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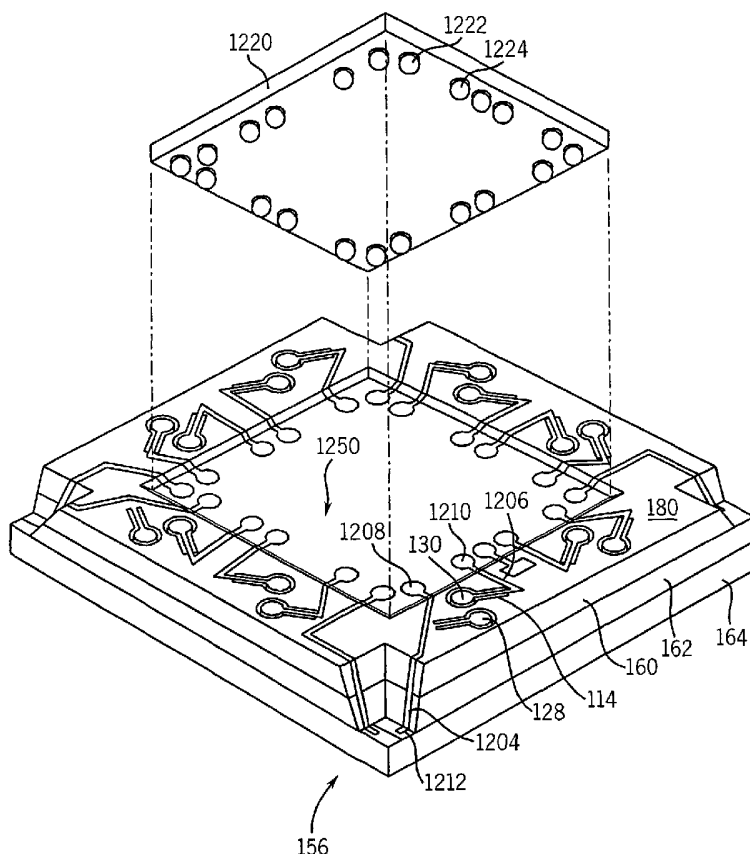
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 - (71) Applicant: NORTHROP GRUMMAN CORPORATION [US/US]; 21240 Burbank Boulevard, Woodland Hills, CA 91367-6675 (US).
 - (72) Inventor: STEWART, Robert, E.; 21847 Ybarra Road, Woodland Hills, CA 91364 (US).
 - (74) Agent: PATTI, Carmen, B.; Patti & Brill, LLC, One North LaSalle Street, 44th Floor, Chicago, IL 60602 (US).
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(54) Title: DIE CONNECTED WITH INTEGRATED CIRCUIT COMPONENT



(57) Abstract: An apparatus in one example includes a die (102) such as a micro-electro-mechanical-system (MEMS) with at least first and second the first portion of the die mechanically and electrically circuit board (310). The apparatus includes an integrated circuit component (1220) mechanically and electrically connected with the second portion of the die. Upon operation the die serves to generate one or more electrical signals that are passed to the integrated circuit component.



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DIE CONNECTED WITH INTEGRATED CIRCUIT COMPONENT

CROSS-REFERENCE TO RELATED APPLICATION

This application is a continuation-in-part of commonly-owned U.S. Patent
5 Application Serial No. (by Robert E. Stewart, filed May 24, 2002, and entitled
“COMPLIANT COMPONENT FOR SUPPORTING ELECTRICAL INTERFACE
COMPONENT”), which is hereby incorporated herein by reference in its entirety.

TECHNICAL FIELD

The invention in one example relates generally to electromechanical systems and
10 more particularly to connection between parts in an electromechanical system.

BACKGROUND

A three dimensional die with multiple layers, as one example of an electrical circuit,
requires electrical connections to multiple layers. For example, wire bonds serve to provide
the electrical connections between the layers. In some cases, the wire bonds must be made to
15 contacts on both the top and bottom of the die. Having wire bond contacts on both the top
and bottom of the die can result in the need to fabricate subassemblies with wire bonds
wrapping around multiple sides of the die. Having wire bonds that wrap around multiple
sides of a die make the die difficult to package. Having wire bonds wrap around the die
increases the periphery of the die. Having a larger periphery increases the space used by the
20 die when the die is mounted to a substrate, circuit board, or the like. In addition, wire bonds
are very thin and therefore susceptible to stress damage.

In another example, the die is packaged in a housing with electrical feed throughs.
Wire bond contacts are made to electrical contacts on different layers of the die. These bond
wires are then attached to feed throughs in the housing. The feed throughs in the housing

allow for an interface with a substrate, circuit board, or the like. Creating the wire bonds and electrical feed through is complicated to assemble, expensive, and fragile.

In another example, the die has one or more layers. The die makes an electrical connection to a substrate, circuit board, or the like, of a different material than the die. Since
5 the materials are different, they are likely to have different expansion/contraction coefficients. When expansion occurs in one or both of the materials, a stress is placed on the connection between the two materials. When the stress is large enough the connection can fail or break.

In another example, the die makes an electrical connection to a substrate, circuit
10 board, or the like. When translational or rotational movement occurs a stress is placed on the connection between the die and the substrate, circuit board, or the like.

In another example, processing electronics are used in combination with the die. Both of the processing electronics and the die must make an electrical connection to a substrate, circuit board, or the like. Two separate connection spaces must be used on the substrate,
15 circuit board, or the like.

In another example, the processing electronics and the die must go through testing together. To test the processing electronics and the die together they must be installed to a substrate, circuit board, or the like.

Thus, a need exists for a die that has increased durability in the interface between the
20 die and a compatible structure. A need also exists for a die with decreased size. A need also exists for a die that is easier to electrically interface with compatible structures. A need also exists for a die and processing electronics to use a same connection space. A need also exists for a die and processing electronics to be tested before installation to a substrate, circuit board, or the like.

SUMMARY

The invention in one embodiment encompasses an apparatus. The apparatus includes a die with at least first and second portions, the first portion of the die mechanically and electrically connectable with a circuit board. The apparatus includes an integrated circuit
5 component mechanically and electrically connected with the second portion of the die. Upon operation the die serves to generate one or more electrical signals that are passed to the integrated circuit component.

DESCRIPTION OF THE DRAWINGS

Features of exemplary implementations of the invention will become apparent from
10 the description, the claims, and the accompanying drawing in which:

FIG. 1 is one example of an apparatus that includes a die that comprises one or more layers, one or more connection paths, one or more electrical contact locations, one or more electrical interface components, and one or more compliant components.

FIG. 2 is one exploded representation of the die of the apparatus of FIG. 1.

15 FIG. 3 is one example of an electrical connection between the die and a separate layer of the apparatus of FIG. 1.

FIG. 4 is a sectional representation of the die directed along line 4-4 of FIG. 1.

FIG. 5 is a sectional representation of the die directed along line 5-5 of FIG. 1.

FIG. 6 is a sectional representation of the die directed along line 6-6 of FIG. 1.

20 FIG. 7 is one example of a compliant component of the apparatus of FIG. 1.

FIG. 8 is another example of the die of the apparatus of FIG. 1.

FIG. 9 is yet another example of the die of the apparatus of FIG. 1.

FIG. 10 is a further example of the die of the apparatus of FIG. 1.

FIG. 11 is one example of a wafer fabrication pattern of the die of the apparatus of FIG. 1.

FIG. 12 is a representation of the die of the apparatus of FIG. 1 and an electrical component receivable in a recess of the die.

5 FIG. 13 is a representation of the die of the apparatus of FIG. 1 and an electrical component connected with the die.

FIG. 14 is a representation of the die of the apparatus of FIG. 1 and an electrical component connected with the die.

10 FIG. 15 is a representation of one example of connection among the die, an electrical component, and a separate layer of the apparatus of FIG. 1.

FIG. 16 is a representation of one example of connection among the die and a separate layer of the apparatus of FIG. 1.

