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(54) Title: ELECTRONIC DEVICE INCLUDING FINGER SENSOR AND RELATED METHODS

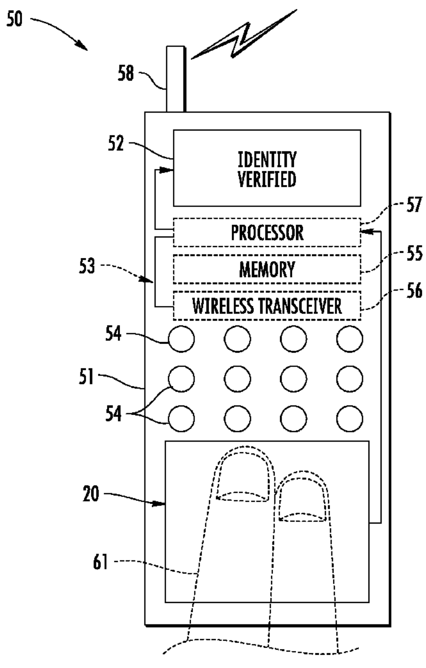

FIG. 1

(57) Abstract: An electronic device may include a housing and circuitry carried by the housing. The electronic device may also include a finger sensing device carried by the housing and coupled to the circuitry. The finger sensing device may include a mounting substrate, and a semiconductor interposer having a lower surface adjacent the mounting substrate. The finger sensing device may also include a plurality of semiconductor finger sensing die on an upper surface of the semiconductor interposer in side-by-side and abutting relation, and defining a finger sensing surface to receive at least one finger thereon.

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ELECTRONIC DEVICE INCLUDING FINGER SENSOR AND RELATED METHODS

Field of the Invention

[0001] The present invention relates to the field of electronics, and, more particularly, to the field of finger sensors.

Background of the Invention

[0002] Fingerprint sensing and matching is a reliable and widely used technique for personal identification or verification. In particular, a common approach to fingerprint identification involves scanning a sample fingerprint or an image thereof and storing the image and/or unique characteristics of the fingerprint image. The characteristics of a sample fingerprint may be compared to information for reference fingerprints already in a database to determine proper identification of a person, such as for verification purposes.

[0003] A particularly advantageous approach to fingerprint sensing is disclosed in U.S. Patent No. 5,953,441 to Setlak and assigned to the assignee of the present invention, the entire contents of which are herein incorporated by reference. The fingerprint sensor is an integrated circuit sensor that drives the user's finger with an electric field signal and senses the electric field with an array of electric field sensing pixels on the integrated circuit substrate.

[0004] U.S. Patent No. 6,289,114 to Mainguet, which is assigned to the assignee of the present invention and is incorporated in its entirety by reference discloses a fingerprint sensor that includes a finger sensing integrated circuit (IC). The finger sensing IC includes a layer of piezoelectric or pyroelectric material placed between upper and lower electrodes to provide electric signals representative of an image of the ridges and valleys of the fingerprint.

[0005] A particularly advantageous approach to multi-biometric fingerprint sensing is disclosed in U.S. Patent No. 7,361,919 to Setlak, which is assigned to the assignee of the present invention and is incorporated in its entirety by reference. The Setlak patent discloses a multi-biometric finger sensor sensing different biometric characteristics of a user's finger that have different matching selectivities.

[0006] A fingerprint sensor may be particularly advantageous for verification and/or authentication in an electronic device, and more particularly, a portable device, for example. Such a fingerprint sensor may be carried by the housing of a portable electronic device, for example, and may be sized to sense a fingerprint from a single-finger. For example, the AES3400 sensor from AuthenTec, Inc. of Melbourne, Florida, is widely used in a variety of notebooks, desktops and PC peripherals. Other fingerprint sensors, for example, the AES850, also from AuthenTec, Inc. of Melbourne, Florida, is a multi-function smart sensor that expands touch-based functionality of touchscreen and QWERTY smartphones with a reduced impact on sensor performance or durability.

[0007] It may be desirable in some applications to sense fingerprints from multiple fingers at a same time or from a relatively large finger sensing area. In some applications, a single large area die may be used to sense multiple fingers. As the area of the finger sensor increases, the yield from each wafer may decrease, thereby rendering the large area integrated circuit much more expensive.

[0008] U.S. Patent No. 5,778,089 to Borza discloses a fingerprint sensing device that includes sensing pads in the form of an array of discrete contact imaging dies that are disposed next to one another in a close, but not contacting relationship. A small gap must be between adjacent dies to avoid contact between adjacent edges. Because of the gaps, fingerprint image data may be lost or may be incomplete. For particular applications, the loss of fingerprint image data may be unacceptable.

