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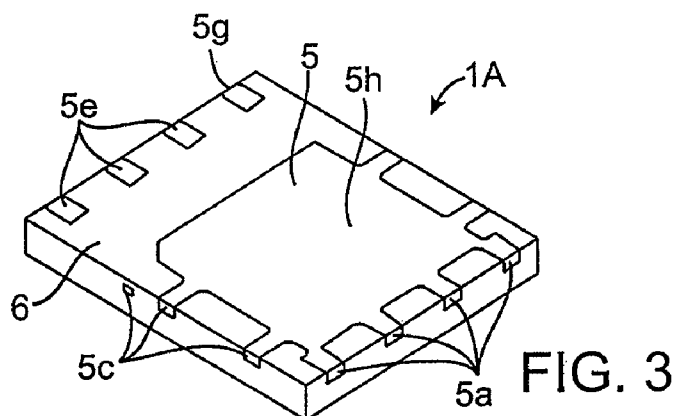
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(54) Title: SEMICONDUCTOR DIE PACKAGE INCLUDING LOW STRESS CONFIGURATION



(57) Abstract: A semiconductor die package. The semiconductor die package comprises a semiconductor die and a molded clip structure comprising a clip structure and a first molding material covering at least a portion of the clip structure. The first molding material exposes an outer surface of the clip structure. The clip structure is electrically coupled to the semiconductor die. The semiconductor die package further comprises a leadframe structure comprising a die attach pad and a plurality of leads extending from the die attach pad. The semiconductor die is on the die attach pad of the leadframe structure. A second molding material covers at least a portion of the semiconductor die and the leadframe structure. The semiconductor die package also includes a heat slug and a thermally conductive material coupling the heat slug to the exposed surface of the clip structure.

SEMICONDUCTOR DIE PACKAGE INCLUDING LOW STRESS CONFIGURATION

CROSS-REFERENCES TO RELATED APPLICATIONS

[0001] NOT APPLICABLE

5

BACKGROUND

[0002] Power semiconductor die packages are known and are used in computers and the like.

[0003] Such semiconductor die packages could be improved. For example, power semiconductor die packages generate a significant amount of heat. It would be desirable to improve upon semiconductor die packages so that they can dissipate more heat. Also, conventional semiconductor die packages are molded with a molded material. Having to directly expose a metal clip that is connected to the semiconductor die source contact pad to allow heat dissipation from the top side of the package presents challenges with respect to the metal clip design and the corresponding assembly process (particularly if the standard package dimensions are to be followed). The exposed metal clip stacked on top of the semiconductor die needs to be thick, and this can result in stress to the semiconductor die and the molding material. This can increase the likelihood of a package failure.

[0004] It would be desirable to provide for a semiconductor die package that can address these and other problems. Embodiments of the invention can address the above problems, and other problems, individually and collectively.

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BRIEF SUMMARY

[0005] Embodiments of the invention relate to semiconductor die packages, methods for making semiconductor die packages, and systems comprising semiconductor die packages.

25 [0006] One embodiment of the invention is directed to a semiconductor die package comprising a semiconductor die and a molded clip structure comprising a clip structure and a

first molding material covering at least a portion of the clip structure. The first molding material exposes an outer surface of the clip structure. The clip structure is electrically coupled to the semiconductor die. The semiconductor die package further comprises a leadframe structure comprising a die attach pad and a plurality of leads extending from the die attach pad. The semiconductor die is on the die attach pad of the leadframe structure. A second molding material covers at least a portion of the semiconductor die and the leadframe structure. The semiconductor die package also includes a heat slug and a thermally conductive material coupling the heat slug to the exposed surface of the clip structure.

[0007] One embodiment of the invention is directed to a method comprising: a) attaching a semiconductor die to a die attach pad of a leadframe structure; b) attaching a molded clip structure comprising a clip structure and a first molding material covering at least a portion of the clip structure, and exposing an outer surface of the clip structure to the semiconductor die; c) forming a second molding material around at least a portion of the semiconductor die and the leadframe structure; and d) attaching a heat slug to the exposed outer surface of the clip structure using a thermally conductive material.

[0008] Other embodiments of the invention are directed to electrical assemblies and methods for forming the same.

[0009] These and other embodiments of the invention are described in further detail below.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010] FIGS. 1(a)-1(c) show three-dimensional top views of three different semiconductor die packages according to embodiments of the invention.

[0011] FIGS. 2(a)-2(c) show side views of the semiconductor die package embodiments shown in FIGS. 1(a)-1(c).

[0012] FIG. 3 shows a three-dimensional bottom view of a semiconductor die package according to the embodiments shown in FIGS. 1(a)-1(c).

[0013] FIG. 4 shows a three-dimensional cutaway top view showing the different components in the semiconductor die package shown in FIG. 1(a).

[0014] FIG. 5(a) shows a top plan view of the semiconductor die package 1A shown in FIG. 1(a). Some internal components are shown.

[0015] FIGS. 5(b)-5(e) respectively show side cross-sectional views along lines A-A, B-B, C-C, and D-D in FIG. 5(a).

[0016] FIG. 6 shows a three-dimensional cutaway top view showing the different components in the semiconductor die package shown in FIG. 1(b).

5 [0017] FIG. 7(a) shows a top plan view of the semiconductor die package 1B shown in FIG. 1(b). Some internal components are shown.

[0018] FIGS. 7(b)-7(d) respectively show side cross-sectional views along lines A-A, B-B, C-C, and D-D in FIG. 7(a).

10 [0019] FIG. 8 shows a three-dimensional cutaway top view showing the different components in the semiconductor die package 1C shown in FIG. 1(c).

[0020] FIG. 9(a) shows a top plan view of the semiconductor die package 1B shown in FIG. 1. Some internal components are shown.

[0021] FIGS. 9(b)-9(d) respectively show side cross-sectional views along lines A-A, B-B, C-C, and D-D in FIG. 9(a).

15 [0022] FIGS. 10(a)-1 to 10(a)-3 show images of precursors that are formed during the formation of molded clips according to an embodiment of the invention.

[0023] FIGS. 10(b)-1 to 10(b)-3 show images of precursors that are formed during the formation of molded clips according to another embodiment of the invention.

20 [0024] FIGS. 10(c)-1 to 10(c)-3 show images of precursors that are formed during the formation of molded clips according to another embodiment of the invention.

[0025] FIGS. 11(a)-11(c) show top and bottom perspective views of three different molded clip embodiments.

[0026] FIG. 12 shows a two dimensional array of clip structures.

25 [0027] FIG. 13 shows a three dimensional perspective view of a clip structure according to an embodiment of the invention.

[0028] FIGS. 14(a)-14(c) show three different heat slugs according to embodiments of the invention.

[0029] FIGS. 15(a)-15(c) show perspective views of three semiconductor die packages with heat slugs in open positions.

[0030] FIG. 16(a)-16(h) show perspective views of precursors that are formed during the formation of a semiconductor die package according to an embodiment of the invention.

5 [0031] FIG. 17(a)-17(h) show perspective views of precursors that are formed during the formation of a semiconductor die package according to an embodiment of the invention.

[0032] FIG. 18(a)-18(g) show perspective views of precursors that are formed during the formation of a semiconductor die package according to an embodiment of the invention.

10 [0033] FIG. 19(a) shows a three-dimensional cutaway view of another semiconductor die package embodiment.

[0034] FIG. 19(b) shows a three dimensional view of a semiconductor die package without a molding material and with the clip structure.

[0035] FIG. 19(c) shows a top perspective cutaway view of a semiconductor die package embodiment with an aperture in a gate clip structure.

15 [0036] FIG. 19(d) shows a top perspective view of a molded clip structure according to an embodiment of the invention.

[0037] FIG. 19(e) shows a top plan view of an array of clip structures according to an embodiment of the invention.

20 [0038] FIG. 19(f) shows a bottom perspective view of a molded clip structure according to an embodiment of the invention.

[0039] FIG. 19(g) shows a top perspective view of a molded clip structure according to an embodiment of the invention.

[0040] FIG. 20 shows a side cross-sectional view of a power MOSFET.

25 [0041] In the Figures, like numerals designate like elements, and the descriptions of some elements may not be repeated.

[0042] Exemplary dimensions are shown in the Figures. Embodiments of the invention are not limited to such exemplary dimensions.

DETAILED DESCRIPTION

[0043] One embodiment of the invention is directed to a semiconductor die package comprising a semiconductor die and a molded clip structure.

5 [0044] A semiconductor die in the semiconductor die package may comprise any suitable type of device, including a power MOSFET. While power MOSFETs are described in detail, any suitable vertical power transistor can be used in embodiments of the invention. Vertical power transistors include VDMOS transistors and vertical bipolar transistors. A VDMOS transistor is a MOSFET (an example of which is shown in FIG. 20) that has two or more semiconductor regions formed by diffusion. It has a source region, a drain region, and
10 a gate. The device is vertical in that the source region and the drain region are at opposite surfaces of the semiconductor die. The gate may be a trench gate structure or a planar gate structure, and is formed at the same surface as the source region. Trenched gate structures are preferred, since trenched gate structures are narrower and occupy less space than planar gate structures. During operation, the current flow from the source region to the drain region
15 in a VDMOS device is substantially perpendicular to the die surfaces. Other electrical devices such as vertical resistors, capacitors, etc. may also be used in embodiments of the invention. In embodiments of the invention, an input region can be at one surface of the semiconductor die, while an output region can be at the opposite surface of the semiconductor die.

20 [0045] The molded clip structure comprises a clip structure and a first molding material covering at least a portion of the clip structure. The clip structure may comprise a metal such as copper, and may be electrically coupled to the semiconductor die in the semiconductor die package. Surfaces of the first molding material may be substantially coplanar with surfaces of the clip structure.

25 [0046] The first molding material may comprise a material such as an epoxy material, and can expose an outer surface of the clip structure. During the process of manufacturing the semiconductor die package, the first molding material may initially cover the outer surface of the clip structure. The outer surface may be subsequently exposed using a material removal process such as a laser ablation process.

30 [0047] The contacts in the molded clip structure can define the shapes of the solder joints that couple the molded clip structure to the semiconductor die. This can result in less

stressful, pre-defined solder joints at the gate and source contact areas of the semiconductor die. Other contacts in the molded clip can also define the shapes of solder joints that couple the molded clip to gate and source top-set lead posts in the leadframe structure.

5 [0048] The molded clip structure can be close to the semiconductor die in the semiconductor die package. In some embodiments of the invention, in order to prevent incomplete filling of a second molding material in the space between the two structures such as the molded clip structure and a semiconductor die, the molded clip structure is laser ablated at its bottom surface (see, e.g., FIG. 13) to provide space for the second molding material to fill the narrow clearances between the semiconductor die and the molded clip structure. After laser ablating the first molding material in the molded clip structure, the gate and source contact pads at the bottom side of the clip structure can protrude from other surfaces of the molded clip structure. This contact pad protrusion can promote vertical filleting of solder joints joining the molded clip structure to the semiconductor die.

10 [0049] The semiconductor die package further comprises a leadframe structure. The leadframe structure may include a die attach pad and leads extending from the die attach pad. The semiconductor die is mounted on the die attach pad of the leadframe structure using solder or some other conductive adhesive.

20 [0050] In some embodiments, the leadframe structure may include a drain lead structure, a gate lead structure, and a source lead structures. The drain lead structure may comprise a die attach pad and a plurality of leads extending from the die attach pad. The leadframe structure may also comprise a gate lead structure including a gate lead post and a gate lead extending from the gate lead post. It may also comprise a source lead structure including a source lead post, and a plurality of source leads extending substantially perpendicularly from the orientation of the source lead post.

25 [0051] The leadframe structure or the above-described clip structure may comprise any suitable material. For example, the leadframe structure and/or the clip structure may comprise a base metal such as copper, nickel etc. The base metal may be coated with a solderable material such as nickel or a non-oxidizing metal.

30 [0052] A second molding material can cover at least a portion of the semiconductor die and the leadframe structure. In some embodiments, a bottom exterior surface of the leadframe structure may be exposed through the second molding material. The second molding material may be the same or different than the first molding material. Because they

are molded at separate times, an interface between the first and second molding materials may be present in the semiconductor die package.

[0053] The semiconductor die package also includes a heat slug and a thermally conductive material such as solder coupling the heat slug to the exposed surface of the clip structure. The heat slug can be attached so that it is an external or internal component in the semiconductor die package.

[0054] The heat slug may comprise a thermally and (optionally) electrically conductive material such as copper, aluminum, or alloys thereof. It may have a major surface that is shaped as a square, and may have a thickness of about 0.250 mm (or less) in some embodiments of the invention.

[0055] The thermally conductive material coupling the heat slug to the exposed surface of the clip structure may comprise any suitable material including a thermally conductive epoxy or solder (Pb-based or lead free).

[0056] The heat slug provides a number of advantages. First, the attached heat slug can form a top source contact for the semiconductor die package. This allows for greater design flexibility in case a source connection is to be formed at the top surface of a semiconductor die package. Second, the heat slug can make the semiconductor die package thicker, in the event that the semiconductor die package needs to conform to a predetermined specification. Third, the heat slug can also be an aesthetic crown for the semiconductor die package.