DETAILED DESCRIPTION

Turning to FIG. 1-3, an apparatus 100 in one example comprises one or more dice 15 102 and one or more separate layers 310. The die 102 comprises, for example, a micro-electro-mechanical system ("MEMS"), sensor, actuator, accelerometer, switch, stress sensitive integrated circuit, or the like. The die 102 includes one or more layers 160, 162, 164, one or more compliant components 104, 106, 108, 110, 112, 114, 116, 118, one or more electrical interface components 120, 122, 124, 126, 128, 130, 132, 134, and one or more 20 connection paths 136, 138, 140, 142, 144, 146, 148, 120. The separate layer 310 in one example comprises a substrate, circuit board, electronic device, die, or the like.

Referring to FIGS. 4 and 5, the one or more layers 160, 162, 164 in one example comprises, semiconductors, insulators, conductors, or the like.

Referring to FIG. 6 (a cross section 6-6 of FIG. 1), in one example, the compliant component 116 is located in an etched well 610 on the cover 160 of the die 102. The well 610 is a large enough size and shape to allow for the flexing of the compliant component 116. In another example, the compliant component 116 is on a surface 180 of the cover 160 of the die 102.

Referring to FIGS. 1 and 7, the compliant component 114 in one example comprises a flexible arm 710. The flexible arm 710 is attached both to the die 102 and the electrical interface component 130. In one example, the die 102 is etched in a pattern such that the arm 710 and the electrical interface component 130 have the space to be able to flex in response to stress applied to the flexible arm 710. In another example, the compliant component 114 is a beam that is micro machined into the die 102.

In one example, referring to FIG. 7, the compliant component 114 comprises a flexible arm 710. In one example, the flexible arm 710 and the cover 160, or the like, are etched from a single homogeneous material. In another example, the flexible arm 710 is etched from a separate homogeneous material as the cover 160, then attached to the cover 160, or the like. In another example, the flexible arm 710 is etched from a heterogeneous material as the cover 160, then attached to the cover 160, or the like.

In one example, the flexible arm 710 is a straight linear structure. In another example, the flexible arm 710 has one or more unstressed bends, or curves, or the like. In another example, the flexible arm 710 is a plurality of flexible arms.

Referring to FIG. 9, in one example a subset of the compliant components 108, 110, 116, 118 are designed to be compliant to translational movement in a single direction as well as being compliant with the direction of movement due to expansion. In one example, the translational movement in a single direction is horizontal on the die 102 plane. In another example, the translational movement in a single direction is vertical on the die 102 plane.

The compliant component 104, 106, 108, 110, 112, 114, 116, 118 orientation of FIG. 9 allows the overall connection of the die 102 to the separate layer 310 to be compliant to translational movement in a single direction as well as being compliant with the direction of movement due to expansion.

5 Referring to FIG. 10, in one example first subset of the compliant components 108, 110, 116, 118 are designed to be compliant to translational movement in a first direction as well as being compliant with the direction of movement due to expansion. A second subset of the compliant components 104, 106, 112, 114 are designed to be compliant to translational movement in a second direction as well as being compliant with the direction of movement
10 due to expansion. In one example the first direction is different from that of the second direction in the plane of the die 102. The compliant component 104, 106, 108, 110, 112, 114, 116, 118 orientation of FIG. 10 allows the overall connection of the die 102 to the separate layer 310 to be compliant to translational movement in multiple directions, compliant to rotation, as well as being compliant with the direction of movement due to expansion. In one
15 example, the translational movement is horizontal on the die 102 plane. In another example, the translational movement is vertical on the die 102 plane. In another example, the translational movement is vertical and horizontal on the die 102 plane. A die 102 connection compliant to translational, rotational, and expansion movements has a use in applications that are, in one example, counter balanced mechanical resonators. The resonators have one or
20 more masses vibrating out of phase with each other. In one example, the masses need to vibrate at a same frequency. When used in such an application the compliant mounting structures 104, 106, 108, 110, 112, 114, 116, 118 that allow translational, rotational, and expansion movements will couple the two masses together so they vibrate at the same frequency.

The electrical interface component 130, in one example is a conductive pad, or the like. In another example, the electrical interface component 130 is a solder ball, or the like. In another example, the electrical interface component 130 is a solder ball, or the like, connected to a conductive pad, or the like. The electrical interface component 130 is
5 electrically insulated from the die 102.

In one example, the connection path 144 is a signal routing trace. The connection path 144 is used to pass the electrical signal from one of the one or more layers 160, 162, 164 to the electrical interface component 130 on the interfacing surface 180.

In one example, a connection between the die 102 and the separated layer 310 can be
10 accomplished by using one or more of flip chip technology, ball grid array technology and pad grid array technology. Ball grid arrays are external connections that are arranged as an array of conducting pads on a interfacing surface 180 of the die 102. For explanatory purposes, the figures represent one example of the apparatus 100 that employs exemplary ball grid array technology. An electrical connection between a layer contact 190, 430, 432, 434,
15 436, 438, 440, and the electrical interface component 120, 122, 124, 126, 130, 132, 134 is made through the connection path 136, 138, 140, 142, 144, 146, 148. In one example, one or more of the electrical interface components 128 are not used to electrically interface the die 102 to the separate layer 310. In one example, the electrical interface component 128 is extra for the specific example of the die 102. In another example, the electrical interface
20 component 128 is intended to accommodate a possible future increase in the number of layer contacts 190, 430, 432, 434, 436, 438, 440 in the die 102.

Referring to FIGS. 1, 3, 4 and 5, in one example each of the layers 160, 162, 164, of a die 102, requiring an electrical connection to a separate layer 310 brings its connection to a single interfacial surface 180 for interface with the separate layer 310. In one example, to

access the various layers 160, 162, 164 of the die 102, one or more notches 150, 152, 154, 156 are created in the die 102.

In one example, the notch 156 could be a hole, cutout, path, window, opening and/or the like. The notch 156 can be at any location on the die 102. The notch 156 can be designed to reach any or all levels and/or depths. One or more layer contacts 430, 432, 434, 436, 438, 440 can be reached through the same notch 156. Each of the notches 150, 152, 154, 156 can be a different size, shape, or depth than any other of the notches 150, 152, 154, 156.

Referring to FIG. 11, the notch 156 is etched at the wafer level in order to take advantage of batch processing. In one example, the notches 150, 152, 154, 156 are etched on the wafer to be a consistent size and depth. In one example, the notches 150, 152, 154, 156 are etched on the wafer to be different sizes and depths. In one example, the etch could be an anisotropic wet etch. In another example, the etch could be a dry reactive ion etch, or the like.

Referring to FIGS. 1-5, the layer contact 434 connection is brought to the single interfacial surface 180 by using a connection path 144. The connection path 144 uses the notch 156 to reach the respective die 102 layer contact 434. An insulator 410 is used to separate the connection path 144 from layer 160 and the other layer contacts 190, 430, 432, 436, 438, 440. In one example, the insulator 410 is a silicon dioxide dielectric insulation layer.

In one example, the die 102 has one or more layer contacts 430, 432, 434, 436, 438, 440 that are located on a different layer 162, 164 than the layer 160 being used for interfacing to a separate layer 310. Each layer 160, 162, 164 may have more than one layer contact 190, 430, 432, 434, 436, 438, 440. An insulator 412, 416, 418, 420, 422, 426 is used to separate each layer 160, 162, 164 from the layer contacts 190, 430, 432, 434, 436, 438, 440 of the

other layers 160, 162, 164, and the other layers 160, 162, 164 themselves. In one example, the insulator 412, 416, 418, 420, 422, 426 is a silicon dioxide dielectric insulation layer.

In one example, the die 102 and the separate layer 310 may not be the same material, and therefore may not have the same expansion coefficients. When the die 102 and the separate layer 310 are connected together and thermal changes, or any other expansion/contraction force, occur the die 102 will expand/contract by one amount and the separate layer 310 expands/contracts by another amount, different from that of the amount of the die 102. When the amount of expansion/contraction is different in the die 102 than in the separate layer 310, there will be a stress applied at the connection of the die 102 and the separate layer 310. This stress is relieved at the connection between the die 102 and the separate layer 310 by the flexing of the compliant component 114.

In one example, as shown in FIG. 1, 7, and 8, the stress applied to the connection is likely to be in a radial direction from/to the midpoint 158 of the die 102 to/from the electrical interface component 130. In one example, the flexible arm 710 attached to the electrical interface component 130, is oriented perpendicular to the radial axis. When the stress in likely to be in a radial direction this perpendicular flexible arm 710 orientation provides a unstressed starting point for the electrical interface component 130. This unstressed starting point provides wide range of motion in either radial direction. In another example, as shown in FIG. 8, the flexible arm 710 attached to the electrical interface component 130, is oriented parallel to one or more of the die 102 edges.

