. In further embodiments, the

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conductive material **240** may be replaced with other suitable heat conducting components (e.g., Peltier elements) or may be omitted.

One feature of several of the foregoing embodiments is that the traces and the ball sites to which they connect can be located on different levels or strata of the substrate. This arrangement allows the designer greater flexibility when selecting the routes for the traces and the locations for the ball sites because the routes can follow paths that are independent of the ball site locations, so long as individual routes can be connected to the corresponding ball sites with vias, as described above. Another feature of at least some embodiments is that the ball sites on one level of the substrate and portions of the traces on another level of the substrate are both accessible from the same side or face of the substrate. This arrangement allows the manufacturer to access the traces for wirebonding and access the ball sites for depositing solder balls or other electrical couplers with the substrate facing the same direction.

From the foregoing, it will be appreciated that specific embodiments of the technology have been described herein for purposes of illustration, but that various modifications may be made without deviating from the technology. For example, in an embodiment shown in FIG. 3A, the two routing levels are initially formed on separate non-conductive cores, which are then joined. As part of this process, the conductive material on one side of each core is removed. In other embodiments, portions of this conductive material can remain, e.g., to carry out additional routing functions. The traces and ball pads can have arrangements different than those specifically illustrated in the foregoing Figures. The materials described in the context of particular embodiments above can have different constituents and/or properties in other embodiments.

Certain aspects of the technology described in the context of particular embodiments may be combined or eliminated in other embodiments. Further, while advantages associated with certain embodiments of the invention have been described in the context of those embodiments, other embodiments may also exhibit such advantages, and not all embodiments need necessarily exhibit such advantages to fall within the scope of the invention. Accordingly, the disclosure and associated technology can encompass other embodiments not expressly shown or described herein.

We claim:

1. A method of processing a substrate for carrying a semiconductor die, comprising:
forming a first routing level carried by a first non-conductive core;
forming a second routing level carried by a second non-conductive core;
generally aligning the first routing level relative to the second routing level;
fixing the first and second non-conductive cores relative to each other; and
forming a conductive via between the first and second routing levels, the conductive via having a first end proximate the first routing level and a second end proximate the second routing level, wherein:
the first routing level includes a terminal and a first trace electrically connected between the terminal and the first end of the conductive via;
the second routing level includes a second trace electrically connected between the second end of the conductive via and a ball site; and
the terminal and the ball site are both accessible from the same side of the substrate.

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2. The method of claim 1 wherein forming the first routing level includes stripping a first conductive material from a first side of the first non-conductive core and patterning and selectively removing a portion of a second conductive material on a second side of the first non-conductive core.

3. The method of claim 1 wherein forming the second routing level includes:

stripping a first conductive material from a first side of the second non-conductive core and patterning and selectively removing a portion of a second conductive material on a second side of the second non-conductive core; and
depositing a solder mask on the patterned second conductive material.

4. The method of claim 1 wherein forming the second routing level includes:

stripping a first conductive material from a first side of the second non-conductive core and patterning and selectively removing a portion of a second conductive material on a second side of the second non-conductive core; depositing a solder mask on the patterned second conductive material; and

forming ball pads on the second conductive material by selectively removing the deposited solder mask.

5. The method of claim 1, further comprising forming an opening through the first and second routing levels after generally aligning the first routing level to the second routing level.

6. The method of claim 1 wherein forming the first routing level includes forming a first routing level that does not include any ball site.

7. The method of claim 1 wherein fixing the first and second non-conductive cores relative to each other includes bonding the first routing level to a surface of the second non-conductive core.

8. The method of claim 1 wherein the first and second routing levels and the conductive via form a substrate, and wherein the method further comprises:

mounting a semiconductor die to the substrate; and
electrically connecting the semiconductor die to the first routing level.

9. The method of claim 1 wherein the first and second routing levels and the conductive via form a substrate, and wherein the method further comprises:

forming an opening in the substrate;
mounting a semiconductor die to the substrate; and
wirebonding the semiconductor die to the terminal of the first routing level first routing level by passing a bond wire through the opening.

10. A method of processing a substrate for carrying a semiconductor die, comprising:

forming a first routing level on a first substrate;
forming a second routing level on a second substrate different than the first substrate;
generally aligning the first routing level relative to the second routing level;

joining the first and second substrates before forming a conductive via; and

forming the conductive via between the first and second routing levels, the conductive via having a first end proximate the first routing level and a second end proximate the second routing level, wherein:

the first routing level includes a terminal and a first trace electrically connected between the terminal and the first end of the conductive via;

the second routing level includes a second trace electrically connected between the second end of the conductive via and a ball site; and the terminal and a ball site are both accessible from the same side of the substrate.

11. The method of claim 10, further comprising: mounting a semiconductor die to the first substrate; forming an opening at least through the first substrate, the opening exposing a bond site on the semiconductor die; and electrically connecting the bond site to the terminal through the opening.

12. The method of claim 11, further comprising attaching a wirebond to the terminal and a solder ball to the pad.

13. The method of claim 10, further comprising forming an opening through the second substrate before joining the first and second substrates, wherein the terminal is exposed through the opening.

14. The method of claim 10, further comprising: forming a first opening through the second substrate before joining the first and second substrates; and forming a second opening through the first substrate after joining the first and second substrates, wherein the second opening is aligned with the first opening.

15. The method of claim 10 wherein the first routing level is formed on a first side of the first substrate, and wherein the method further comprises: stripping a conductive material from a surface on a second side of the first substrate opposite the first side; and attaching a semiconductor die to at least a portion of the surface.

16. The method of claim 10, further comprising stripping a conductive material from a surface of the second substrate, and wherein joining the first and second substrates includes attaching the first substrate to at least a portion of the surface.

17. A method for manufacturing a semiconductor assembly, the method comprising:

patterning a first conductive material to define a first trace and a terminal connected to the first trace, wherein the first conductive material is carried by a first non-conductive core;

5 patterning a second conductive material to define a second trace and a pad connected to the second trace, wherein the second conductive material is carried by a second non-conductive core;

10 attaching the second non-conductive core to at least a portion of the first trace and a surface of the first non-conductive core;

forming a conductive via at least through the second non-conductive core, wherein the conductive via electrically connects the first trace with the second trace; and forming an opening at least through the second non-conductive core to expose the terminal through the opening.

18. The method of claim 17 wherein: the surface of the first non-conductive core is at a first side of the first non-conductive core; the opening extends through the first non-conductive core; and the method further comprises attaching a semiconductor die to a surface of the first non-conductive core at a second side of the first non-conductive core opposite the first side, wherein a portion of the semiconductor die is exposed through the opening.

19. The method of claim 17 wherein the opening is a first opening, and wherein the method further comprises forming a second opening through the first non-conductive core and adjacent the first opening.

20. The method of claim 19, further comprising attaching a semiconductor die to the first non-conductive core, wherein a portion of the semiconductor die is exposed through the first and second openings.

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