[0057] Embodiments of the invention also solve a number of problems. First, embodiments of the invention can eliminate or reduce the problem of compressive stress within the semiconductor die package. As noted above, an outer surface of the clip structure is not covered with either the second molding material or first molding material in some embodiments. In such embodiments, the outer surface of the clip structure is exposed during manufacturing using a non-mechanical, material removal process such as laser ablation. Second, in embodiments of the invention, a molded clip structure with a defined soldering area is placed between the two structures within the semiconductor die package. This reduces uncontrolled scattering of the solder joints and connections between the semiconductor die and the heat slug. Third, in embodiments of the invention, the semiconductor die, molded clip and heat slug can use the same solder metallurgy and solder reflow can take place simultaneously. This can result in a method that requires fewer

processing steps and results in a less expensive package. Fourth, embodiments of the invention can be self-aligning, and there is no need to use jigs in the alignment of the semiconductor die, the molded clip and heat-slug. Fifth, in embodiments of the invention, it is possible to expose the outer exterior surface of the clip structure even when using dies of different sizes. Sixth, embodiments of the invention, which include an outer clip structure surface that is exposed through a first molding material, can use the same manufacturing equipment as semiconductor die packages which have an outer clip structure surface overmolded with a molding material. Seventh, the density of a clip structure array can be high and is independent of the leadframe structure pitch.

[0058] FIGS. 1(a), 2(a), and 3 show various views of a semiconductor die package **1A** including a heat slug **2a** at the top of the semiconductor die package **1A**. The semiconductor die package **1A** can be an MLP - type (micro lead package).

[0059] In some embodiments of the invention, the second molding material **6** initially covers an exterior surface of the clip structure in the semiconductor die package **1A**. The second molding material **6** is then removed using a laser ablation process (or the like) to form a second molding material surface **6a**. This exposes the exterior surface of the clip structure in the molded clip (not shown) that is within the semiconductor die package **1A**. The heat slug **2a** is then attached to the exposed exterior surface of the clip structure using a thermally and (optionally) electrically conductive material such as solder. The heat slug **2a** can thereafter be a top source contact for the semiconductor die package **1A**. As shown, the lateral dimensions of the heat slug **2a** can be smaller than the lateral dimensions of the second molding material **6**.

[0060] The semiconductor die package **1A** includes a second molding material **6** under the heat slug **2a**. The second molding material **6** may comprise an epoxy material, or any other suitable electrically insulating material. As shown, the second molding material **6** is under the heat slug **2a**.

[0061] As shown in FIG. 1(a), a number of leads and tie bars may be exposed through the second molding material **6**. The leads may include source terminals **5e**, gate terminals **5g**, as well as drain terminals **5a** (see FIG. 3). The tie bars **5c** in this example are at different sides of the semiconductor die package **1A** as the leads **5a**, **5e**, and **5g**. In this example, the ends of the leads **5a**, **5e**, and **5g** are substantially co-extensive with the lateral surfaces of the

second molding material 6. In other embodiments of the invention, the leads 5a, 5e, and 5g may extend past the lateral surfaces of the second molding material 6.

[0062] FIG. 3 shows a bottom perspective view of the semiconductor die package 1A shown in FIGS. 1(a) and 2(a). As shown in FIG. 3, the bottom surface 5h of the leadframe structure 5 is exposed through the second molding material 6. The bottom surface 5h is also substantially coplanar with the bottom surface of the second molding material 6 as well as the bottom surfaces of the leads 5a, 5e, and 5g. It also occupies a substantial portion (e.g., greater than 50%) of the lateral surface area of the bottom of the semiconductor die package 1A, and is integral with the drain leads 5e. The bottom surface 5h can be mounted directly on to a circuit substrate or the like. It may form a drain connection for a drain region in a semiconductor die in the semiconductor die package 1A.

[0063] FIG. 4 shows a three-dimensional, cutaway top view showing the different components in the semiconductor die package 1A. As shown in FIG. 4, a molded clip structure 3 is between the external heat slug 2a and a semiconductor die 4.

[0064] The molded clip structure 3 may comprise any suitable components and may include any suitable configuration. For example, the molded clip structure 3 may comprise a clip structure 3c, and a first molding material 3m at least partially covering the clip structure 3c. The molded clip structure 3 may also have a thickness of about 0.25 mm (or less), and may also have lateral dimensions of about 4.30 mm by about 5.10 mm (or less).

[0065] The clip structure 3d may have any suitable configuration and/or materials. For example, if the semiconductor die package 1A is a power MOSFET package, the clip structure 3 may comprise a source clip structure 3st and a gate clip structure (not shown), which is electrically isolated from the source clip structure 3st. In the molded clip structure 3, an exterior surface of the source clip structure 3st is exposed through the first molding material 3m. Solder 10 may be used to electrically and mechanically couple the heat slug 2a and the source clip structure 3st. Solder 10 may comprise lead-based (e.g., PbSn) or lead-free solder. It may be deposited as discrete joints, or may be in the form of a layer of solder.

[0066] The semiconductor die 4 may be mounted on a die attach pad 5b of the leadframe structure 5. Solder 7 may be between the semiconductor die 4 and the leadframe structure 5. Tie bars 5c may extend from the die attach pad 5b. The second molding material 6 may cover at least a portion of the semiconductor die 4 and the leadframe structure 5. An

exterior surface **6a** of the second molding material **6** may be substantially coplanar with the exterior surface of the source clip structure **3st**.

[0067] The semiconductor die **4** shown in FIG. 4 also has a passivation layer (e.g., comprising an insulator such as polyimide or silicon oxide) **4a** thereon. Regions of the semiconductor die **4** that are not covered by the die passivation layer **4a** may be covered with solder. Such regions may include a source region covered by a source solder structure **8s** and a gate region covered by a gate solder structure **8g**. The source solder structure **8s** may be coupled to the source clip structure **3st** in the clip structure **3c**, which may in turn be coupled to source solder **9s** on a source lead post **5d**. Source leads **5e** may extend from the source lead post **5d**. The gate solder structure **8g** may be coupled to a gate clip structure in the clip structure **3c**, which may in turn be coupled to gate solder **9g** on the gate lead post **5f**. A gate lead **5g** may extend from the gate lead post **5f**.

[0068] The molded clip **3** can define the solder joints with the semiconductor die **4** in such a manner that it forms less stressful, pre-defined solder joints at the gate region and source region of the semiconductor die **4**. The exposed surfaces of the clip structure **3c** in the molded clip **3** can also define the shapes of the solder joints formed with the source and gate lead posts **5d** and **5f** of the leadframe structure **5**.

[0069] As shown in FIG. 4, in the semiconductor die package **1A**, the stack of components including the heat slug **2a**, the semiconductor die **4**, and the leadframe structure **5**, can form a very efficient heat transfer path, since there is little molding material that would impede the transfer of heat from the semiconductor die **4** to the surrounding environment. Also, the solder that interconnects these components may be the same (or different) and may be reflowed at the same time (or different times).

[0070] FIG. 5(a) shows a top plan view of the semiconductor die package **1A** shown in FIG. 1. FIGS. 5(b)-5(e) show side cross-sectional views along lines A-A (across a gate region), B-B (across source region), C-C (across a gate region), and D-D (across source region), respectively. The elements shown in FIGS. 5(a)-5(e) are described above and their descriptions need not be repeated here. Exemplary dimensions (in mm) are shown in FIGS. 5(b) and 5(c). Embodiments of the invention can have dimensions that are greater than or less than the illustrated dimensions.

[0071] Another semiconductor die package **1B** according to another embodiment of the invention is shown in FIGS. 1(b), 2(b), 3, and 6. The semiconductor die package **1B** has

similar components as in the previously described semiconductor die package **1A** in FIGS. 1(a), 2(a), and 4. Accordingly, descriptions of similar components are not repeated herein.

[0072] However, in the semiconductor die package **1B** in FIG. 1(b), 2(b), and 6, the second molding material **6** has two different portions with two different thicknesses, whereas in the semiconductor die package **1A**, the second molding material **6** has only one thickness at edge regions of the package **1A**. In the semiconductor die package **1B** in FIG. 1(b), these two different thicknesses are exemplified by surface **6a** and surface **6b** in FIGS. 1(b) and 2(b). The thicker portion including surface **6b** has some of the second molding material **6** covering a gate clip structure (not shown) so that it is electrically isolated from the heat slug **2a**, which is mechanically and electrically connected to the source clip structure (not shown).

[0073] Another difference between the semiconductor die package **1A** shown in FIG. 1(a) and the semiconductor die package **1B** shown in FIG. 1(b) is that the heat slug **2a** has a half-etched (or partially etched) region **2ah** to provide space for the higher second molding material surface **6b**. The heat slug **2a** can be etched using any suitable etching process.

[0074] As shown in FIG. 2B, the half-etched heat slug **2a** and the second molding material **6** are cooperatively structured with each other. There is a space between the top surface **6b** of the second molding material **6** and the half-etched part **2ah**. It is noted that in other embodiments, the space need not be present.

[0075] FIG. 7(a) shows a top plan view of the semiconductor die package **2A** shown in FIG. 1(b). FIGS. 7(b)-7(e) show side cross-sectional views along lines A-A, B-B, C-C, and D-D, respectively. The elements shown in FIGS. 7(a)-7(e) are described above. Exemplary dimensions (in mm) are shown in FIGS. 7(b) and 7(c). Embodiments of the invention can have dimensions that are greater than or less than the illustrated dimensions.

[0076] Another semiconductor die package **1C** according to another embodiment of the invention is shown in FIGS. 1(c), 2(c), 3, and 8. The semiconductor die package **1B** has similar components as in the previously described semiconductor die package **1A** in FIGS. 1(a), 2(a), and 4. Accordingly, descriptions of similar components are not repeated herein.

[0077] However, the heat slug **2b** for the semiconductor die package **1C** is designed with peripheral half-etched or stamped regions at its topside for mold locking, and a predefined half-etched area at its bottom correspondingly for gate isolation. Put another way, the heat slug **2b** is thinner above the gate region in the semiconductor die in the

semiconductor die package than above the source region in the semiconductor die in the semiconductor die package. Also, the edges are thinner than central portions of the heat slug **2b** so that the second molding material **6** can lock to the heat slug **2b**. Thus, unlike the previously described packages **1A** and **1B**, in the package **1C**, the second molding material **6** surrounds the edges of the heat slug **2a**.

[0078] FIG. 9(a) shows a top plan view of the semiconductor die package **1A** shown in FIG. 1. FIGS. 9(b)-9(e) show side cross-sectional views along lines A-A, B-B, C-C, and D-D, respectively. The elements shown in FIGS. 9(a)-9(e) are described above. Exemplary dimensions (in mm) are shown in FIGS. 9(b). Embodiments of the invention can have dimensions that are greater than or less than the illustrated dimensions.

[0079] Embodiments of the invention also include novel and unique methods for making semiconductor die packages. For example, as will be described in greater detail below, in some embodiments (e.g., the package **1C** shown in FIG. 1(c)), after assembling the semiconductor die and a stack of metallic components (including a leadframe structure, a clip structure, and a heat slug) together, the combination is molded with the second molding material **6**. After molding, surfaces of the leadframe structure terminals **5a**, **5g** and **5e** are exposed through the second molding material **6** at the bottom of the semiconductor die package. Any overmolded portion at the top of the semiconductor die package can be ablated using a laser to expose the top side surface of the heat slug **2b** down to package surface **6c**. The ablated mold compound and exposed heat slug **2b** form a coplanar surface **6c**.

[0080] Also, in embodiments of the invention, the heat slug and/or the molded clip assembly can be designed to isolate gate current associated with the gate region in the semiconductor die, with source current. This prevents shorting of the gate clip structure in the clip structure with the heat slug, which is coupled to the source region in the semiconductor die. For example, the semiconductor die package **1A** in FIG. 1(a) has a gate isolation feature built into the molded clip structure. In the semiconductor die package **1B** in FIG. 1(b), a gate isolation feature is produced by selective ablation of the second molding material **6b**. The surface **6b** of the second molding material **6** is higher than the surface **6a** of the second molding material. This is done in order to hide the gate contact pad in the gate structure of the clip structure. In the semiconductor die package **1C** in FIG. 1C, a gate isolation feature is designed by making a half-etched metal clearance in the heat slug above the exposed gate contact pad of the molded clip. The second molding material can fill this

space during the final package molding process. This is accomplished by completely molding the stack with the second molding material **6** and then followed by a laser ablation step to partly remove the second molding material **6** while allowing exposure of the heat slug **2b** such that the second molding material on the edges of the heat slug **2a** is coplanar to it.

5 [0081] FIGS. 10(a)-1 to 10(a)-3, 10(b)-1 to 10(b)-3, and 10(c)-1 to 10(c)-3 show process flows for making molded clip structures according to embodiments of the invention. As shown in FIGS. 10(a)-1 to 10(a)-3, 10(b)-1 to 10(b)-3, and 10(c)-1 to 10(c)-3, a clip structure **3c** is first obtained in embodiments of the invention. Each clip structure **3c** may include a gate clip structure **3gt** and a source clip structure **3st**. The clip structures **3c** in
10 FIGS. 10(a)-1 to 10(a)-3, 10(b)-1 to 10(b)-3, and 10(c)-1 to 10(c)-3 are respectively used in the molded clip structures **3-1**, **3-2**, and **3-3** shown in FIGS. 11(a)-11(c).