[0008a] Reference to any prior art in the specification is not an acknowledgment or suggestion that this prior art forms part of the common general knowledge in any jurisdiction or that this prior art could reasonably be expected to be understood, regarded as relevant, and/or combined with other pieces of prior art by a skilled person in the art.

[0008b] As used herein, the term "comprise" and variations of the term, such as "comprising", "comprises" and "comprised", are not intended to exclude other additives, components, integers or steps.

Summary of the Invention

[0009] In view of the foregoing background, it is therefore an object of the present invention to provide a finger sensor with a reduced amount of fingerprint image data loss, reduced cost, and an increased finger sensing area.

[0010] This and other objects, features, and advantages in accordance with the present invention are provided by an electronic device that may include a housing and circuitry carried by housing. The electronic device may also include a finger sensing device carried by the housing and coupled to the circuitry, for example. The finger sensing device may include a mounting substrate and a semiconductor interposer having a lower surface adjacent the mounting substrate. The finger sensor may also include a plurality of semiconductor finger sensing die on an upper surface of the semiconductor interposer in side-by-side and abutting relation, and defining a finger sensing surface to receive at least one finger thereon. Accordingly, the finger sensing device advantageously has an increased structural rigidity and a reduced amount of lost fingerprint image data as compared to other increased area finger sensing devices, for example.

[0011] The semiconductor interposer and the plurality of semiconductor finger sensing die may each have a coefficient of thermal expansion (CTE) within ±20% of each other. Each semiconductor finger sensing die may include an array of pixels defining a pixel pitch, for example. Each adjacent pair of semiconductor finger sensing die may include opposing edge portions so that a spacing between pixels on opposing edge portions is not greater than 1.5 times the pixel pitch, for example. The opposing edge portions may define missing pixel positions, and a processor may be configured to generate image data for the missing pixel positions based upon adjacent pixels, for example.

[0012] The semiconductor interposer and the plurality of semiconductor finger sensing die may each include a same semiconductor material, for example. The plurality of semiconductor finger sensing die may be arranged in a plurality of rows and a plurality of columns. At least one of the plurality of rows and plurality of columns may not be greater than two, for example.

[0013] Each of the plurality semiconductor finger sensing die may include a plurality of bond pads along at least one side thereof on a periphery of the plurality of semiconductor finger sensing die. The mounting substrate may include one of a ball grid array substrate and a land grid array substrate coupled to the plurality of bond pads, for example. The electronic device may further include a connector carried by the mounting substrate and coupled to the plurality of bond pads.

[0014] The circuitry may include a processor and a wireless transceiver coupled thereto. The electronic device may further include a protection layer over the plurality of semiconductor finger sensing die, for example.

[0015] A method aspect is directed to a method of a method of making finger sensing device. The method may include positioning a semiconductor interposer having a lower surface adjacent a mounting substrate, for example. The method may further include positioning a plurality of semiconductor finger sensing die on an upper surface of the semiconductor interposer in side-by-side and abutting relation to define a finger sensing surface to receive at least one finger thereon.

Brief Description of the Drawings

[0016] FIG. 1 is a schematic plan view of an electronic device including a finger sensing device in accordance with the present invention.

[0017] FIG. 2 is a top plan view of the finger sensing device of FIG. 1.

[0018] FIG. 3 is a cross-sectional view of the finger sensing device of FIG. 2.

[0019] FIG. 4 is an enlarged plan view of abutting edges of edge-abutting finger-sensing die of the multi-finger sensing device of FIG. 2.

[0020] FIG. 5 is a top plan view of another multi-finger sensing device in accordance with another embodiment of the present invention.

[0021] FIG. 6 is a cross-sectional view of a finger sensing device in accordance with another embodiment of the present invention.

[0022] FIG. 7 is a cross-sectional view of a finger sensing device in accordance with another embodiment of the present invention.

[0023] FIG. 8 is a cross-sectional view of a finger sensing device in accordance with another embodiment of the present invention.

Detailed Description of the Preferred Embodiments

[0024] The present invention will now be described more fully hereinafter with reference to the accompanying drawings, in which preferred embodiments of the invention are shown. This invention may, however, be embodied in many different forms and should not be construed as limited to the embodiments set forth herein. Rather, these embodiments are provided so that this disclosure will be thorough and complete, and will fully convey the scope of the invention to those skilled in the art. Like numbers refer to like elements throughout, and prime and multiple prime notation are used to indicate similar elements in different embodiments.

[0025] Referring initially to FIG. 1, an embodiment of a finger sensing device **20** in accordance with the present invention is now described. The finger sensing device **20** is illustratively mounted on an exposed surface of an electronic device **50**. Of course, the finger sensor sensing device **20** can also be used with other portable or stationary electronic devices.