Referring to FIGS. 4 and 5, in one example, the die 102 is a sensor system. The die 102 has three element layers, a top cover 160, bottom cover 164, and a sensing center element 162. Each element layer 160, 162, 164 has a dielectric insulating layer 412, 416, 418, 420, 422, 426 added to each surface that will be bonded to another surface. A conducting material 414, 424 is laid down on the dielectric insulating layer 412, 416, 418,

420, 422, 426 of each of the top cover 160, and the bottom cover 164 on the surface that is adjacent to the center element 162. A dielectric insulating layer 412, 416, 418, 420, 422, 426 is laid down over the conducting materials 414, 424. The three element layers 160, 162, 164 are bonded together.

5 In one example, a plurality of layer contacts 430, 432, 434, 436, 438, 440 are buried between the layers 160, 162, 164 of the die 102. The layer contacts 430, 432, 434, 436, 438, 440 are required to be on a interfacing surface 180 for the die 102 to be mounted directly to the separate layer 310, such as a substrate or circuit board. The interfacing surface 180 has a plurality of electrical interfacing components 120, 122, 124, 126, 128, 130, 132, 134.

10 Notches 150, 152, 154, 156 are made through the die 102 to expose the buried layer contacts 430, 432, 434, 436, 438, 440. Along the walls of the notch 156 a dielectric insulating layer 410 is applied to separate the connection path 144 from the element layers 160, 162, 164 and the other layer contacts 430, 432, 436, 438, 440. The desired layer contact 434 will not be covered by the dielectric insulating layer 410 to allow connection between the layer contact

15 434 and the connection path 144. The connection path 144 is used to pass the electrical signal from the layer contact 434 to the electrical interface component 130 on the interfacing surface 180. In one example, the connection path 144 is a signal routing trace. The electrical interface component 130 on the interfacing surface 180 is attached to compliant component 114. The compliant component 114 allows the die 102 to directly connect to the separate

20 layer 310 with the same expansion properties or the separate layer 310 with different expansion properties.

Turning to FIG. 12-15 an apparatus 100, in another example, comprises one or more dice 102, one or more electrical components 1220, and one or more separate layers 310. The die 102 in one example further comprises, one or more connection paths 1204 and 1206, and

25 one or more electrical interface components 1208 and 1210. The electrical component 1220

in one example comprises one or more of processing electronics, central processing unit (“CPU”), integrated circuit, and application specific integrated circuit (“ASIC”). The electrical component 1220 in one example comprises one or more electrical interface components 1222 and 1224.

5 In one example, the connection paths 1204 and 1206 are signal routing traces. In one example, the connection paths 1204 and 1206 comprise a conducting material. The connection path 1204 is used to pass the electrical signal from one of the one or more layers 160, 162, 164, exposed by notch 156, to the electrical interface component 1208.

The one or more electrical interface components 1208 and 1210 in one example
10 comprise one or more of electrical contacts, conductive pads, and solder balls. The one or more electrical interface components 1208 and 1210 are electrically insulated from the die 102.

Referring to FIG. 12, in one example, the electrical component 1220 and the die 102 are made from a same material, and therefore are not likely to experience differences in
15 expansion. In one example, the connection between the electrical component 1220 and the die 102 can be accomplished by using one or more of flip chip technology, ball grid array technology, and pad grid array technology. In one example, the connection between the electrical component 1220 and the die 102 is made through one or more solder balls. The one or more solder balls electrically and mechanically connect the electrical component 1220 to
20 the die 102. The one or more solder balls comprise a conductive material to electrically connect the electrical component 1220 to the die 102. The one or more solder balls comprise a bonding material to mechanically connect the electrical component 1220 to the die 102.

In another example, the electrical component 1220 and the die 102 are made from different materials, and therefore are likely to experience differences in expansion. In one
25 example, the expansion is due to one or more of thermal changes, material aging, difference

in stability, and moisture swelling. In addition to one or more of flip chip technology, ball grid array technology, and pad grid array technology, the connection between the electrical component 1220 and the die 102, would benefit from using a compliant mounting component to support the electrical interface components 1208 and 1210. The compliant mounting
5 component in one example comprises a structure similar to compliant component 114. The connection between the electrical component 1220 and the die 102 using the compliant component 114 is forgiving to differences in relative movement between the electrical component 1220 and the die 102.

Referring to FIG. 12, an electrical connection, to route the electrical signal between a
10 layer contact 1212 and the electrical interface component 1208, is made through the connection path 1204. The electrical interface component 1208 transfers the electrical signal to electrical interface component 1222 of the electrical component 1220. In one example, the electrical interface component 1222 comprises an input to the electrical component 1220. In one example, the electrical component 1220 processes one or more electrical signals from the
15 die 102. In one example, the processed electrical signal results are placed on electrical interface component 1224 of the electrical component 1220. In one example, the electrical interface component 1224 comprises an output of the electrical component 1220. The processed electrical signal results are transferred to the electrical interface component 1210 on the die 102. The processed electrical signal results are transferred to the electrical
20 interface component 130 through the connection path 1206. The electrical interface component 130 is mounted to the flexible support, compliant component 114. In one example, electrical interface component 130 comprises a connection component for connection with the separate layer 310.

Referring to FIG. 15 in one example the die 102 and electrical component 1220
25 mount to a separate layer 310. The die 102 comprises one or more electrical interface

components 1510, 1512, 1514, 1516, 1518, 1520, 1522, 1524, 1526, 1528, 1530, 1532, 1534, 1536, 1538, and 1540 to make connection to the respective electrical interface components 1550, 1552, 1554, 1556, 1558, 1560, 1562, 1564, 1566, 1568, 1570, 1572, 1574, 1576, 1578, and 1580 of the separate layer 310. In one example, the electrical interface component 1550
5 comprises an input of the electrical component 1220. In another example, the electrical interface component 1550 comprises an output of the electrical component 1220. In one example, the electrical interface component 1550 is connected to the electrical interface component 1592 through a connection path 1590. The electrical interface component 1592 comprises one or more connections slots 1594 to electrically and physically attach to a
10 separate component. The connection path 1590 in one example comprises a conducting path.

Referring to FIG. 12-15, in one example, the electrical component 1220 is a separate chip. To integrate the electrical component 1220 to the die 102, an electrical and mechanical connection is made between the electrical interface components 1208 of the die 102 and the electrical interface components 1222 of the electrical component 1220. In one example, the
15 electrical component 1220 electrically connects at the interfacing surface 180. In another example, the electrical component 1220 electrically connects in a recess 1250 of the die 102. The recess 1250 is designed so that the electrical component 1220 can rest in the recess 1250. The depth of the recess 1250 is designed so that when the die 102 and the electrical component 1220 are connected to the separate layer 310 the electrical component 1220 is not
20 obstructing the electrical interface component 1510 of the die 102 from making contact with the electrical interface component 1550 of the separate layer 310.

Referring to FIG. 14, in one example, the electrical components 1220 are completely integrated into the die 102 by designing the die 102 to include the electrical components 1220. The one or more of the electrical signals generated by the die 102 are fed directly to
25 the integrated electrical components 1220.

Referring to FIG. 12-15, having the electrical component 1220 within the periphery the die 102 creates a higher level of integration. Rather than having the electrical component 1220 and the die 102 use separate footprints, integrating them uses a single footprint on the separate layer 310. Thus, saving space on the separate layer 310.

5 Having the electrical component 1220 integrated into the die 102 allows for testing of the electrical component 1220 and the die 102 together without complete installation to the separate layer 310.

Turning to FIG. 16, in one example, the attachment of the die 102 to the separate layer 310 is made with one or more of electrical interface components 1512. Electrical
10 interface component 1512 of the separate layer 310 is connected to the die 102 through the electrical interface component 1552. In one example, the connection between the die 102 and the separate layer 310 is made through one or more solder balls. In one example, the solder ball is heated, centered, and cooled to complete the connection between layers. In one
15 example, the solder ball is pressed together during the connection process, thus the solder ball is deformed from a spherical shape. The one or more solder balls electrically and mechanically connect the die 102 to the separate layer 310. The one or more solder balls comprise a conductive material to electrically connect the die 102 to the separate layer 310. The one or more solder balls comprise a bonding material to mechanically connect the die 102 to the separate layer 310.