[0082] In FIGS. 10(a)-2, 10(b)-2, and 10(c)-2, the clip structures **3c** are then molded with the first molding material **3ao**. In FIG. 10(a)-2, the clip structure **3c** is overmolded with the first molding material **3ao** at its top surface, while in FIGS. 10(b)-2 and 10(c)-2, the clip
15 structures **3c** are not overmolded at their top surfaces.

[0083] Portions of the first molding material of the clip structures **3c** are then laser ablated at their bottom surfaces (see surface **3b** in FIGS. 11(a)-11(c)) so that the gate and source contact pads **3gb** and **3sb** protrude from the bottom surfaces of the first molding material.

20 [0084] Then, as shown in FIGS. 10(a)-3, 10(b)-3, and 10(c)-3, the arrays of molded clip structures are then singulated by a cutting process such as sawing or laser cutting. The resulting molded clip structures **3-1**, **3-2**, and **3-3** are shown in FIGS. 11(a)-11(c).

[0085] FIG. 11(a) shows a molded clip structure **3-1** with a bottom first molding material surface **3b** exposing the clip gate and source contact pads **3gb**, **3sb**. These pads **3gb**,
25 **3sb** can be used for connections to the semiconductor die and leadframe structure in the semiconductor die package. Top surface **3ao** of the first molding material **3m** covers (i.e., overmolds) an outer surface of the clip structure. This molded clip structure **3-1** can be formed by placing tape against surfaces of the clip structure **3c** that are not to be covered with the first molding material **3m**.

30 [0086] FIG. 11(b) shows a molded clip structure **3-2**. Top gate and source contact pads **3gt** and **3st** are exposed by and are substantially coplanar with the top surface **3ae** of the

molding material **3m**. Bottom contact pads **3gb** and **3sb** are exposed by the surface **3b** of the first molding material **3m**. The pads **3gb** and **3sb** may be exposed through, protrude from, and/or substantially coplanar with the surface **3b** of the first molding material **3m**.

[0087] The molded clip structure **3-2** can be produced by fully clamping the clip structure **3c** during the molding process. Molded clip structure **3-2** does not require the use of a tape assisted molding process. As explained above, the top exposed source pad **3st** can be used for a heat slug connection during the assembly of the semiconductor die package.

[0088] FIG. 11(c) shows a molded clip structure **3-3** with a first molding material **3m** having two opposing surfaces **3ae** and **3b** that expose clip structure surfaces. Top surface **3ae** exposes source contact pad **3st** for a heat slug connection. The gate contact pad in the clip structure is not exposed by the top surface **3ae** as it is half-etched at its topside. Bottom surface **3b** exposes gate and source contact pads **3gb**, **3sb** for connection to a semiconductor die and leadframe structure connections. Molded clip structure **3-3** may or may not use a leadframe tape during clip structure molding.

[0089] FIG. 12 shows an array of clip structures **3c** connected to one another by half-etched tie bars **3t**. The bulk of the clip structure array is half-etched metal **3h**. The full metal areas are the contact pads **3gb** and **3sb** to be used for soldering connections with previously described semiconductor die **4** and the leadframe structure **5** during final package assembly. Exemplary dimensions (in mm) are shown in FIG. 12. Embodiments of the invention can have dimensions that are greater than or less than the illustrated dimensions.

[0090] Referring to FIGS. 11(b) and 11(c), the molding process for the molded clips **3-2** and **3-3** can involve full clamping of the full metal contact areas **3gb** and **3sb** exposing them at the bottom surface **3b**. The other side of the clip structure **3c** can be exposed by the top surface **3ae** of the molding material **3m** whereby it will be used for a soldering connection with the previously described heat slug. The half-etched areas can be filled in with the first molding material **3m**.

[0091] Referring to FIG. 11(a), the molding process for molded clip **3-1** can include clamping of the array periphery to allow an overmold on the clip structure to form top surface **3ao**. The clip structure **3c** can use tape in the overmolding process. The thickness of the overmolded first molding material **3m** could be greater or less than 0.1 mm.

[0092] With respect to FIG. 13, the protruding gate and source contact pads **3gb** and **3sb** can promote vertical filleting of the solder **8g** and **8s** during the clip structure attach process. The molding material **3m** that is removed during the laser ablation process can provide space for the second molding material **6** during encapsulation of the components of the semiconductor die package.

[0093] FIGS. 14(a)-14(c) show top and bottom perspective views of different heat slug embodiments for use with semiconductor die packages **1A**, **1B**, and **1C** shown in FIGS. 15(a)-15(c).

[0094] The heat slug **2a** in FIG. 14(a) resembles a flat plate with lateral dimensions slightly less than the lateral dimensions of the semiconductor die package **1A** in FIG. 15(a). The heat slug **2a** may be coupled to solder **10**. Also, the molded clip structure **3-1** has a gate clip structure covered with the first molding material.

[0095] The heat slug **2a** in FIG. 14(b) has a partially etched region **2ah** and an unetched region. The etched region **2ah** may be cooperatively structured with a portion of the second molding material of the semiconductor die package **1B**, which includes surface **6b**. Surface **6b** is higher than surface **6a**. The heat slug **2a** may be coupled to solder **10**.

[0096] Also, the molded clip structure **3-2** has a gate clip structure covered with the second molding material **6** so that the gate clip structure is electrically isolated from the heat slug **2a**. The second molding material **6** is selectively laser ablated and surface **6b** is not laser ablated so that the second molding material **6** is removed above the solder **10** and above the surface **6a**.

[0097] The heat slug **2b** in FIG. 14(c) has a number of partially etched regions **2ah**, **2ah'** and an unetched region. As shown in FIG. 15(c), the first etched region **2ah** may be disposed over and spaced from a gate contact pad **3gt** so that the gate contact pad **3gt** and the first etched region **2ah** are physically separated from each other and are not electrically coupled together. When the second molding material (not shown) is molded around the components shown in FIG. 15(c), it will fill the space between the first etched region **2ah** and the gate contact pad **3gt**. A second etched region **2ah'** may be used as a mold locking feature to allow the second molding material to lock to the heat slug **2b**. The first and second etched regions **2ah**, **2ah'** are at opposite sides of the heat slug **2a**.

[0098] The methods according to embodiments of the invention can include stacking package components and sandwiching a silicon die between conductive components (e.g., a leadframe structure, a clip structure, and a heat slug). The methods may also include some of the following processes: solder screen printing, solder dispensing (or an equivalent solder application process), pick and place assembly of a die, clip molding and heat slug attachment. Specific details regarding methods according to embodiments of the invention are described below with reference to FIGS. 16, 17, and 18.

[0099] After full assembly of the semiconductor die and the stack of metal components, the resulting semiconductor die package precursor is then over-molded with the second molding material. No compressive force is applied to the stack of components during the molding process. The molding material covering the surface of the clip structure is then removed to expose the surface, which may correspond to a top source contact pad of the clip structure (see the packages 1A and 1B in FIGS. 1(a) and 1(b)).

[0100] Alternatively, in another embodiment, the heat slug is covered with the second molding material. It can be thinned down to expose the surface of the heat slug (see the package 1C in FIG. 1(c)). In embodiments of the invention, the package thinning process can be performed using laser ablation. This prevents the introduction of mechanical stress into the formed semiconductor die package. The laser ablation process could also be applied in a selective manner (e.g., to produce the package in FIG. 1(b)) or in a full scan of package top surface (e.g., to produce the package shown in FIG. 1(a)). Selective ablation of the molding material in the semiconductor die package 1B can isolate the gate clip structure from electrical contact with the heat slug (which is electrically coupled to the source clip structure).

[0101] One embodiment of the invention is directed to a method comprising: a) attaching a semiconductor die to a die attach pad of a leadframe structure; b) obtaining a molded clip structure comprising a clip structure and a first molding material covering at least a portion of the clip structure, and exposing an outer surface of the clip structure to the semiconductor die; c) molding a second molding material around at least a portion of the semiconductor die and the leadframe structure; and d) attaching a heat slug to the exposed outer surface of the clip structure using a thermally conductive material.

[0102] FIGS. 16(a)-16(h) show perspective views of precursors that are formed during the formation of a semiconductor die package according to an embodiment of the invention.

[0103] In FIG. 16(a), solder 7 is deposited on the die attach surface of the leadframe structure 5. Solder can be deposited using any suitable solder paste printing process. In other embodiments, a conductive epoxy could be used instead of solder.

[0104] As shown in FIG. 16(b), a semiconductor die 4 is attached to the die attach region of the leadframe structure 5. The semiconductor die 4 includes a passivation layer 4a.

[0105] As shown in FIG. 16(c), additional solder 9s, 9g is deposited on the source and gate lead posts 5d, 5f of the leadframe structure 5. Additional solder 8s, 8g, is also deposited on the source and gate regions of the semiconductor die 4. Then, the molded clip structure 3 is attached to the top surface of the semiconductor die 4. A source contact 3sb at the bottom of the molded clip structure 3 can couple to the source solder 8s, while a gate contact 3gb at the bottom of the clip structure 3 can couple to the gate solder 8g. Other source and gate contacts in the clip structure 3 can couple to the solder 9s, 9g.

[0106] As shown in FIG. 16(d), the molded clip structure 3 is then attached to the leadframe structure 5 and the semiconductor die 4.

[0107] As shown in FIG. 16(e), a second molding material 6 is formed over at least part of the leadframe structure 5 and the semiconductor die 4.

[0108] As shown in FIG. 16(f), at least part of the second molding material 6 is removed to expose the top surface of the clip structure 3. A laser ablation process can be used to remove the second molding material 6. In this and in other embodiments, suitable conditions for laser ablation may be determined by those of skill in the art.

[0109] As shown in FIG. 16(g), solder 10 is deposited on the exposed source contact pad 3st. The heat slug 2a is attached to the exposed source contact pad 3st via the solder 10.

[0110] As shown in FIG. 16(h), a reflow process is then performed. In this and in other embodiments, the reflow process may reflow some or all of the solder previously used to attach the components of the package together. A singulation process, a solder plating process, and a test/mark/tape and reel process are then performed.

[0111] FIGS. 17(a)-17(h) show perspective views of precursors that are formed during the formation of a semiconductor die package according to an embodiment of the invention.

[0112] In FIG. 17(a), solder 7 is deposited on the die attach surface of the leadframe structure 5. Solder can be deposited using any suitable solder paste printing process. In other embodiments, a conductive epoxy could be used instead of solder.

[0113] As shown in FIG. 17(b), a semiconductor die 4 is attached to the die attach region of the leadframe structure 5. The semiconductor die 4 includes a passivation layer 4a.

[0114] As shown in FIG. 17(c), additional solder is 9s, 9g is deposited on the source and gate lead posts 5d, 5f of the leadframe structure 5. Additional solder 8s, 8g, is also deposited on the source and gate regions of the semiconductor die 4. Then, the molded clip structure 3 is attached to the top surface of the semiconductor die 4. A source contact 3sb at the bottom of the molded clip structure 3 can couple to the source solder 8s, while a gate contact 3gb at the bottom of the clip structure 3 can couple to the gate solder 8g. Other source and gate contacts in the clip structure 3 can couple to the solder 9s, 9g.

[0115] As shown in FIG. 17(d), the molded clip structure 3 is then attached to the leadframe structure 5 and the semiconductor die 4.

[0116] As shown in FIG. 17(e), a second molding material 6 is formed over at least part of the leadframe structure 5 and the semiconductor die 4.

[0117] As shown in FIG. 17(f), at least part of the second molding material 6 is removed to expose the top surface of the clip structure 3. A laser ablation process can be used to remove the second molding material 6.

[0118] As shown in FIG. 17(g), solder 10 is deposited on the exposed source contact pad 3st. The heat slug 2a is attached to the exposed source contact pad 3st via the solder 10.

[0119] As shown in FIG. 17(h), a reflow process is then performed. A singulation process, a solder plating process, and a test/mark/tape and reel process are then performed.

[0120] Referring to FIG. 18, in another manufacturing process flow for the semiconductor die package 1-C, the heat slug 2b can be attached to the molded clip structure 3 using a high melting solder like 95Pb5Sn before a clip sawing process is performed. FIGS.

18(a)-18(g) show perspective views of precursors that are formed during the formation of a semiconductor die package according to an embodiment of the invention.

[0121] In FIG. 18(a), solder 7 is deposited on the die attach surface of the leadframe structure 5. Solder can be deposited using any suitable solder paste printing process. In other
5 embodiments, a conductive epoxy could be used instead of solder.

[0122] As shown in FIG. 18(b), a semiconductor die 4 is attached to the die attach region of the leadframe structure 5. The semiconductor die 4 includes a passivation layer 4a.

[0123] As shown in FIG. 18(c), additional solder 9s, 9g is deposited on the source and gate lead posts 5d, 5f of the leadframe structure 5. Additional solder 8s, 8g, is also deposited
10 on the source and gate regions of the semiconductor die 4. Then, the molded clip structure 3 is attached to the top surface of the semiconductor die 4. A source contact 3sb at the bottom of the molded clip structure 3 can couple to the source solder 8s, while a gate contact 3gb at the bottom of the clip structure 3 can couple to the gate solder 8g. Other source and gate contacts in the clip structure 3 can couple to the solder 9s, 9g.