[0026] The electronic device **50** includes a housing **51**, a display **52** carried by the housing, and circuitry **53** also carried by the housing and connected to the display and to the finger sensing device **20**. An array of input keys **54** are also provided and, where, for example, the electronic device **50** is in the form of a cellphone, may be used for dialing and other applications as will be appreciated by those skilled in the art.

[0027] The circuitry **53** may include a processor **57** and memory **55** coupled thereto, for example. The circuitry **53** may also include a wireless transceiver **56** configured to perform wireless communications functions, for example, voice and/or data communications. An antenna **58** is illustratively carried by the housing **51** and is coupled to the wireless transceiver **56**.

[0028] Of course, the finger sensing device **20** may also include circuitry embedded therein and/or in cooperation with the circuitry **53** to provide menu navigation and selection functions, tactile feedback, and/or power up functions as will be appreciated by those skilled in the art.

[0029] Referring additionally to FIGS. 2-3, the finger sensing device **20** includes a mounting substrate **21**. The mounting substrate may be ceramic, for example. The mounting substrate **21** may be another material as will be appreciated by those skilled in the art.

[0030] The finger sensing device **20** also includes a semiconductor interposer **22** having a lower surface adjacent said mounting substrate **21**. The semiconductor interposer **22** may be silicon, for example, or another semiconductor material, as will be appreciated by those skilled in the art. The semiconductor interposer **21** may be 600 microns thick, for example. The semiconductor interposer **22** may be coupled to the mounting substrate **21** with an adhesive material, for example, an epoxy.

[0031] The finger sensing device **20** also includes semiconductor finger sensing die **23** on an upper surface of the semiconductor interposer **22**. The semiconductor interposer **22** and semiconductor finger sensing die **23** may each include a same semiconductor material. For example, the semiconductor interposer **22** and the semiconductor finger sensing die **23** may each be silicon. Of course, the semiconductor interposer **22** and the semiconductor finger sensing die **23** may be another semiconductor material. As will we appreciated by those skilled in the art, in some embodiments, the semiconductor interposer **22** and the semiconductor finger sensing die **23** may include different materials, but may have respective coefficients of thermal expansion (CTEs) that are within a range, for example, ±20% of each other, and more preferably ±10% of each other. Of course, in some embodiments, the semiconductor interposer **22** and the semiconductor finger sensing die **23** may have a same CTE, for example, when the semiconductor interposer and the semiconductor finger sensing die are each silicon. As will be appreciated by those skilled in the art, as the number of finger sensing die **23** carried by the semiconductor interposer **22** increase, it may be desirable to have respective CTEs within a more narrow range, for example. Additionally, matching of CTEs, for example, may increase the structural rigidity of the finger sensing device **20**. The semiconductor interposer **22** and the semiconductor finger sensing die **23** may each have a CTE within a different range of each other, such as, for example ±40%, or another range.

[0032] The semiconductor finger sensing die **23** are arranged in side-by-side and abutting relation, and more particularly, are arranged in rows and columns. The side-by-side and abutting relation of the semiconductor finger sensing die **23** advantageously define a finger sensing surface sufficient in area to receive multiple fingers **61** thereon, for example.

[0033] Illustratively, the semiconductor finger sensing die **23** are configured in two rows and three columns for a total of six semiconductor finger sensing die (FIG. 2). In this configuration, each semiconductor finger sensing die **23** is an exterior semiconductor finger sensing die, that is, each has an edge on the periphery of the sensing surface. The six semiconductor finger sensing die **23** may define a finger sensing surface to receive two fingers **61**, for example. Of course, in other embodiments, the semiconductor finger sensing die **23** may be arranged in other configurations, as will be described in further detail below. An exemplary semiconductor finger sensing die **23** may be about 0.5 inches wide by 0.8 inches long.

[0034] Referring now additionally to FIG. 4, each semiconductor finger sensing die **23** includes an array of pixels **24** defining a pixel pitch. The pixels **24** may be electric-field sensing pixels, for example, as described in U.S. Patent No. 5,953,441 to Setlak. Alternatively, or additionally, the pixels **24** may be capacitive sensing pixels, as described in U.S. Patent No. 6,927,581 to Gozzini, for example, and assigned to the assignee of the present invention and the entire contents of which are herein incorporated by reference.

[0035] An exemplary pitch **P** between adjacent pixels may be 50.8

microns, for example. Each adjacent pair of semiconductor finger sensing die **23** has opposing edge portions so that spacing between pixels on opposing edge portions **VP** is not greater than 1.5 times the pixel pitch **P**. In other words, the spacing between pixels on opposing edge portions **VP** may be less than or equal to about 76.2 microns. In some embodiments, it may be more preferable that each adjacent pair of semiconductor finger sensing die **23** has opposing edge portions so that spacing between pixels on opposing edge portions **VP** is not greater than the pixel pitch **P**, i.e., about 50.8 microns. This advantageously reduces any lost image data to a single pixel row or column, for example. Each semiconductor sensing die **23** is configured to sense adjacent portions of the multiple fingers.