20 One or more features described herein with respect to one or more of the compliant components 104, 106, 108, 110, 112, 114, 116, 118 in one example apply analogously to one or more other of the compliant components 104, 106, 108, 110, 112, 114, 116, 118. One or more features described herein with respect to one or more of the electrical interface components 120, 122, 124, 126, 128, 130, 132, 134 in one example apply analogously to one
25 or more other of the electrical interface components 120, 122, 124, 126, 128, 130, 132, 134.

One or more features described herein with respect to one or more of the connection paths 136, 138, 140, 142, 144, 146, 148 in one example apply analogously to one or more other of the connection paths 136, 138, 140, 142, 144, 146, 148. One or more features described herein with respect to one or more of the notches 150, 152, 154, 156 in one example apply analogously to one or more other of the notches 150, 152, 154, 156. One or more features described herein with respect to one or more of the electrical interface components 130, 1510, 1512, 1514, 1516, 1518, 1520, 1522, 1524, 1526, 1528, 1530, 1532, 1534, 1536, 1538, and 1540 in one example apply analogously to one or more other of the electrical interface components 130, 1510, 1512, 1514, 1516, 1518, 1520, 1522, 1524, 1526, 1528, 1530, 1532, 1534, 1536, 1538, and 1540. One or more features described herein with respect to one or more of the electrical interface components 1550, 1552, 1554, 1556, 1558, 1560, 1562, 1564, 1566, 1568, 1570, 1572, 1574, 1576, 1578, and 1580 in one example apply analogously to one or more other of the electrical interface components 1550, 1552, 1554, 1556, 1558, 1560, 1562, 1564, 1566, 1568, 1570, 1572, 1574, 1576, 1578, and 1580.

The steps or operations described herein are just exemplary. There may be many variations to these steps or operations without departing from the spirit of the invention. For instance, the steps may be performed in a differing order, or steps may be added, deleted, or modified.

Although exemplary implementations of the invention have been depicted and described in detail herein, it will be apparent to those skilled in the relevant art that various modifications, additions, substitutions, and the like can be made without departing from the spirit of the invention and these are therefore considered to be within the scope of the invention as defined in the following claims.

CLAIMS

What is claimed is:

1. An apparatus, comprising:

a die with at least first and second portions, the first portion of the die mechanically
5 and electrically connectable with a circuit board; and

an integrated circuit component mechanically and electrically connected with the
second portion of the die;

wherein upon operation the die serves to generate one or more electrical signals that
are passed to the integrated circuit component.

10 2. The apparatus of claim 1, wherein the one or more electrical signals comprise
one or more first electrical signals;

wherein upon operation the integrated circuit component serves to generate one or
more second electrical signals, based upon the one or more first electrical signals, that are
passed to the die for output to the circuit board.