15 [0124] As shown in FIG. 18(d), the molded clip structure 3 is then attached to the leadframe structure 5 and the semiconductor die 4.

[0125] As shown in FIG. 18(e), a reflow process is performed to secure the molded clip structure 2b to the semiconductor die 4.

[0126] As shown in FIG. 18(f), a second molding material 6 is formed over at least
20 part of the leadframe structure 5 and the semiconductor die 4.

[0127] As shown in FIG. 18(g), at least part of the second molding material 6 is removed to expose the top surface of the heat slug 2b. A laser ablation process can be used to remove the second molding material 6.

[0128] FIG. 19(a) shows another semiconductor die package 1D according to an
25 embodiment of the invention. The inner assembly of the semiconductor die package 1D comprises a molded clip structure 3 where through-hole slots 3s are designed into the clip structure so that the second molding material 6 can fill the slots 3s. This molded clip structure 3 could use, but does not require the use of a laser ablation process to remove molding material at a bottom surface. The slots 3s in the molded clip structure 3 will allow
30 vertical locking of the mold compound 6 during final package assembly. It also creates

vertical filleting of the solder **8g**, **8s** that will improve the inner solder joint reliability of the product.

[0129] The heat slug **2b** also has one or more slots **2s** to match the one or more molded clip structure slots **3s** for effective mold filling and mold locking. The slots in these structures may be aligned or may at least overlap. The heat slug **2b** can be a stamped metal with swaged or etched edges **2w** for mold locking during final package molding. The heat slug **2b** also can be exposed through the second molding material **6** using a non-contact ablation process.

[0130] The slots **2s**, **2g** are examples of apertures, and such apertures may be elongated slots, regular holes, etc. Such apertures may also have any suitable dimensions. They may occupy less than about 50% of the lateral surface area of the clip structures.

[0131] Referring to FIG. 19(b), in the absence of a heat slug **2b**, the inner package assembly can be a functional product including a molded clip structure. The illustrated package (due to the use of the slots) has good solder joints due to the vertical filleting of the solder **8g**, **8s** with the vertical walls of the molded clip slot **3s**. This provides for better electrical and mechanical contact between the die **4** and the source and gate clip structures. The package also has good mold locking properties.

[0132] In both package assemblies, the through-hole slots **3s** in the molded clip structure **3** can also serve as a venting window for flux during solder reflow and at the same time can provide a viewing window for visual inspection during manufacturing assembly.

[0133] Referring to FIGS. 19(c) and 19(d) (which shows the underside of the molded clip structure **3**), in another semiconductor die package according to an embodiment of the invention, the molded clip structure **3** and the heat slug **2b** are designed without the source through-hole slot to maximize the heat-sinking area of the clip structure. The second molding material fills the space between the semiconductor die **4** and the molded clip structure **3**. The space may include the open half-etched area **3h** at the underside of the clip structure. The half-etched area **3h** is defined in part by source pads **3x**. The source pads **3x** have areas corresponding to source region contact pads on a semiconductor die.

[0134] FIGS. 19(e)-19(g) show arrays of clip structures and arrays of molded clip structures and illustrate a molded dam feature that is present in the clip structures.

[0135] FIG. 19(e) shows a bottom view of an array of clip structures 208. An integrally formed mold dam structure 208 is present in the array of clip structures 208, as well as in each of the clip structures in the array of clip structures 208. The area defined by the mold dam structure 206 will not be flooded with the first molding material during the process of molding the first molding material around the array of clip structures 208. Because the mold dam structures are designed in the clip structures in the array of clip structures 208, the solid metal mold dam structures will prevent the molding material from filling-in the enclosed spaces.

[0136] FIG. 19(f) shows a molded clip structure array 208. The source contact pads of the molded clip will form an integral part of the mold dam structures 206. All of the metal area shown are in direct contact with the mold tool during the clip structure molding process.

[0137] FIG. 19(g) shows a top perspective view of a molded clip structure array 208.

[0138] Additional advantages of embodiments of the invention include a simplified assembly construction and better manufacturability. Heat slug attachment could also be performed while package precursors are still in matrix leadframe or substrate.

[0139] Embodiments of the invention have a number of additional advantages. First, major surfaces of the clip structure and a leadframe structure are exposed through molding material in the semiconductor die packages according to embodiments of the invention. Second, the components in the semiconductor die package are stacked in a way that minimizes stress. Third, the top exterior surface of the clip structure can be exposed through a first molding material using a process such as a laser ablation process. Fourth, embodiments of the invention add a heat slug in collection of stacked components in the semiconductor die package. Fifth, using heat slugs with different thicknesses allows for flexibility when manufacturing semiconductor die packages with exposed exterior clip and leadframe structure surfaces. Fifth, depending upon the die lay-out configuration, the heat slug design can be configured such that the outer exposed contact pad dimension is universal. Sixth, the heat slug will provide for an electrical and thermal conductive path to the top of the package, but will not add stress to the stack assembly as it is attached to the top-ablated molded package as a conductive external appendage to the package. The manufacturing process before heat slug attach can be made common with the over-molded version of the package. It is noted that embodiments of the invention may have some or all of the above-noted advantages.

[0140] Any of the above-described packages can be used in an electrical assembly, which may include a package mounted to a circuit substrate such as a circuit board. Such assemblies may also be used in systems such as server computers, cell phones, etc.

5 [0141] Any one or more features of one or more embodiments may be combined with one or more features of any other embodiment without departing from the scope of the invention. For example, the clip structure shown in FIG. 19(d) could be used in any of the previously described embodiments.

[0142] Any recitation of "a", "an" or "the" is intended to mean "one or more" unless specifically indicated to the contrary.

10 [0143] The above description is illustrative but not restrictive. Many variations of the invention will become apparent to those skilled in the art upon review of the disclosure. The scope of the invention should, therefore, be determined not with reference to the above description, but instead should be determined with reference to the pending claims along with their full scope or equivalents.

WHAT IS CLAIMED IS:

1 1. A semiconductor die package comprising:
2 a semiconductor die;
3 a molded clip structure comprising a clip structure and a first molding material
4 covering at least a portion of the clip structure, and exposing an outer surface of the clip
5 structure wherein the clip structure is electrically coupled to the semiconductor die;
6 a leadframe structure comprising a die attach pad and a plurality of leads
7 extending from the die attach pad, wherein the semiconductor die is on the die attach pad of
8 the leadframe structure;
9 a second molding material covering at least a portion of the semiconductor die
10 and the leadframe structure;
11 a heat slug; and
12 a thermally conductive material coupling the heat slug to the exposed surface
13 of the clip structure.

1 2. The semiconductor die package of claim 1 wherein the semiconductor
2 die comprises a first surface comprising an input region and a second surface comprising an
3 output region, the input region being coupled to the clip structure and the output region
4 coupled to the die attach pad of the leadframe structure.

1 3. The semiconductor die package of claim 1 wherein the semiconductor
2 die comprises a first surface comprising a source region and a gate region and a second
3 surface comprising a drain region, the gate region and the drain region are coupled to the clip
4 structure and the drain region is coupled to the die attach pad of the leadframe structure.

1 4. The semiconductor die package of claim 3 wherein the semiconductor
2 die comprises a power MOSFET.

1 5. The semiconductor die package of claim 3 wherein the clip structure
2 comprises a gate clip structure and a source clip structure, wherein the gate clip structure is
3 coupled to the gate region in the semiconductor die and the source clip structure is coupled to
4 the source region in the semiconductor die.

1 6. The semiconductor die package of claim 5 wherein the source clip
2 structure comprises an aperture.

1 7. The semiconductor die package of claim 5 wherein the gate clip
2 structure comprises an aperture.

1 8. The semiconductor die package of claim 7 comprising solder coupling
2 the gate clip structure and the gate region.

1 9. The semiconductor die package of claim 1 wherein the heat slug
2 comprises a first portion having a first thickness and a second portion comprising a second
3 thickness, wherein the first thickness and the second thickness are different.

1 10. The semiconductor die package of claim 1 further comprising an
2 aperture in the heat slug.

1 11. A system comprising the semiconductor die package of claim 1.

1 12. A method comprising:

2 a) attaching a semiconductor die to a die attach pad of a leadframe
3 structure;

4 b) attaching a molded clip structure comprising a clip structure and a first
5 molding material covering at least a portion of the clip structure, and exposing an outer
6 surface of the clip structure to the semiconductor die;

7 c) molding a second molding material around at least a portion of the
8 semiconductor die and the leadframe structure; and

9 d) attaching a heat slug to the exposed outer surface of the clip structure
10 using a thermally conductive material.

1 13. The method of claim 12 wherein the semiconductor die comprises a
2 first surface comprising an input region and a second surface comprising an output region.

1 14. The method of claim 12 wherein d) is performed before c).

1 15. The method of claim 13 wherein the second molding material covers at
2 least the heat slug.

1 16. The method of claim 12 wherein a), b), c), and d) are performed in
2 order.

1 17. The method of claim 12 wherein the heat slug comprises an aperture.

1 18. The method of claim 17 wherein the semiconductor die comprises a
2 first surface comprising an input region and a second surface comprising an output region,
3 wherein the first surface is opposite to the second surface.

1 19. The method of claim 12 wherein the second molding material exposes
2 an exterior surface of the leadframe structure.

1 20. The method of claim 12 wherein a semiconductor die package is
2 formed after performing steps a), b), c), and d), and wherein the method further comprises:
3 attaching the semiconductor die package to a circuit substrate.

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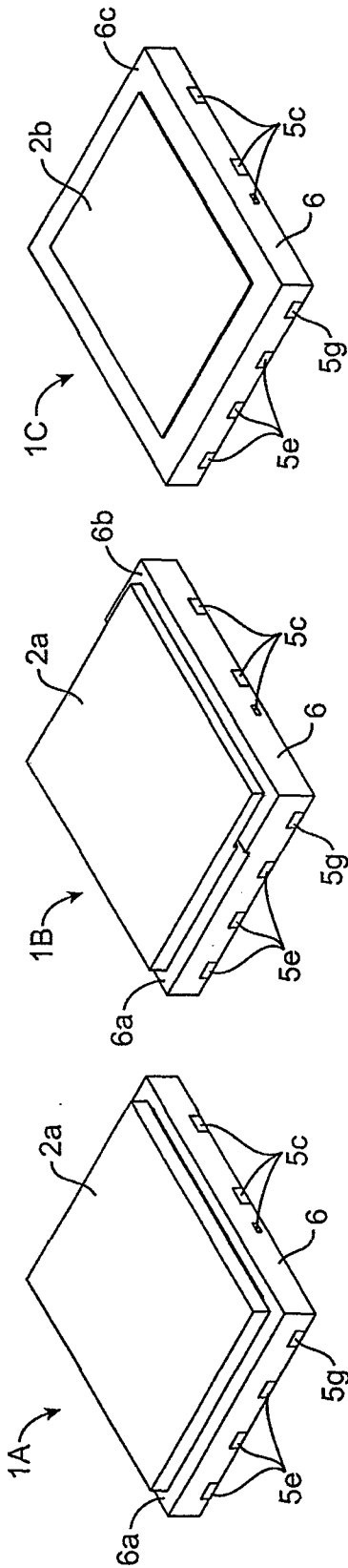


FIG. 1(a)

FIG. 1(b)

FIG. 1(c)

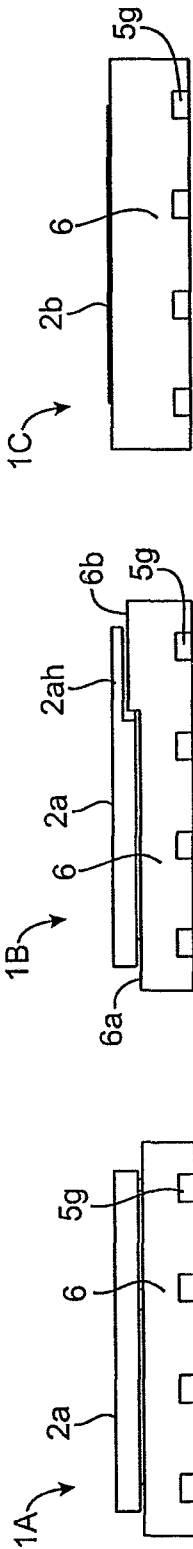


FIG. 2(a)

FIG. 2(b)

FIG. 2(c)