[0036] The opposing edge portions define missing pixel positions, and in particular, a row or column of missing pixel portions. In other words, the edges where adjacent semiconductor finger sensing die **23** abut would typically include a row or column of pixels if the adjacent die were a single die, for example. The processor **57** is configured to generate image data for the missing pixel positions based upon adjacent pixels. The processor **57** may generate the image data for the missing pixel positions by interpolating the image data from adjacent pixels, for example. In other words, the processor **57** may use adjacent pixels to sense dead space, which, for example, may be particularly advantageous with a relatively thick protection layer or coating. Alternatively, or additionally, the processor **57** may also generate the image data from the missing pixel positions by using weighting functions, as will be appreciated by those skilled in the art. Advantageously, the image data may not be completely lost, which may increase accuracy, for example to an acceptable threshold for a particular application.

[0037] The processor **57** may also be configured to cooperate with the semiconductor finger sensing die **23** and the memory **55** to perform an authentication function, for example. The processor **57** may also cooperate with the semiconductor finger sensing die **23** to perform a spoof detection function. Other and/or additional functions may be performed by the processor **57**, as will be appreciated by those skilled in the art.

[0038] Each of the semiconductor finger sensing die **23** also includes bond pads **25** along a side of the outer periphery of the semiconductor finger sensing die (FIG. 2). Of course, in other embodiments, the bond pads **25** may be along one or any number of peripheral sides of the semiconductor finger sensing die **23**. As noted above, each semiconductor finger sensing die **23** is an exterior finger sensing die. As will be appreciated by those skilled in the art, this configuration advantageously allows each semiconductor finger sensing die **23** to have bond pads **25** along a peripheral side thereof, as will be appreciated by those skilled in the art.

[0039] The mounting substrate **21** further includes a mounting feature in the form of a ball **32** grid array coupled to the bond pads **25** (FIG. 3). In other embodiments, the mounting feature may be in the form of a land grid array coupled to the bond pads **25**. Of course, the mounting substrate **21** may include additional or other types of mounting arrangements or features, as will be appreciated by those skilled in the art.

[0040] The semiconductor interposer **22** and mounting substrate **21** illustratively include conductive vias **33** for coupling the bond pads **25** to the mounting substrate. In particular, the vias **33** couple the bond pads **25** to the mounting feature, i.e., the ball grid array via bond wires **36**.

[0041] A protection layer **31** is illustratively over the semiconductor finger sensing die **23** (FIG. 3). The protection layer **31** may be an epoxy, for example. The protection layer **31** may be polyimide, glass, or other protective material, for example. As will be appreciated by those skilled in the art, the protection layer **31** advantageously provides increased protection to the finger sensing die **23** from damage, such as for example, from scratching. The protection layer may provide increased structural rigidity.

[0042] A frame **34** or bezel may surround the semiconductor finger sensing die **23** (FIG. 3). The frame **34** may provide additional structural rigidity. Of course, in some embodiments, the mounting substrate **21** may extend upwardly to surround the semiconductor finger sensing die **23**. Additionally, a drive ring may be used, as will be appreciated by those skilled in the art. In other embodiments, the frame **34** may provide the drive ring.

[0043] As will be appreciated by those skilled in the art, a single large area finger sensing die with a plurality of pixels, for example, to sense multiple fingers, may be particularly susceptible to defects. More particularly, as the size of the finger sensing die increases, a defect in a single pixel, for example, may cause the entire finger sensing die to fail. The present embodiments advantageously use smaller die fabrication techniques with an understood yield curve. Additionally, the placement of the finger sensing die **23** and the cooperation of the processor **57** may advantageously allow compliance with image quality specifications, for example, as defined by PIV, Appendix F, and FIPS 201 standards, as will be appreciated by those skilled in the art.

[0044] Referring now to FIG. 5, in another embodiment, the semiconductor finger sensing die **23'** are configured in four rows and four columns for a total of sixteen semiconductor finger sensing die and are mounted on an upper surface of a silicon interposer **22'** similarly to the embodiments described above with respect to FIGS. 1-4. The sixteen semiconductor finger sensing die **23'** may define a finger sensing surface to receive four or more fingers, for example. The sixteen semiconductor finger sensing die **23'** may total about 3 inches high and 3.2 inches wide. As will be appreciated by those skilled in the art, the middle die are not accessible at an edge thereof, for example, for bond pads, and thus cannot be used. Other die assembly techniques are used for these die, for example, through silicon vias (TSVs), as will be appreciated by those skilled in the art.