15

* * * * *

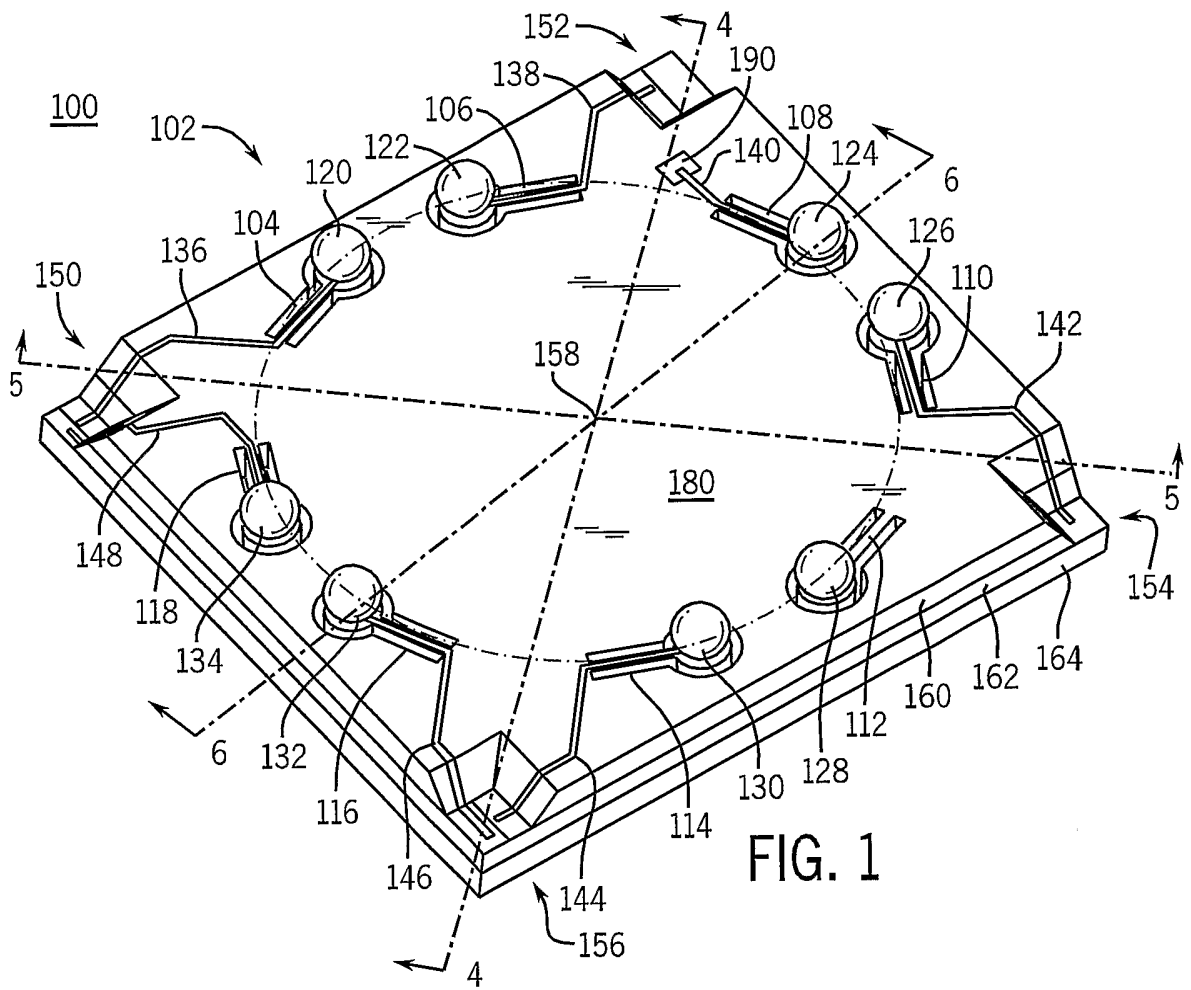


FIG. 1

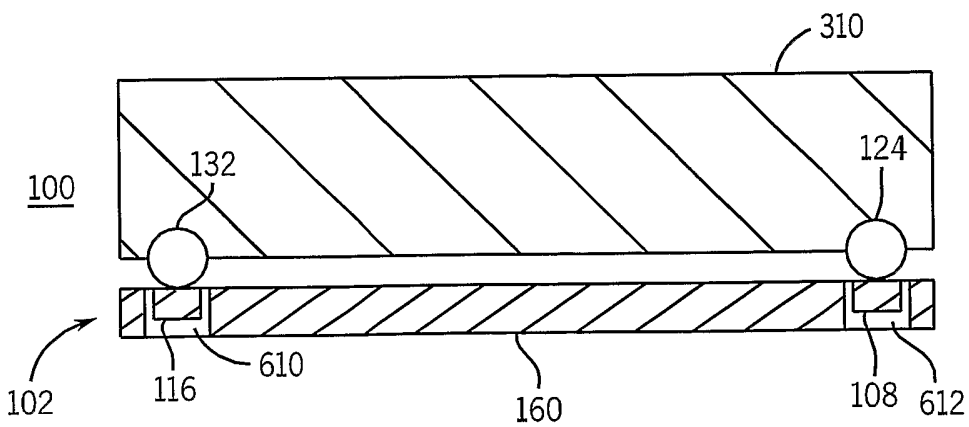
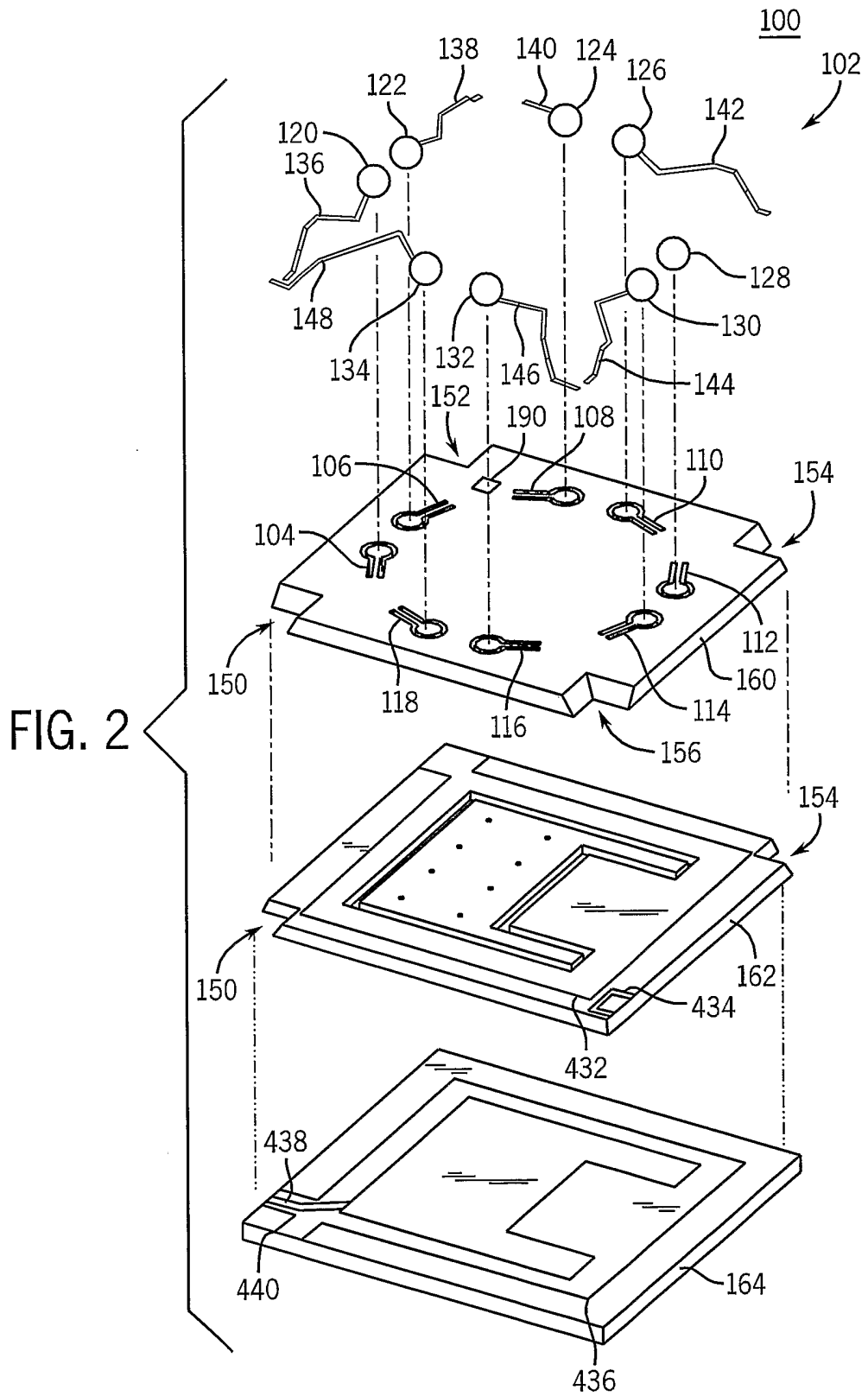