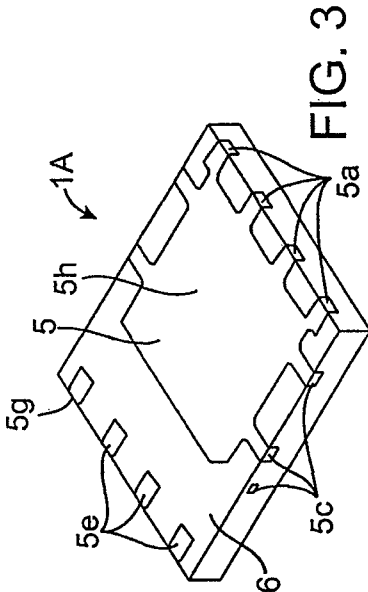


FIG. 3

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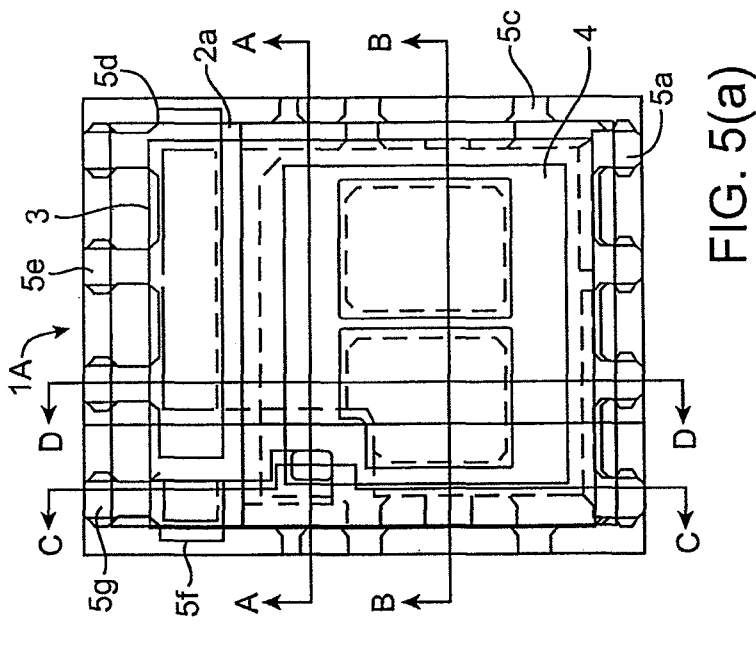


FIG. 5(a)

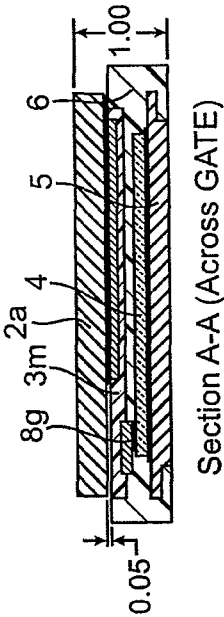
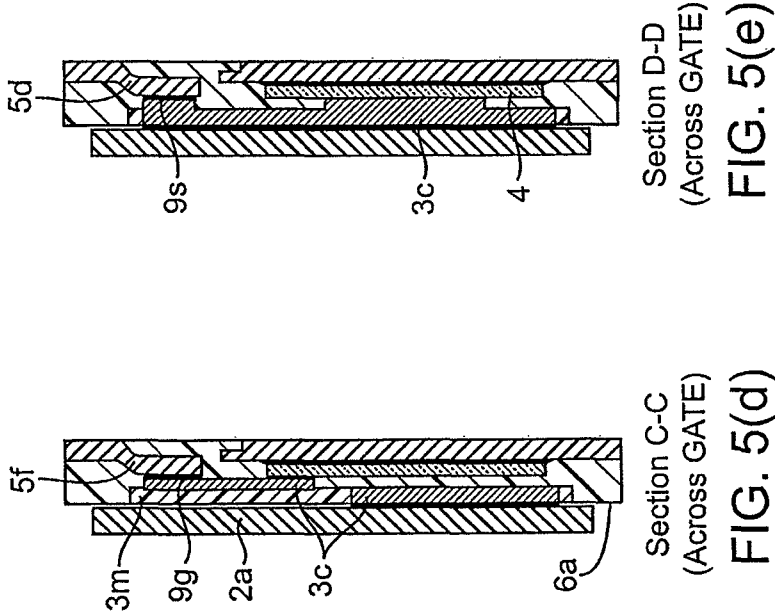


FIG. 5(b)



Section C-C
(Across GATE)
FIG. 5(d)

Section D-D
(Across GATE)
FIG. 5(e)

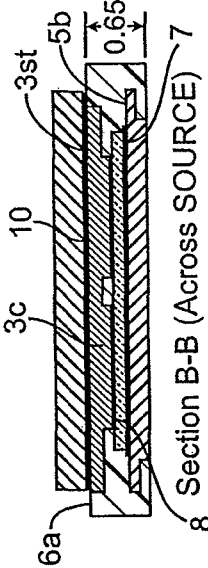


FIG. 5(c)

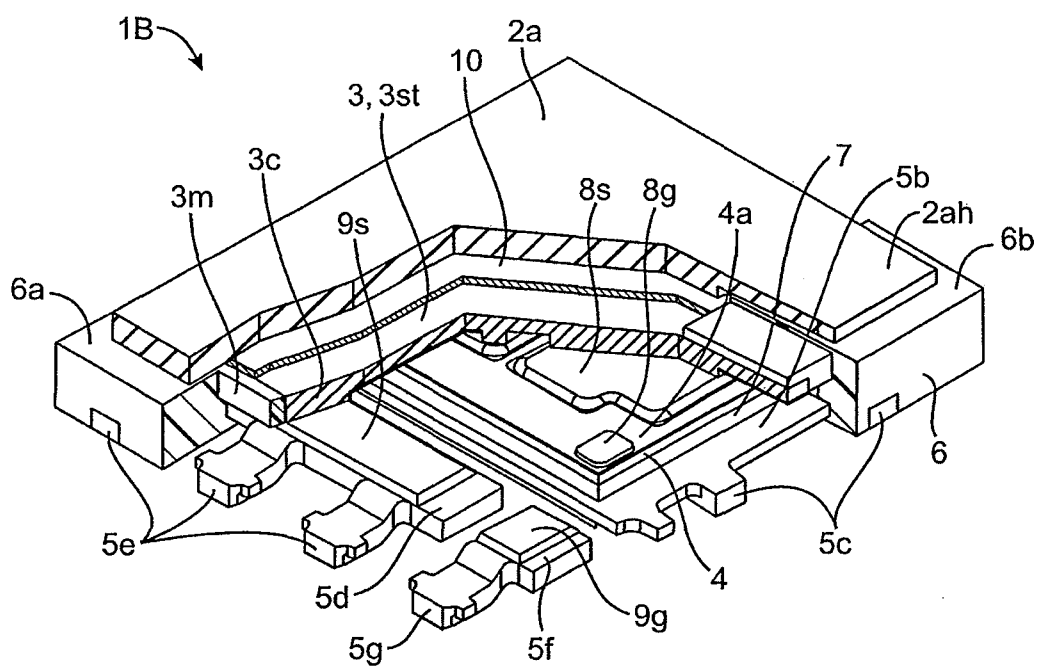


FIG. 6

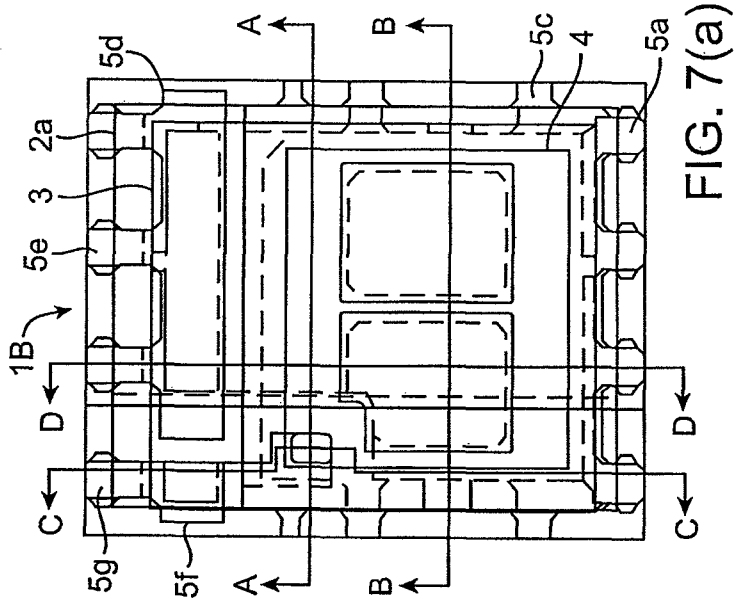
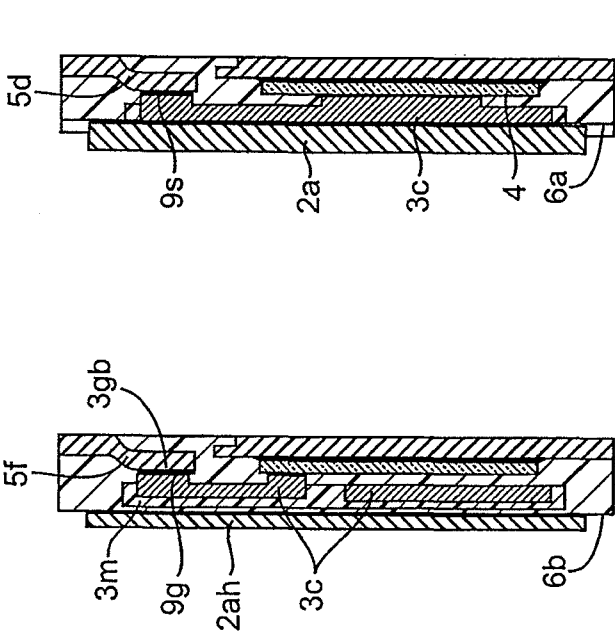


FIG. 7(a)

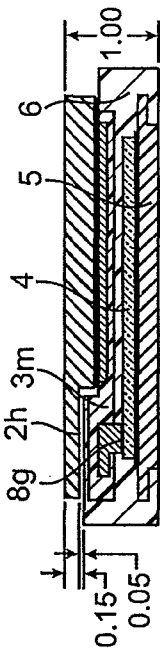


Section C-C
(Across GATE)

FIG. 7(d)

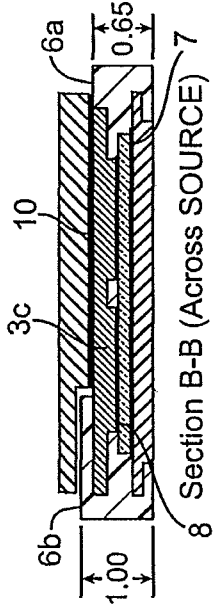
Section D-D
(Across GATE)

FIG. 7(e)



Section A-A (Across GATE)

FIG. 7(b)



Section B-B (Across SOURCE)

FIG. 7(c)

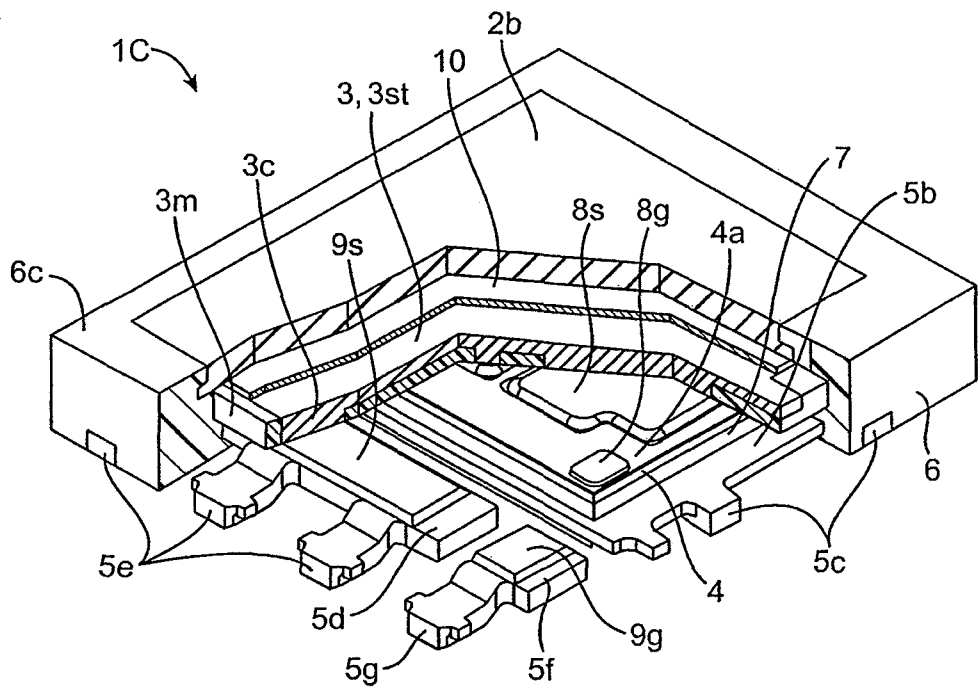


FIG. 8

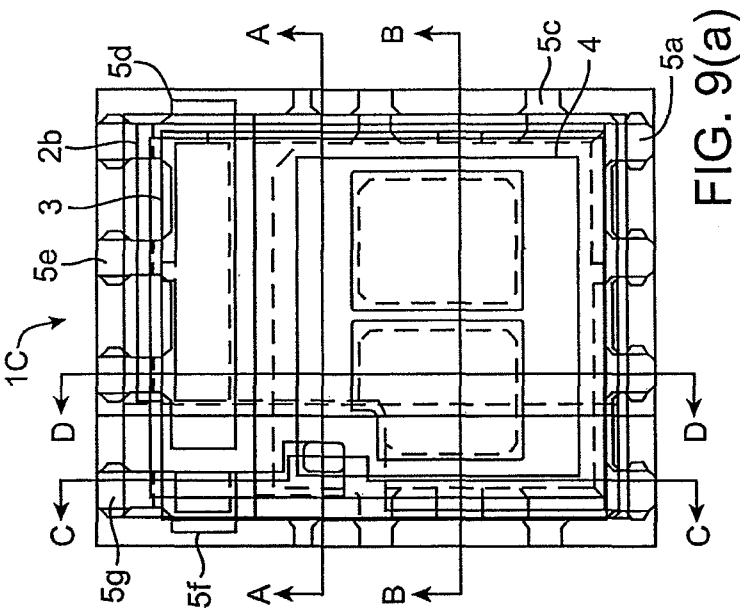
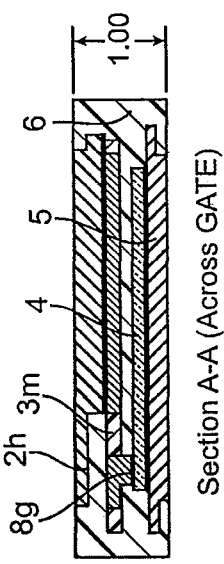
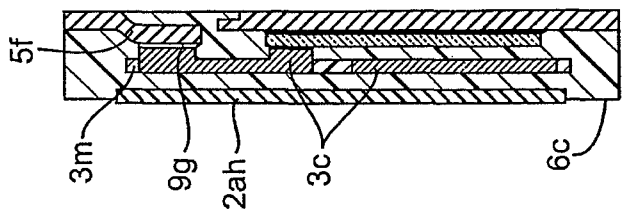