[0045] Referring now to FIG. 6, in another embodiment, the semiconductor interposer **22''** may be smaller than the mounting substrate **21''**. This advantageously allows the frame **34''** to couple to an upper surface of the mounting substrate **21''** adjacent the lower surface of the semiconductor interposer **22''**. The frame **34''** may be coupled to the mounting substrate **21''** by an adhesive layer, for example, epoxy.

[0046] The mounting substrate **21''** illustratively carries a connector **37''** and its flexible cable, for example, such as for a universal serial bus (USB) connection.

[0047] Referring now to FIG. 7, the semiconductor interposer **22'''** may include circuitry **38'''** carried by an upper surface thereof. The circuitry **38'''** may be active circuitry, for example, for processing image or pixel data. The circuitry **38'''** may include other circuitry and, in some embodiments, may cooperate with the processor to perform any of the above-noted functions. The circuitry **38'''** may advantageously enhance the functionality of the finger sensing device **20'''**, as will be appreciated by those skilled in the art.

[0048] Referring now to FIG. 8, another embodiment where middle die are not accessible for bond pads, (i.e, there are more than two rows and/or two columns), is described. Where the middle die are not accessible, TSVs **39''''** may be configured to route connections of the middle die to a conductive trace **40''''** on the top of the semiconductor interposer **22''''**.

[0049] Another aspect is directed to a method of making a finger sensing device **20** that includes positioning a semiconductor interposer **22** having a lower surface adjacent a mounting substrate **21**. The method also includes positioning semiconductor finger sensing die **23** on an upper surface of the semiconductor interposer **22** in side-by-side and abutting relation to define a finger sensing surface to at least one finger thereon.

[0050] As will be appreciated by those skilled in the art, a dicing saw or a laser may be used to singulate silicon die from a wafer with a placement tolerance of about 5 microns. Thus, the edges of the finger sensing die **23** may be defined with increased precision. The wafer from which the finger sensing die **23** are cut is about 700 microns thick, which allows sufficient material to achieve a repeatable die butting placement, as described above.

[0051] While several semiconductor finger sensing die arrangements have been described herein, which may be particularly advantageous for sensing multiple fingers, it will be appreciated by those skilled in the art that the finger sensing device may include only two semiconductor finger sensing die for sensing a single finger. These single finger embodiments may benefit from a lower cost due to better wafer yield. Many modifications and other embodiments of the invention will come to the mind of one skilled in the art having the benefit of the teachings presented in the foregoing descriptions and the associated drawings. Therefore, it is understood that the invention is not to be limited to the specific embodiments disclosed, and that modifications and embodiments are intended to be included within the scope of the appended claims.

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THE CLAIMS DEFINING THE INVENTION ARE AS FOLLOWS:

1. A finger sensing device comprising:
a mounting substrate;
a semiconductor interposer having a lower surface adjacent said mounting substrate; and
a plurality of semiconductor finger sensing die on an upper surface of said semiconductor interposer in side-by-side and abutting relation, and defining a finger sensing surface to receive at least one finger thereon.

2. The finger sensing device of Claim 1, wherein said semiconductor interposer and said plurality of semiconductor finger sensing die each having a coefficient of thermal expansion (CTE) within ±20% of each other.

3. The finger sensing device of Claim 1, wherein each semiconductor finger sensing die includes an array of pixels defining a pixel pitch; and wherein each adjacent pair of semiconductor finger sensing die comprises opposing edge portions so that a spacing between pixels on opposing edge portions is not greater than 1.5 times the pixel pitch.

4. The finger sensing device of Claim 1, wherein said semiconductor interposer and said plurality of semiconductor finger sensing die each comprises a same semiconductor material.

5. The finger sensing device of Claim 1, wherein said plurality of semiconductor finger sensing die are arranged in a plurality of rows and a plurality of columns.

6. The finger sensing device of Claim 5, wherein at least one of the plurality of rows and plurality of columns is not greater than two.

7. The finger sensing device of Claim 1, wherein each of said plurality semiconductor finger sensing die comprises a plurality of bond pads along at least one side thereof on a periphery of said plurality of semiconductor finger sensing die.

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8. The finger sensing device of Claim 7, wherein said mounting substrate comprises one of a ball grid array substrate and a land grid array substrate coupled to said plurality of bond pads.

9. The finger sensing device of Claim 7, further comprising a connector carried by said mounting substrate and coupled to said plurality of bond pads.

10. The finger sensing device of Claim 1, further comprising a protection layer over said plurality of semiconductor finger sensing die.