FIG. 3



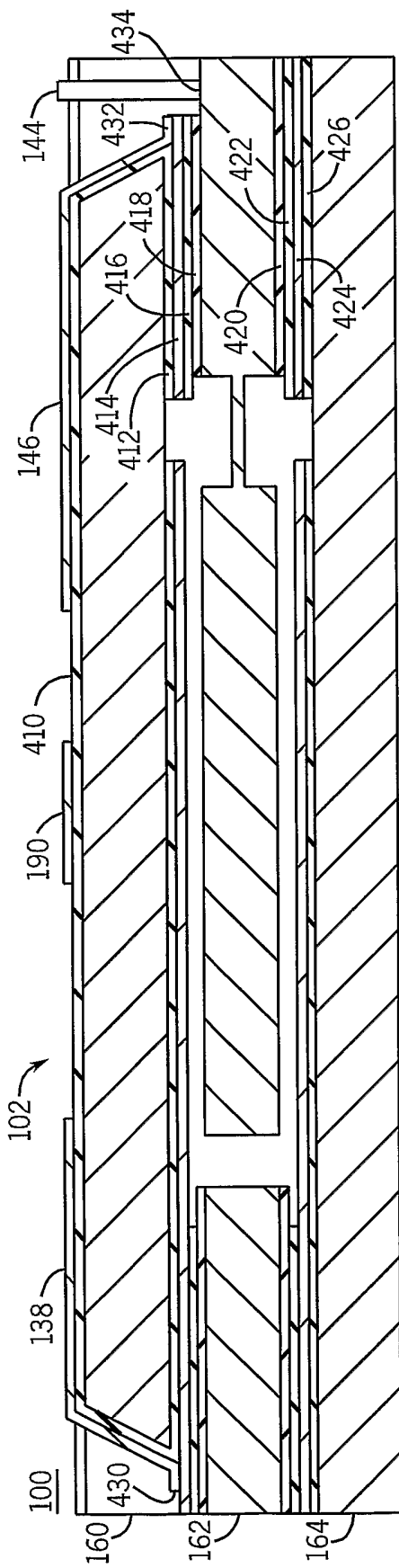


FIG. 4

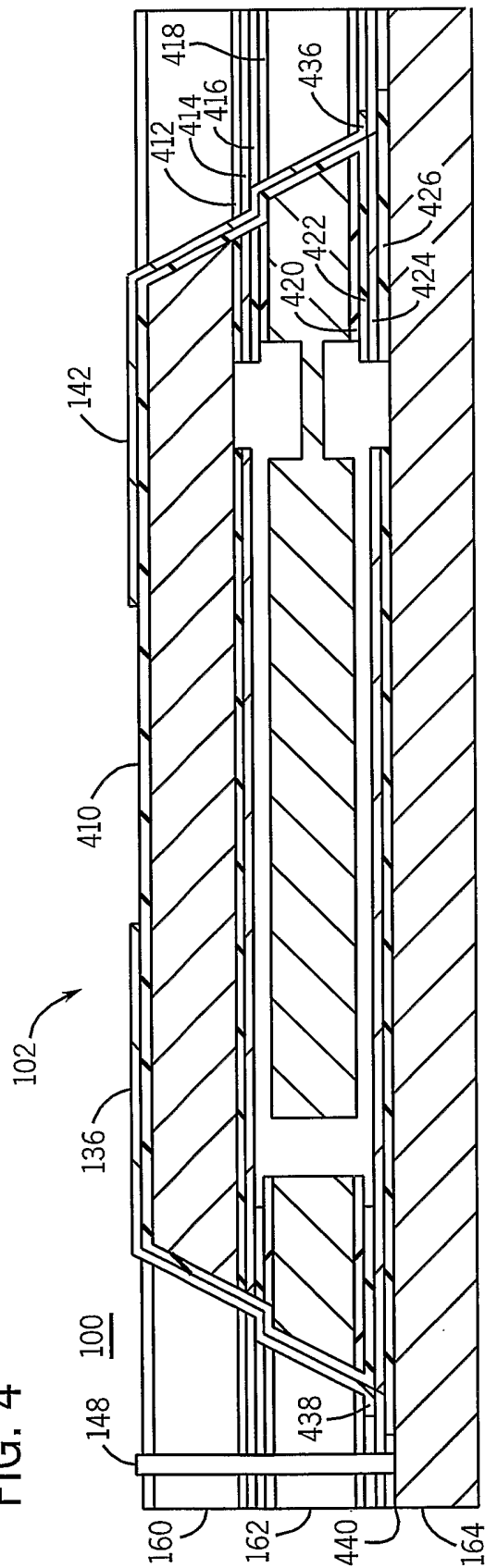


FIG. 5

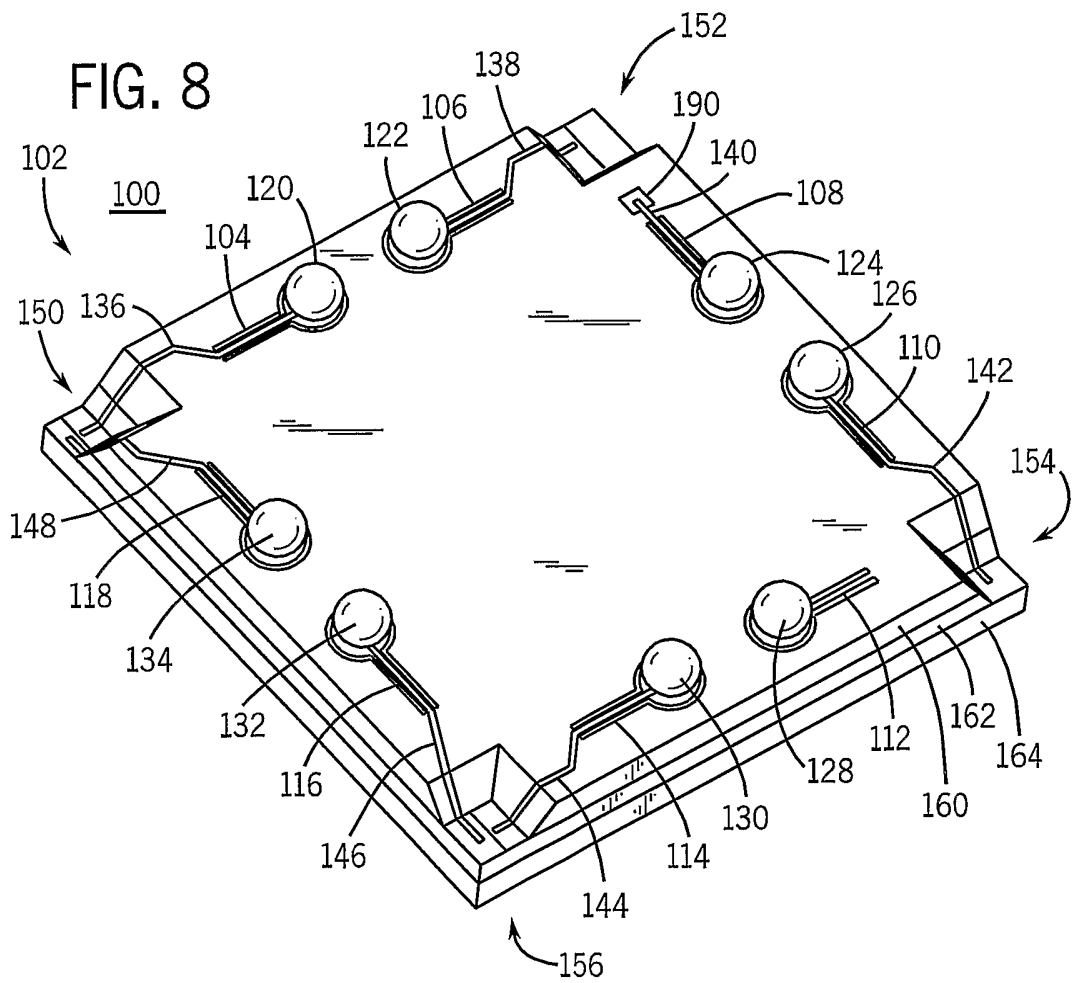
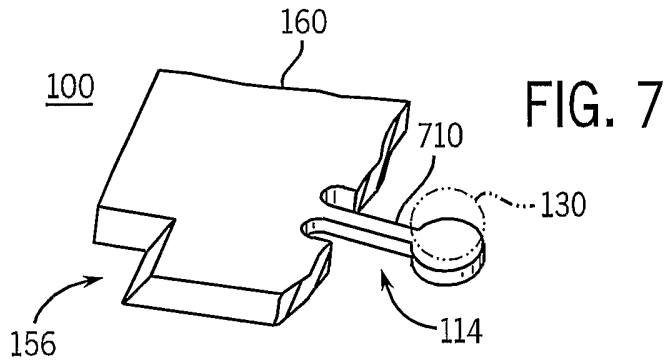
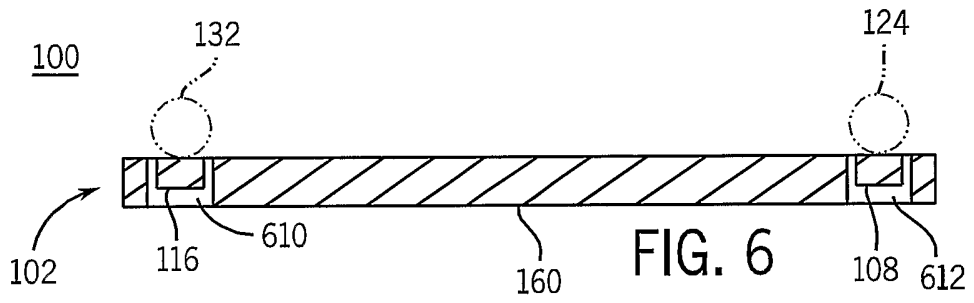