FIG. 9(a)



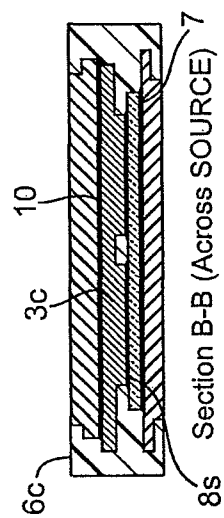
Section A-A (Across GATE)

FIG. 9(b)



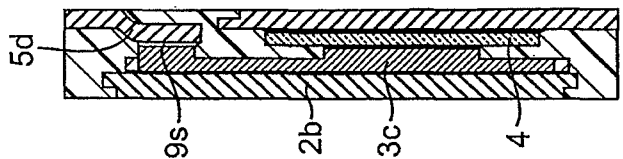
Section C-C
(Across GATE)

FIG. 9(d)



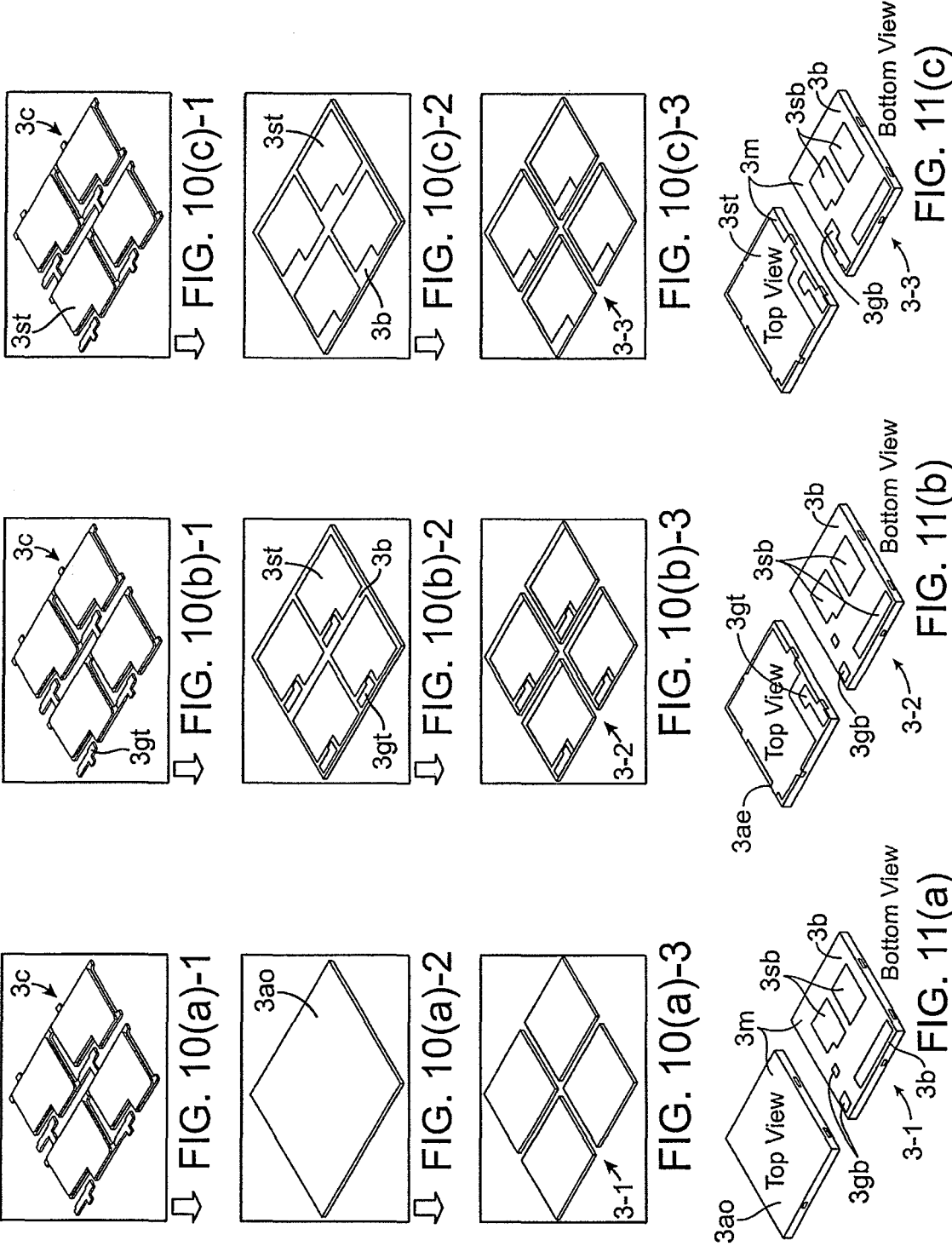
Section B-B (Across SOURCE)

FIG. 9(c)



Section D-D
(Across GATE)

FIG. 9(e)



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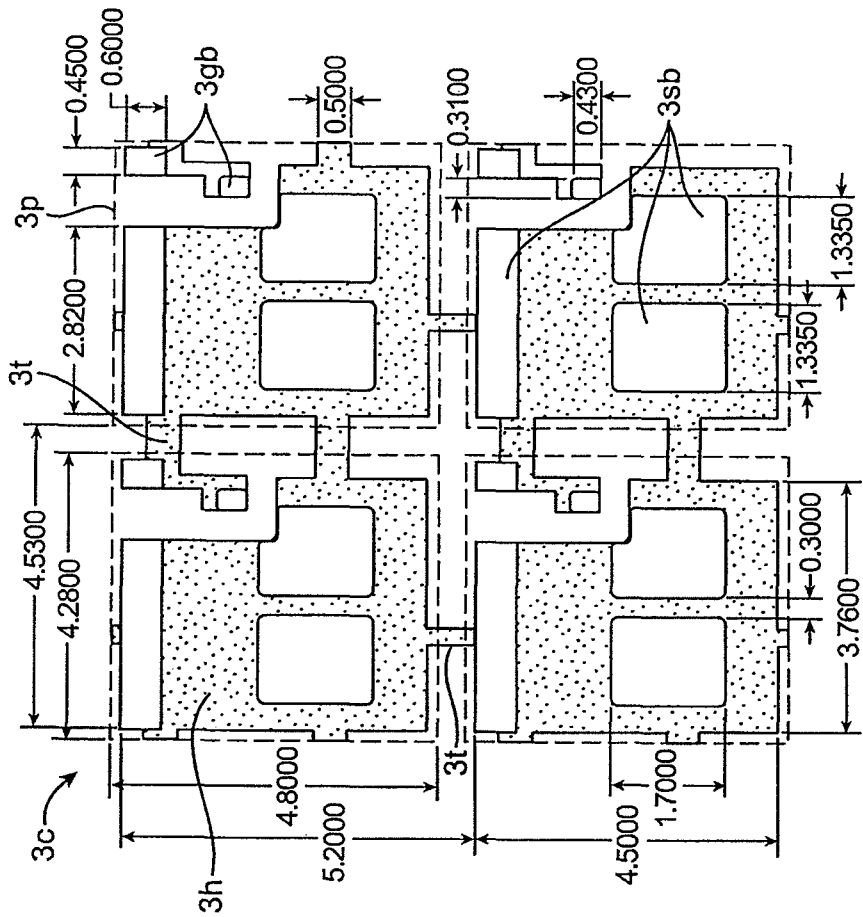


FIG. 12

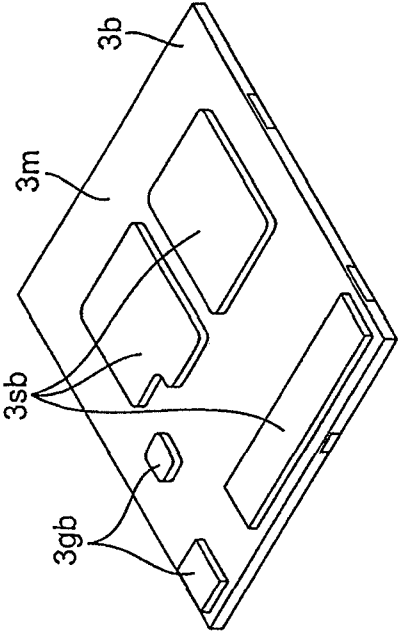
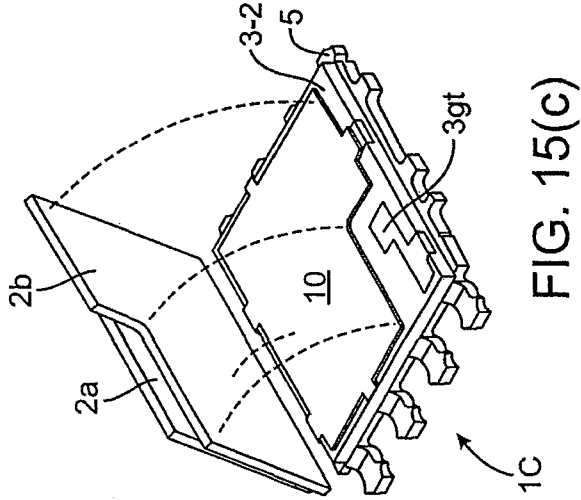
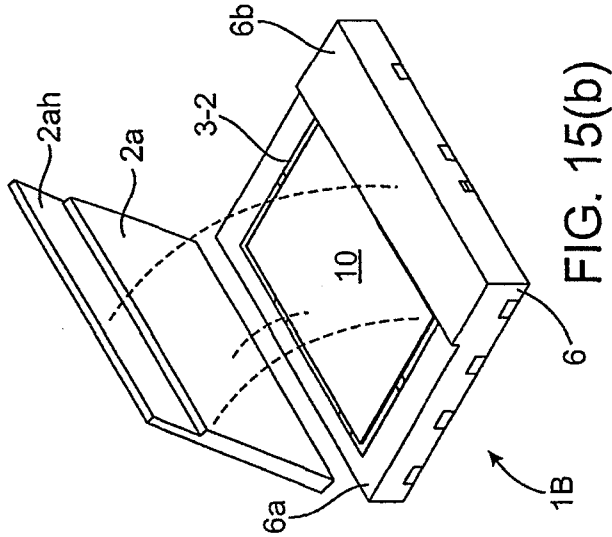
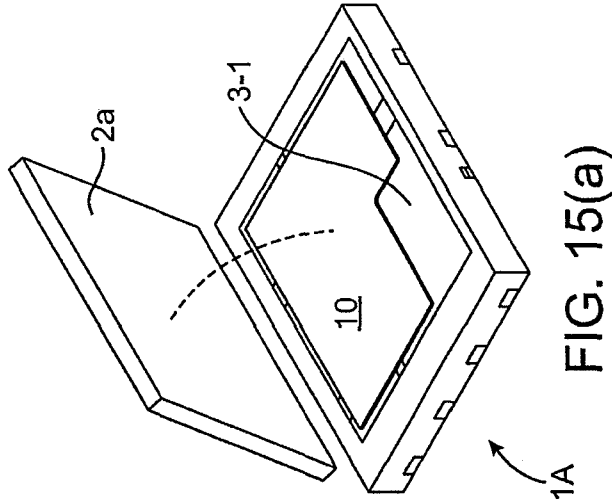
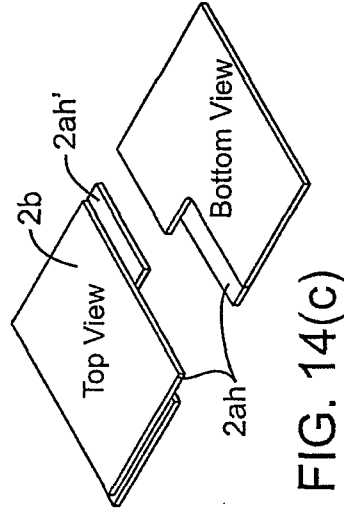
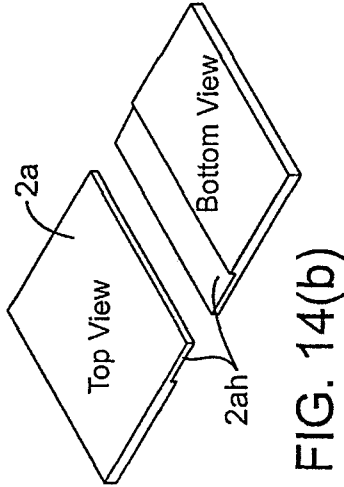
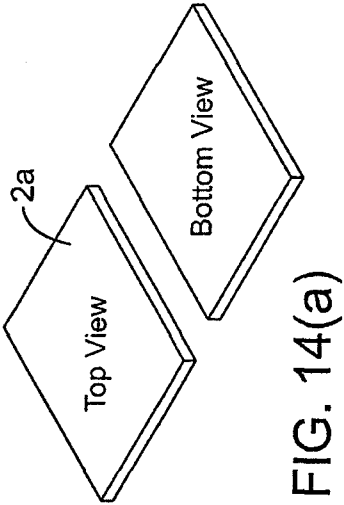