11. An electronic device comprising:

a housing;

circuitry carried by said housing; and

a finger sensing device carried by said housing and coupled to said circuitry, said finger sensing device comprising a finger sensing device as claimed in any one of the preceding claims.

12. The electronic device of Claim 11, wherein each semiconductor finger sensing die includes an array of pixels defining a pixel pitch; and wherein each adjacent pair of semiconductor finger sensing die comprises opposing edge portions so that a spacing between pixels on opposing edge portions is not greater than 1.5 times the pixel pitch and wherein said opposing edge portions define missing pixel positions; and further comprising a processor configured to generate image data for the missing pixel positions based upon adjacent pixels.

13. The electronic device of Claim 11, wherein said circuitry comprises a processor and a wireless transceiver coupled thereto.

14. A method of making a finger sensing device comprising:

positioning a semiconductor interposer having a lower surface adjacent a mounting substrate; and

positioning a plurality of semiconductor finger sensing die on an upper surface of the semiconductor interposer in side-by-side and abutting relation to define a finger sensing surface to at least one finger thereon.

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15. The method of Claim 14, wherein the semiconductor interposer and the plurality of semiconductor finger sensing die each having a coefficient of thermal expansion (CTE) within ±20% of each other.

16. The method of Claim 14, wherein each semiconductor finger sensing die includes an array of pixels defining a pixel pitch; and wherein each adjacent pair of semiconductor finger sensing die comprises opposing edge portions so that a spacing between pixels on opposing edge portions is not greater than 1.5 times the pixel pitch.

17. The method of Claim 14, wherein the semiconductor interposer and the plurality of semiconductor finger sensing die each comprises a same semiconductor material.

18. The method of Claim 14, wherein the plurality of semiconductor finger sensing die are arranged in a plurality of rows and a plurality of columns.

19. The method of Claim 18, wherein at least one of the plurality of rows and plurality of columns is not greater than two.

20. The method of Claim 14, further comprising a forming a protection layer over the plurality of semiconductor finger sensing die.

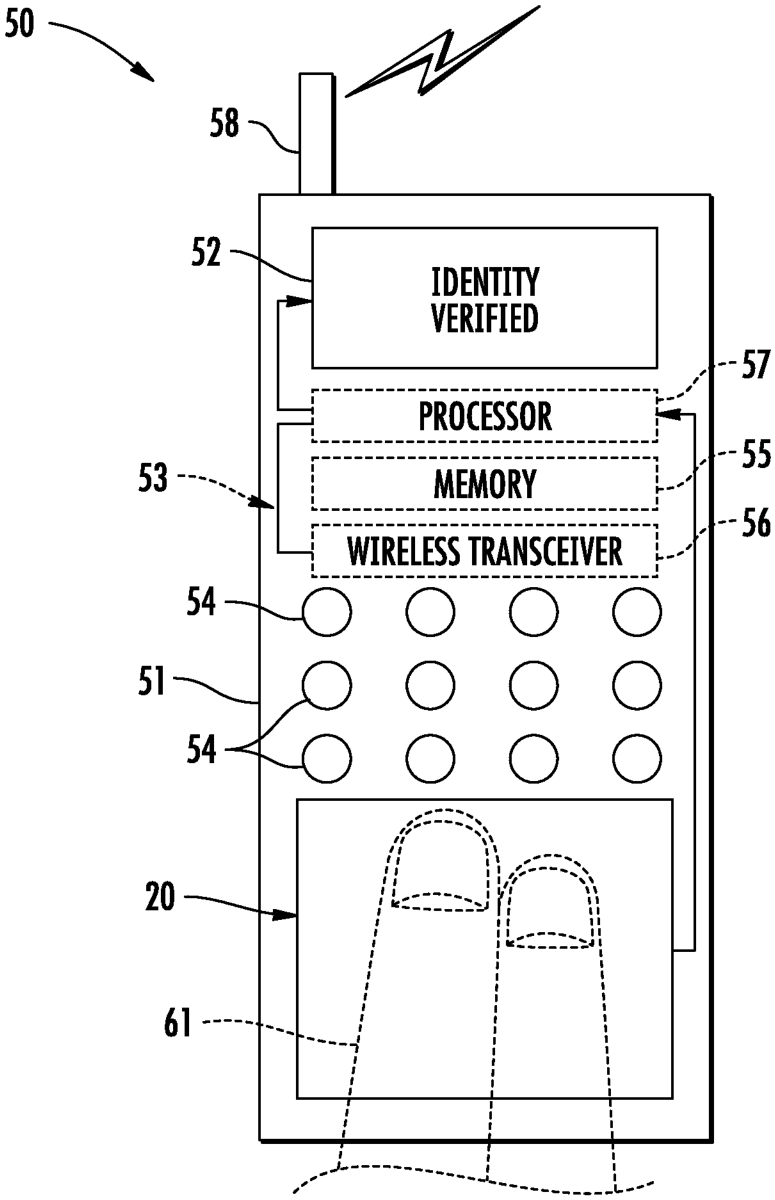
50
58
52
IDENTITY VERIFIED
57
PROCESSOR
55
MEMORY
53
WIRELESS TRANSCEIVER
56
54
51
54
20
61