FIG. 9

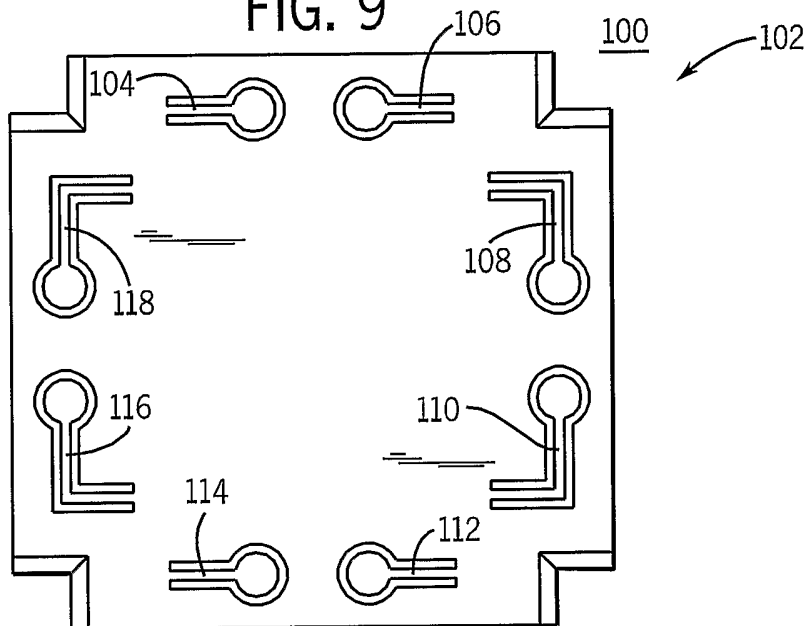


FIG. 10

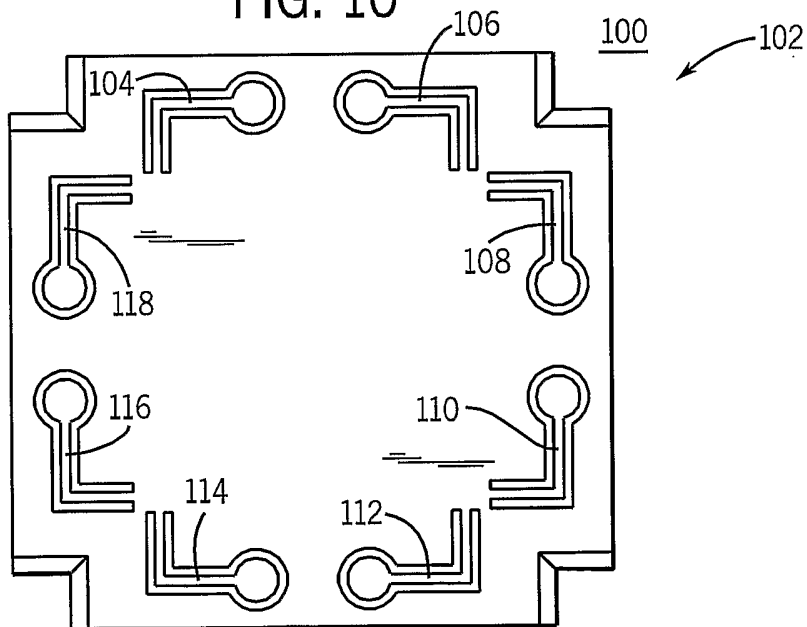
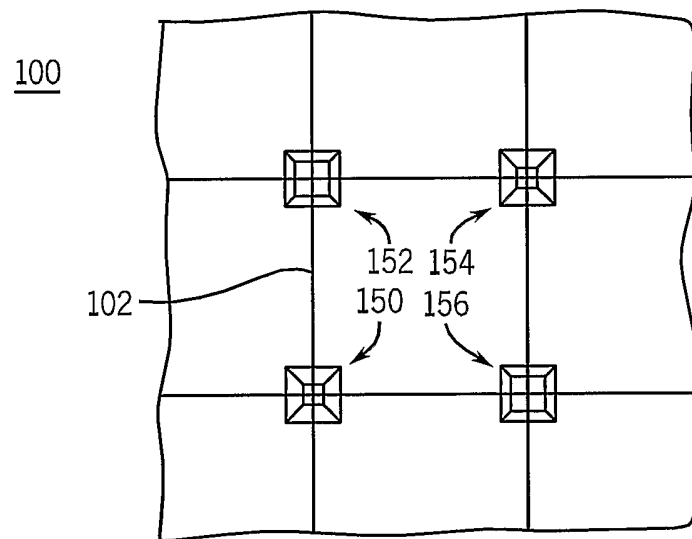


FIG. 11



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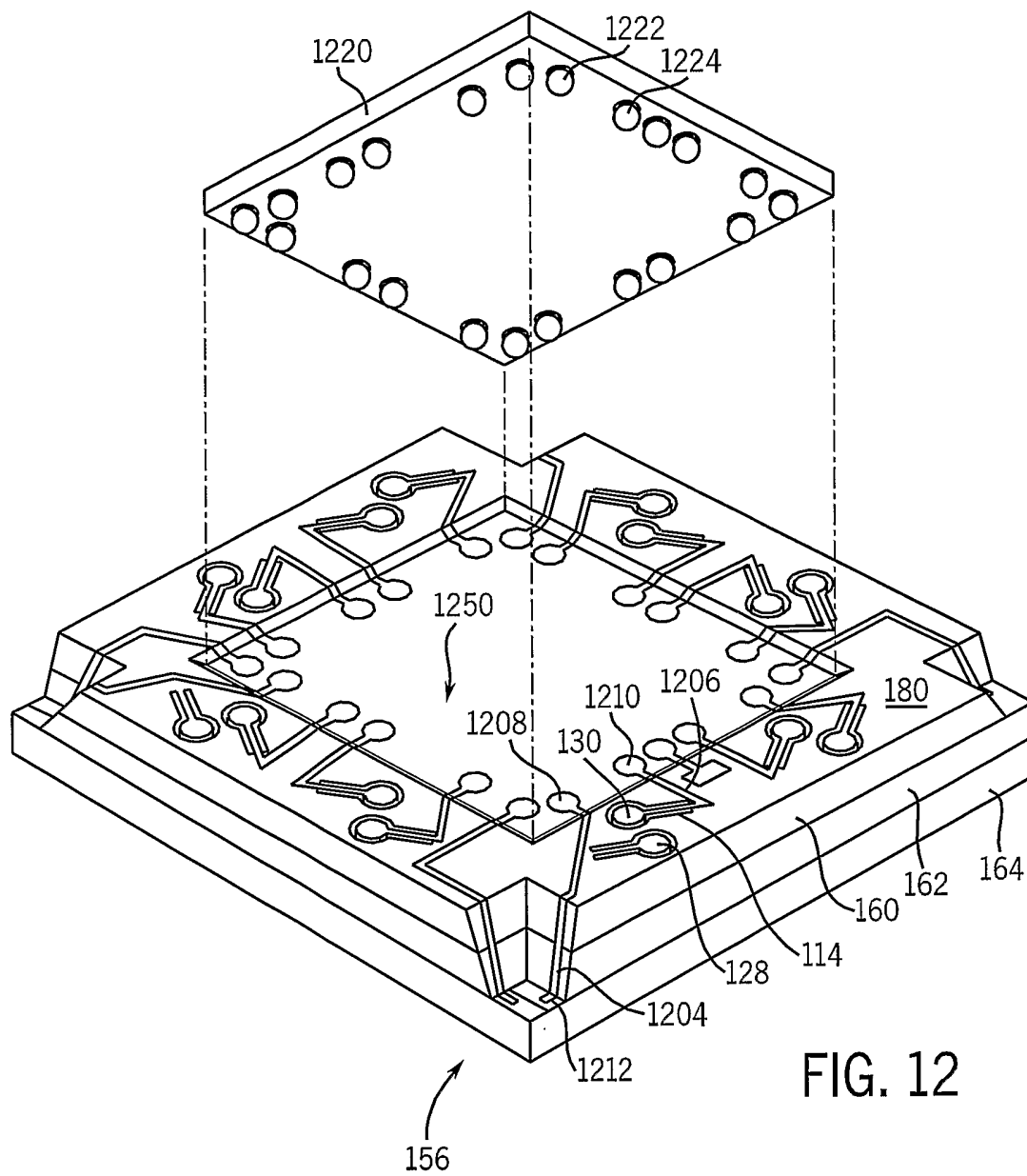