FIG. 13

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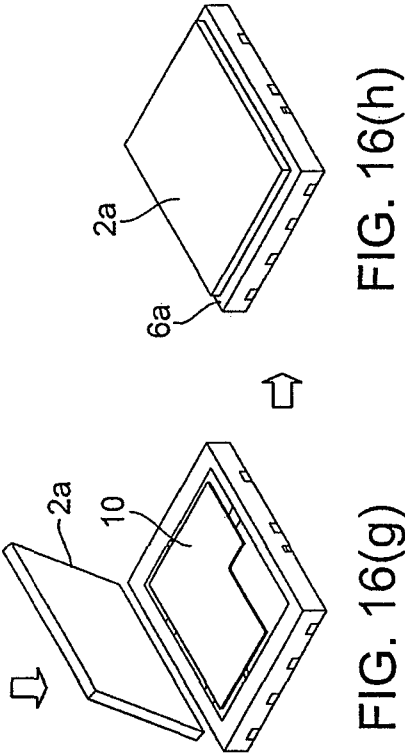
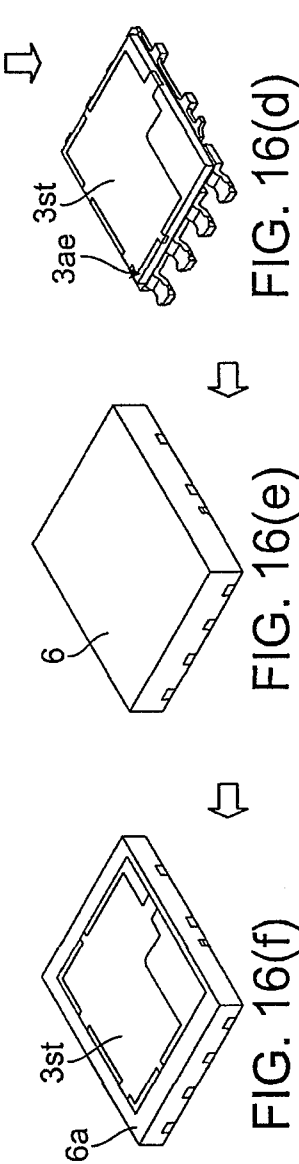
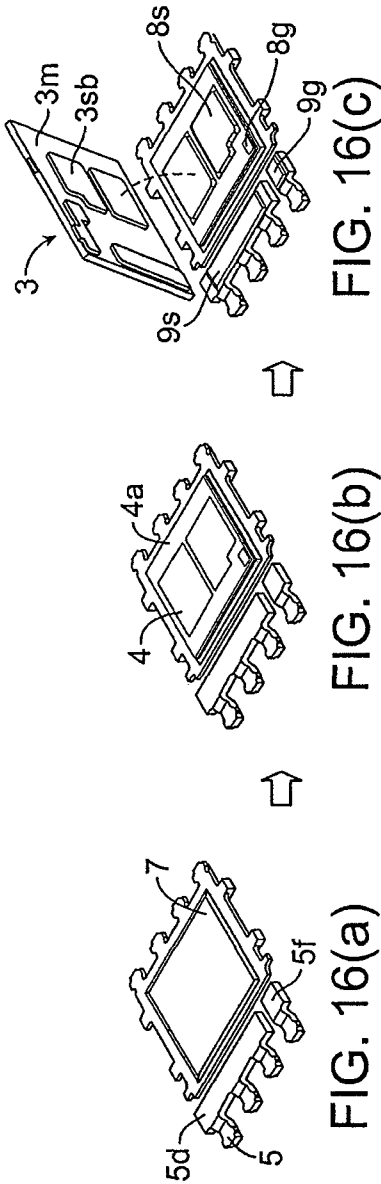
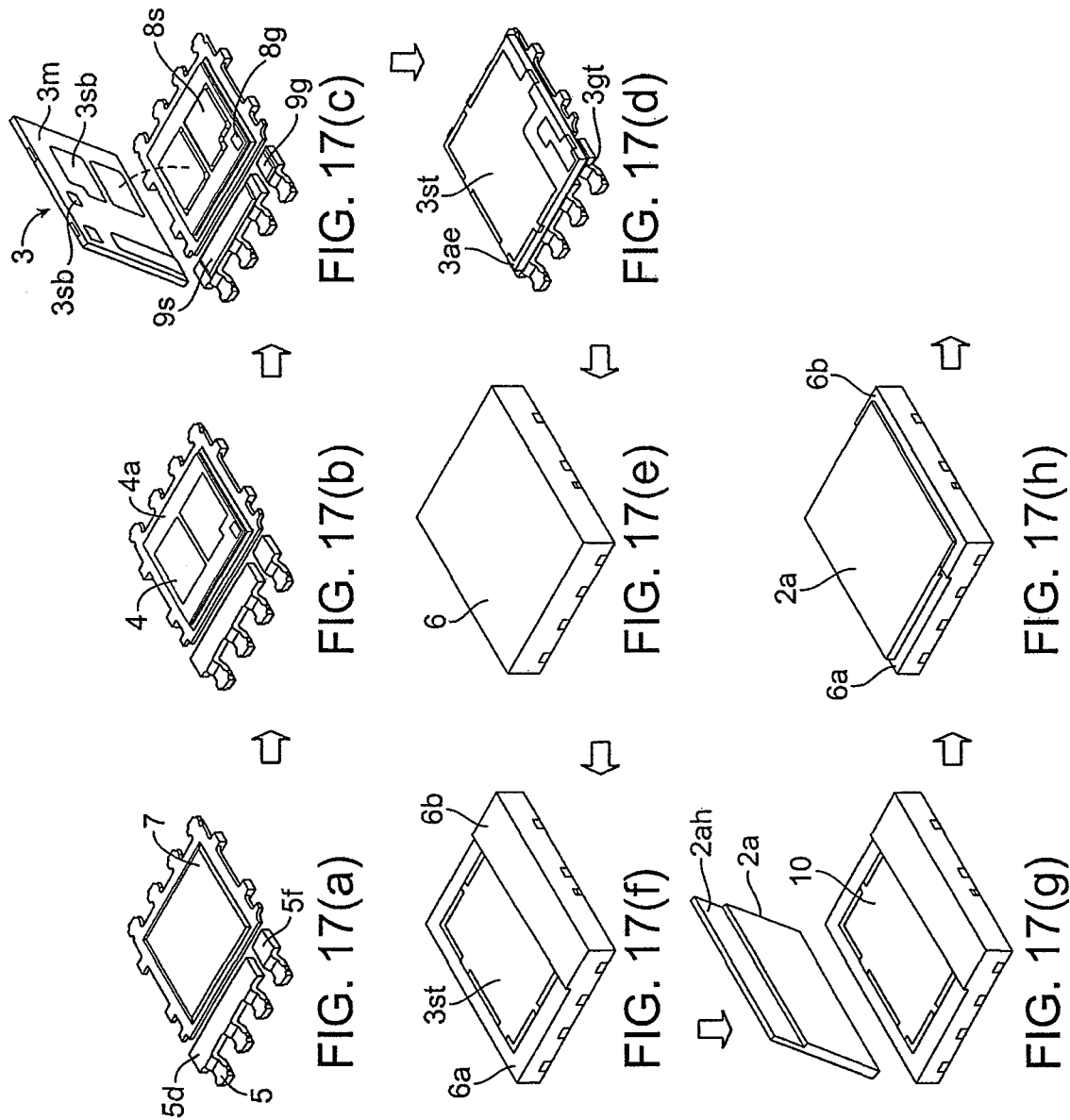
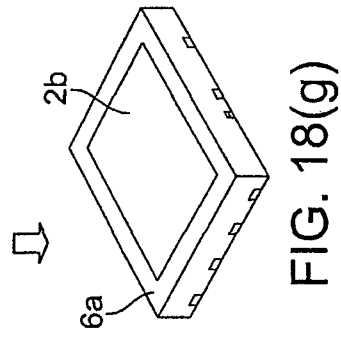
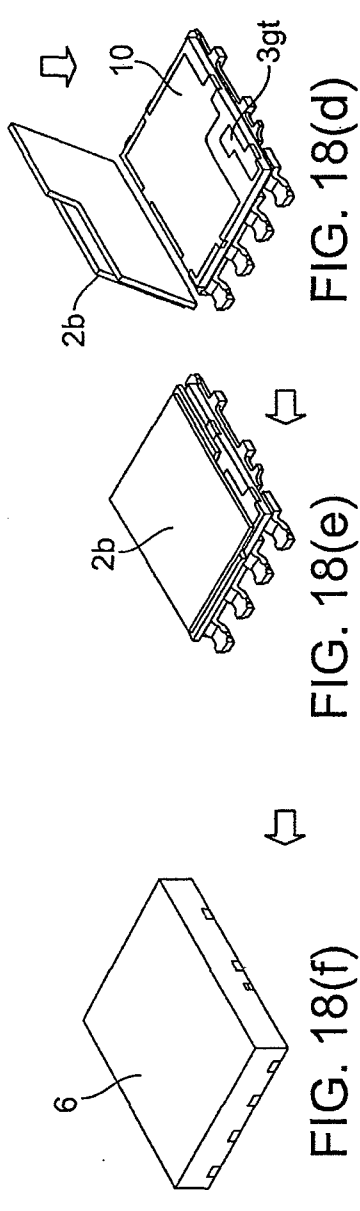
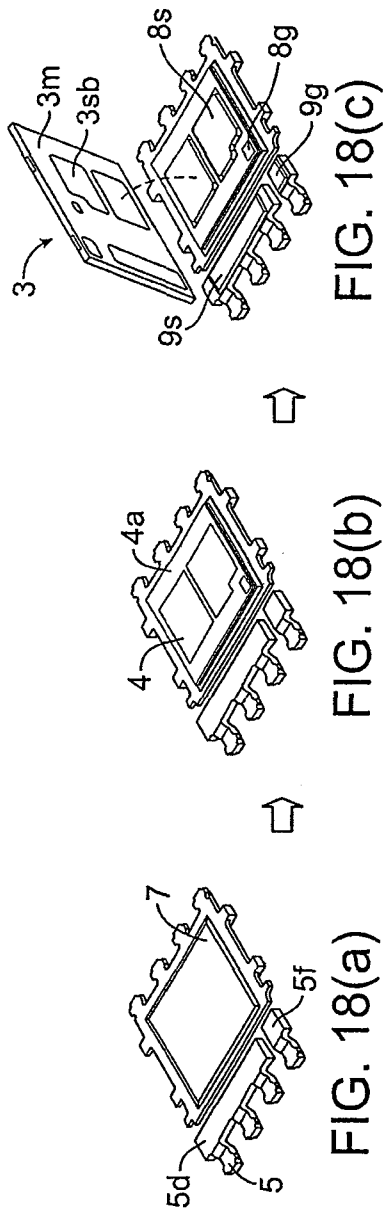


FIG. 16(h)

FIG. 16(g)