FIG. 1

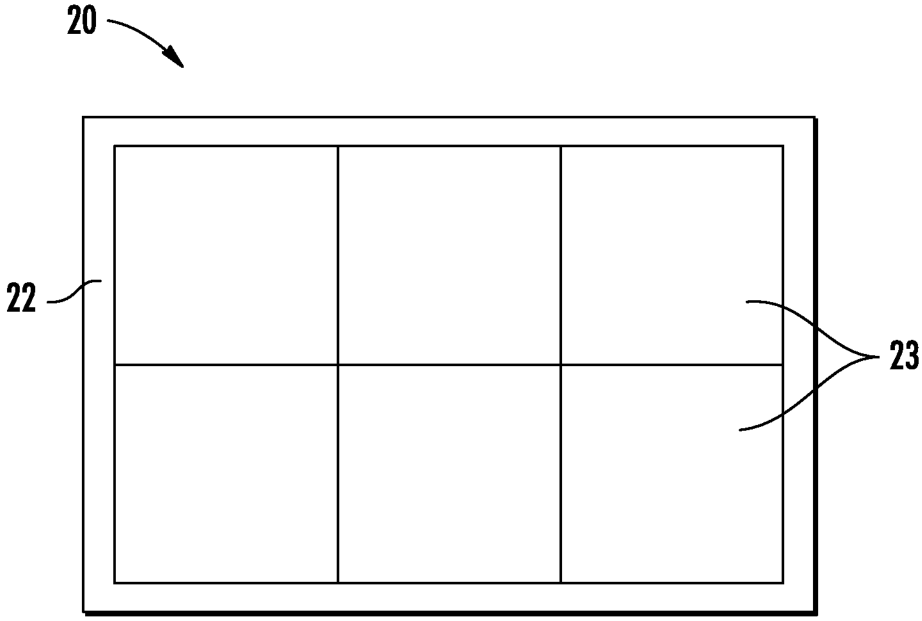

FIG. 2

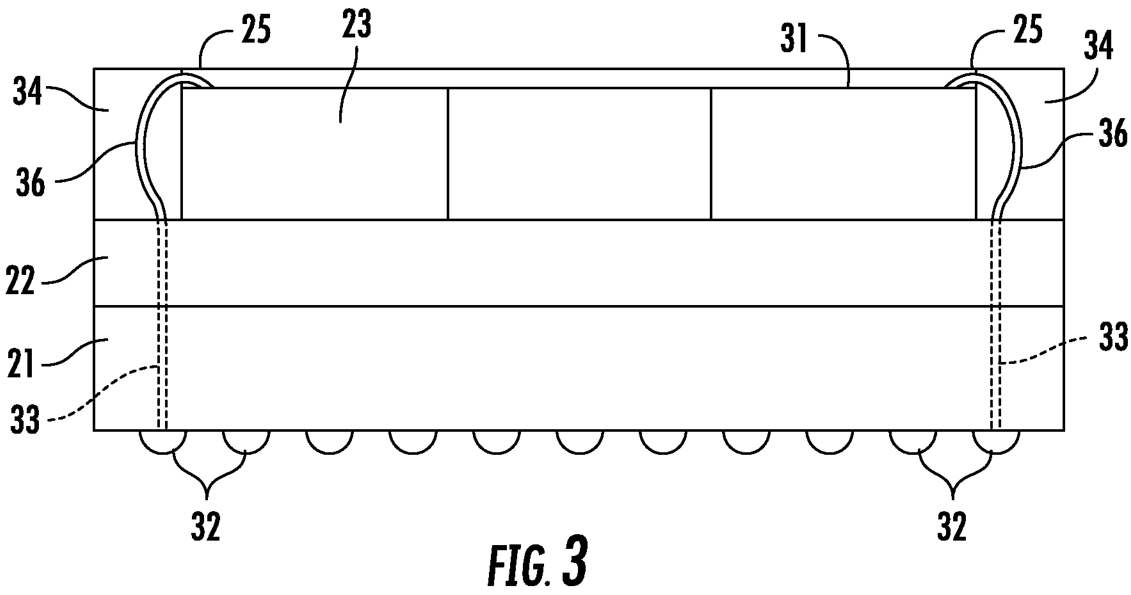