FIG. 12

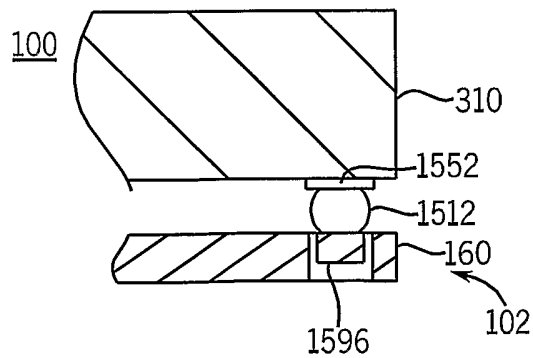
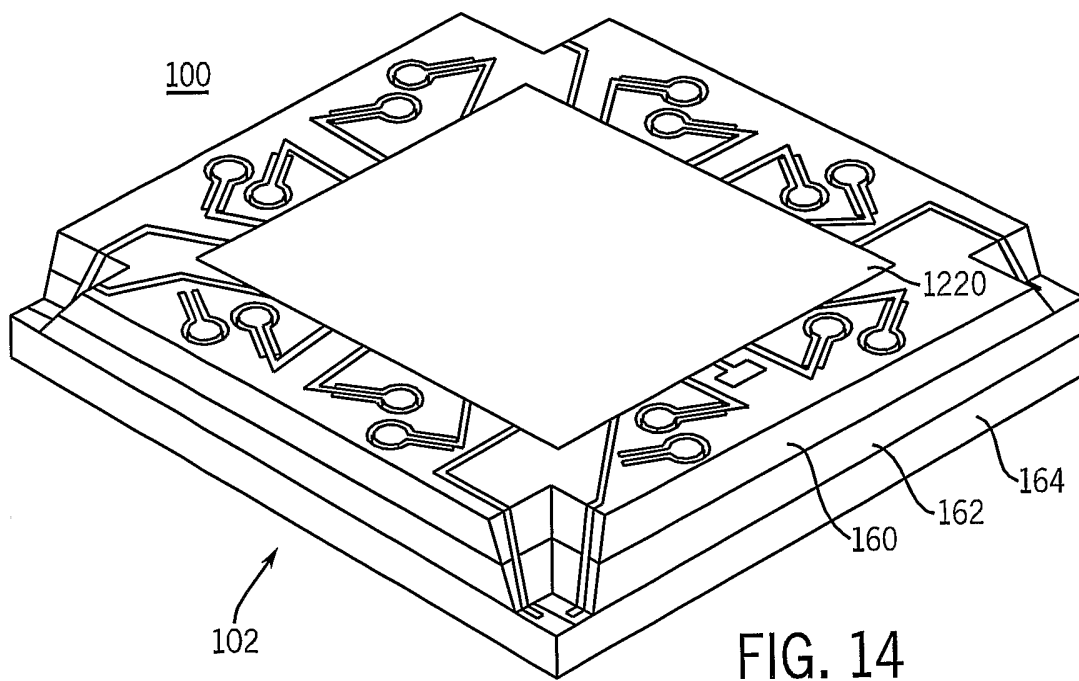
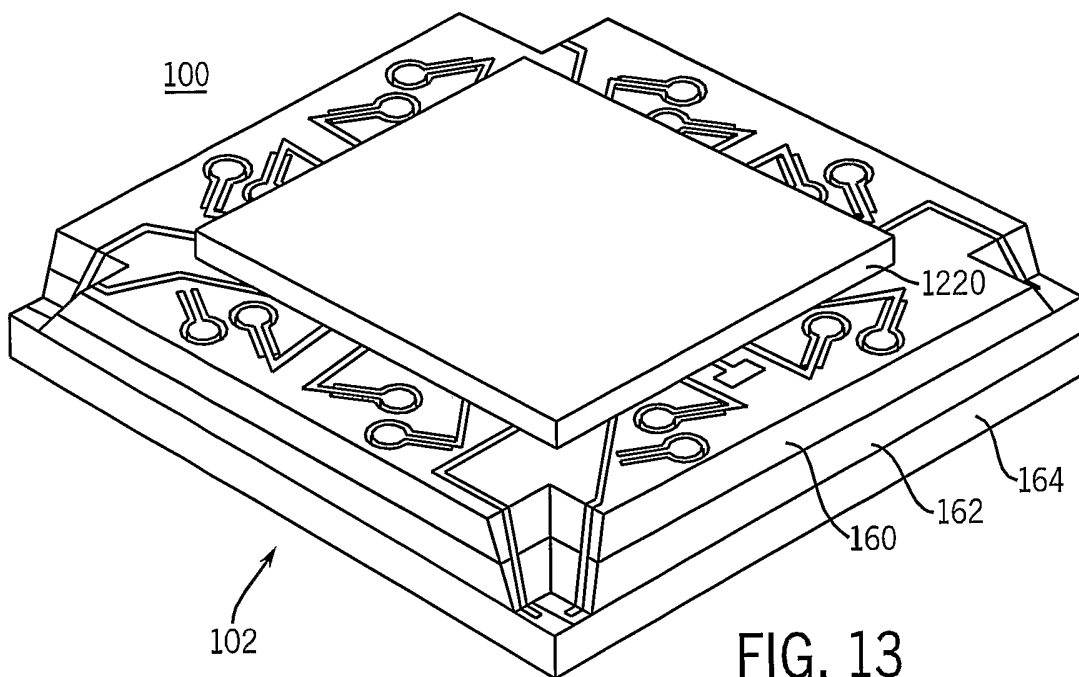


FIG. 16



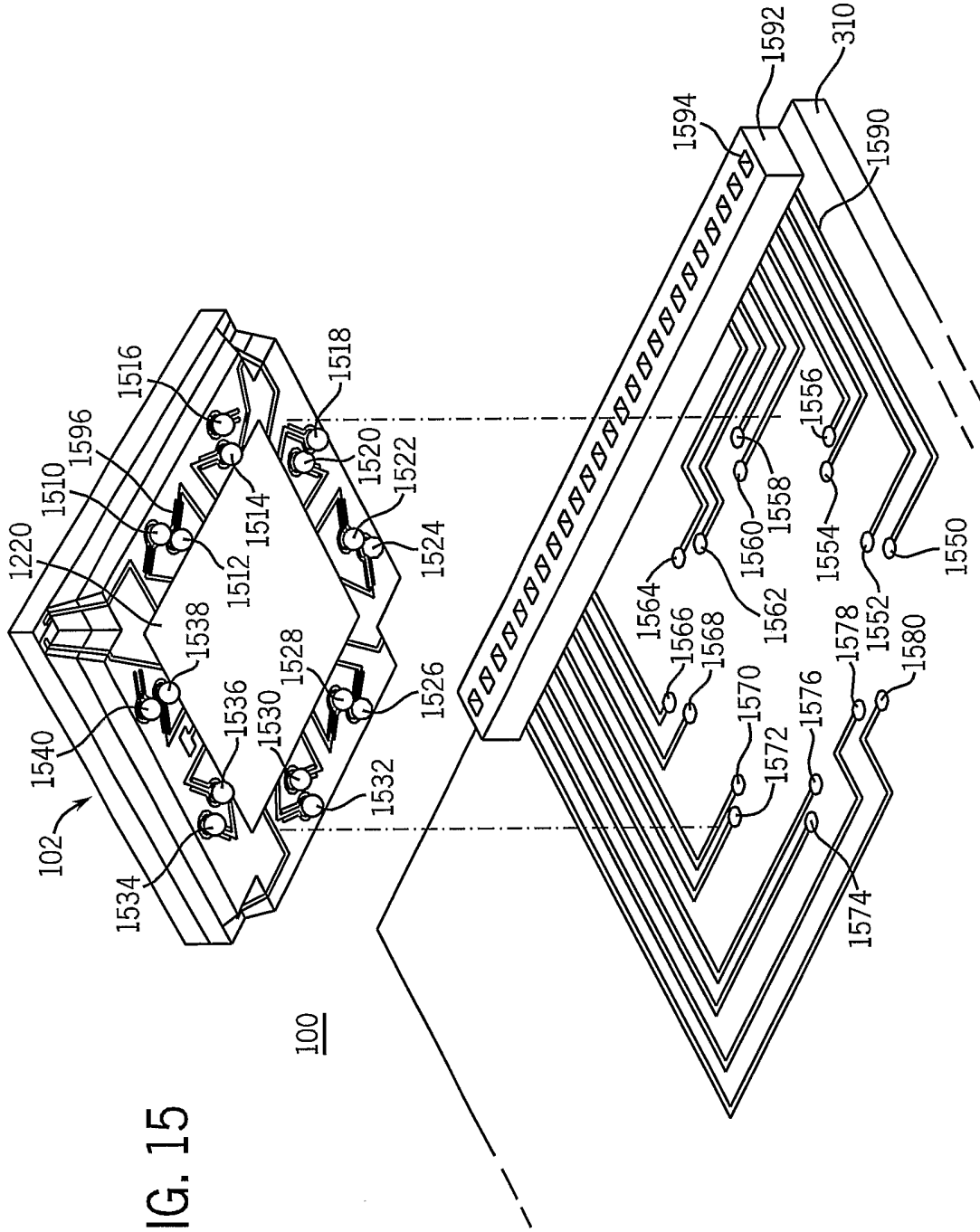


FIG. 15

INTERNATIONAL SEARCH REPORT

PCT/US 03/16136

A. CLASSIFICATION OF SUBJECT MATTER

IPC 7 H01L25/065 H01L23/498

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 7 H01L

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 6 052 287 A (GASSMAN RICHARD A ET AL) 18 April 2000 (2000-04-18) column 4, line 65 -column 5, line 65; figure 1	1,2
X	US 5 164 328 A (DUNN WILLIAM C ET AL) 17 November 1992 (1992-11-17) the whole document	1,2
X	EP 1 151 962 A (ST MICROELECTRONICS SRL) 7 November 2001 (2001-11-07) column 2, line 28 -column 4, line 19; figure 8 figures 13-16	1,2
A	US 5 148 265 A (KHANDROS IGOR Y ET AL) 15 September 1992 (1992-09-15) figure 14	1,2

 Further documents are listed in the continuation of box C. Patent family members are listed in annex.

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Date of the actual completion of the international search

25 September 2003

Date of mailing of the international search report

06/10/2003

Name and mailing address of the ISA

European Patent Office, P.B. 5818 Patentlaan 2
NL - 2280 HV Rijswijk
Tel. (+31-70) 340-2040, Tx. 31 651 epo nl,
Fax: (+31-70) 340-3016

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Information on patent family members

International application No

PCT/US 03/16136

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