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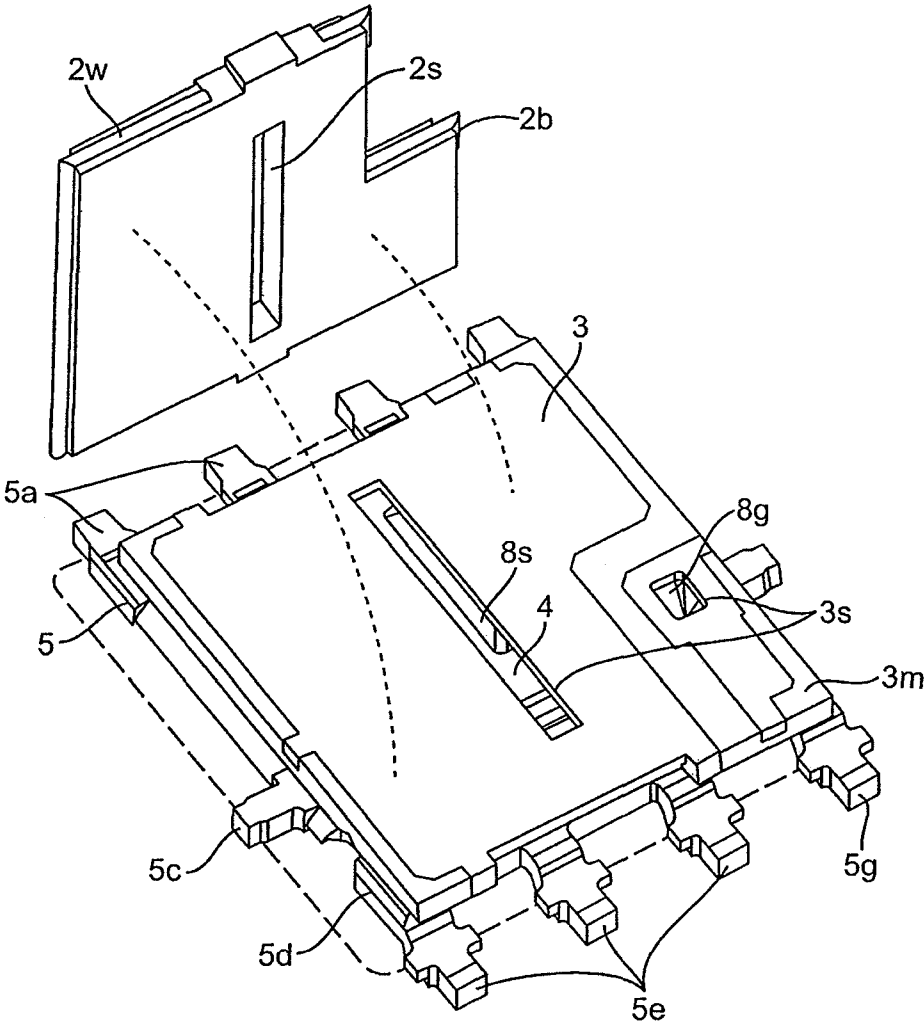


FIG. 19(b)

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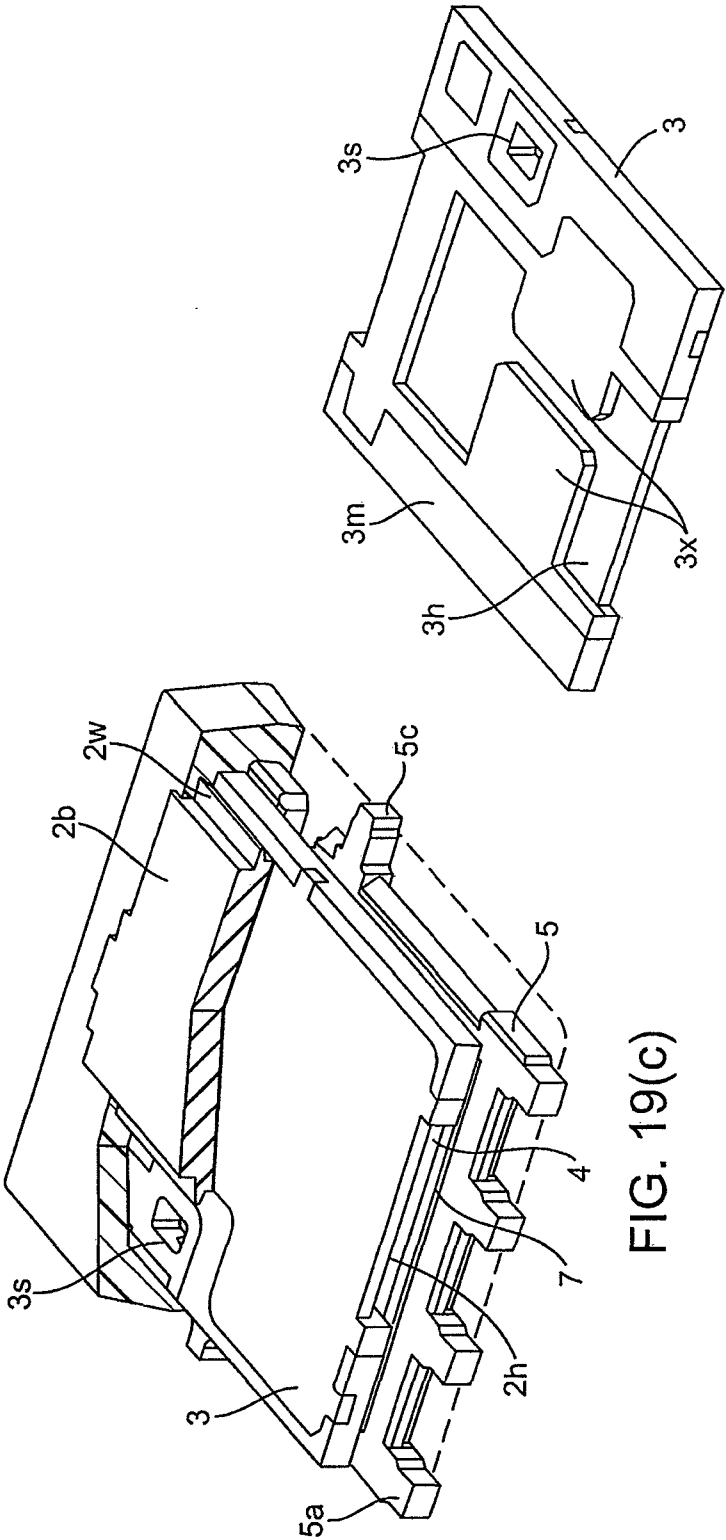


FIG. 19(d)

FIG. 19(c)

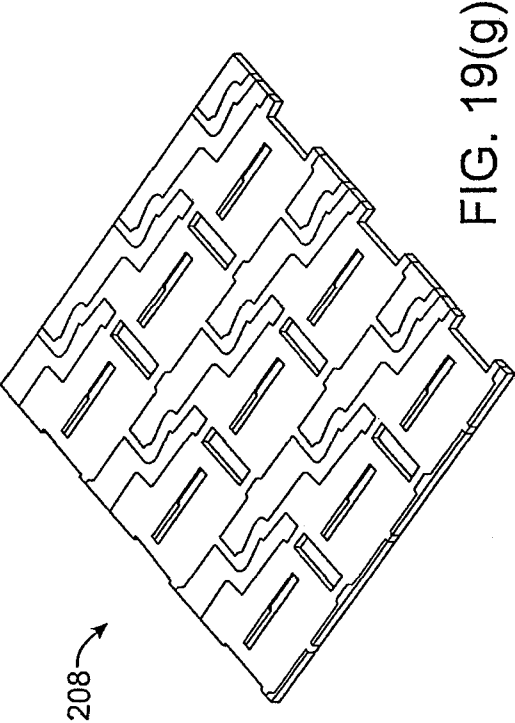


FIG. 19(g)

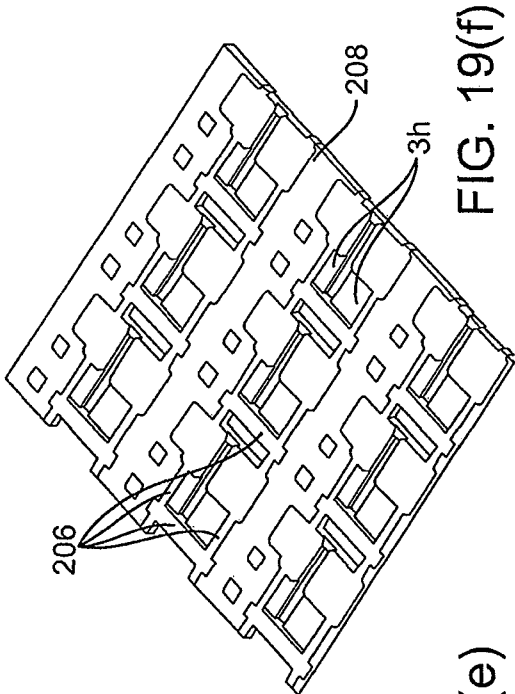


FIG. 19(f)

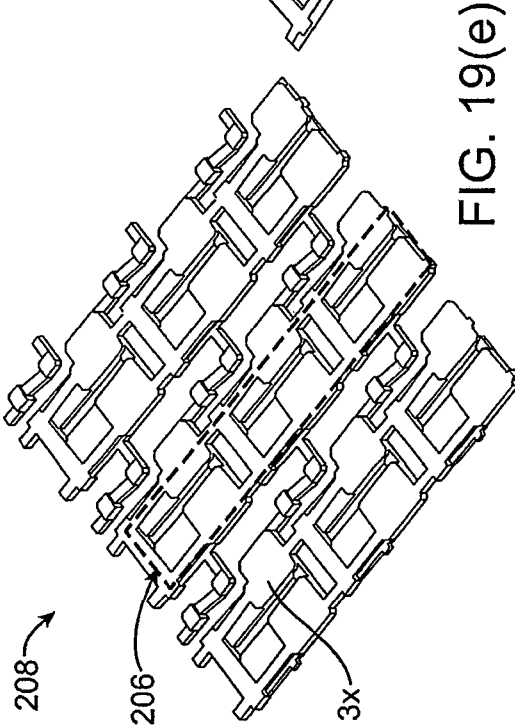


FIG. 19(e)

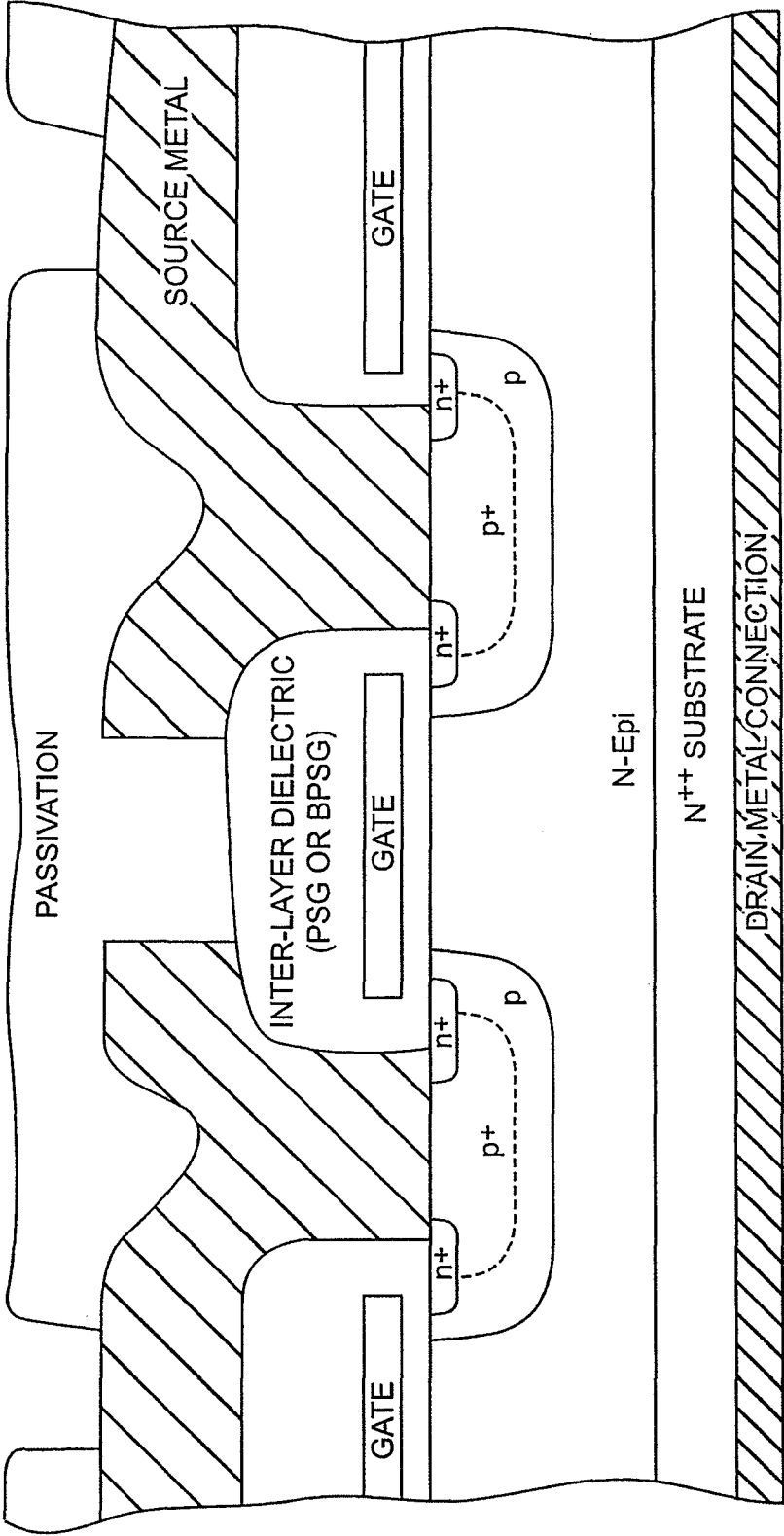


FIG. 20