FIG. 3

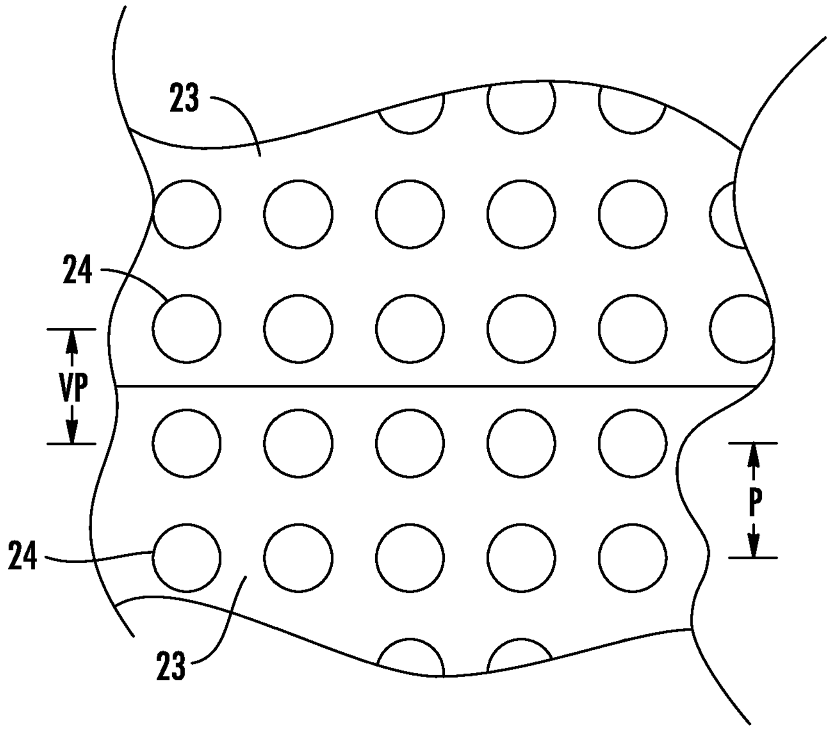

FIG. 4

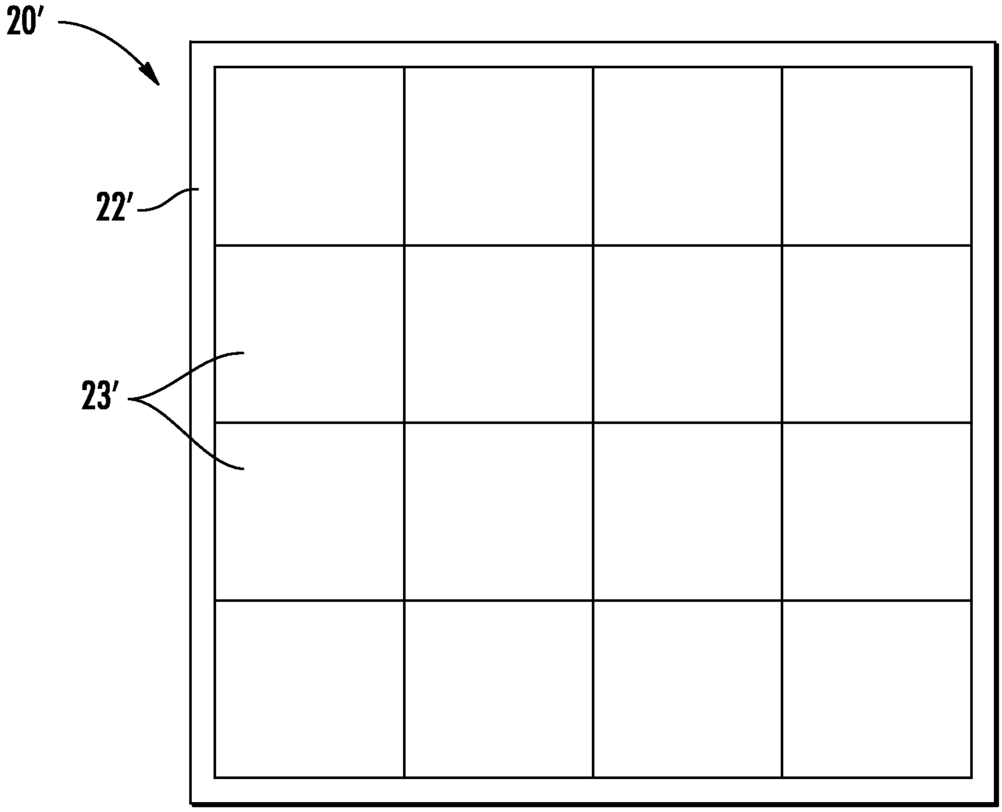

FIG. 5

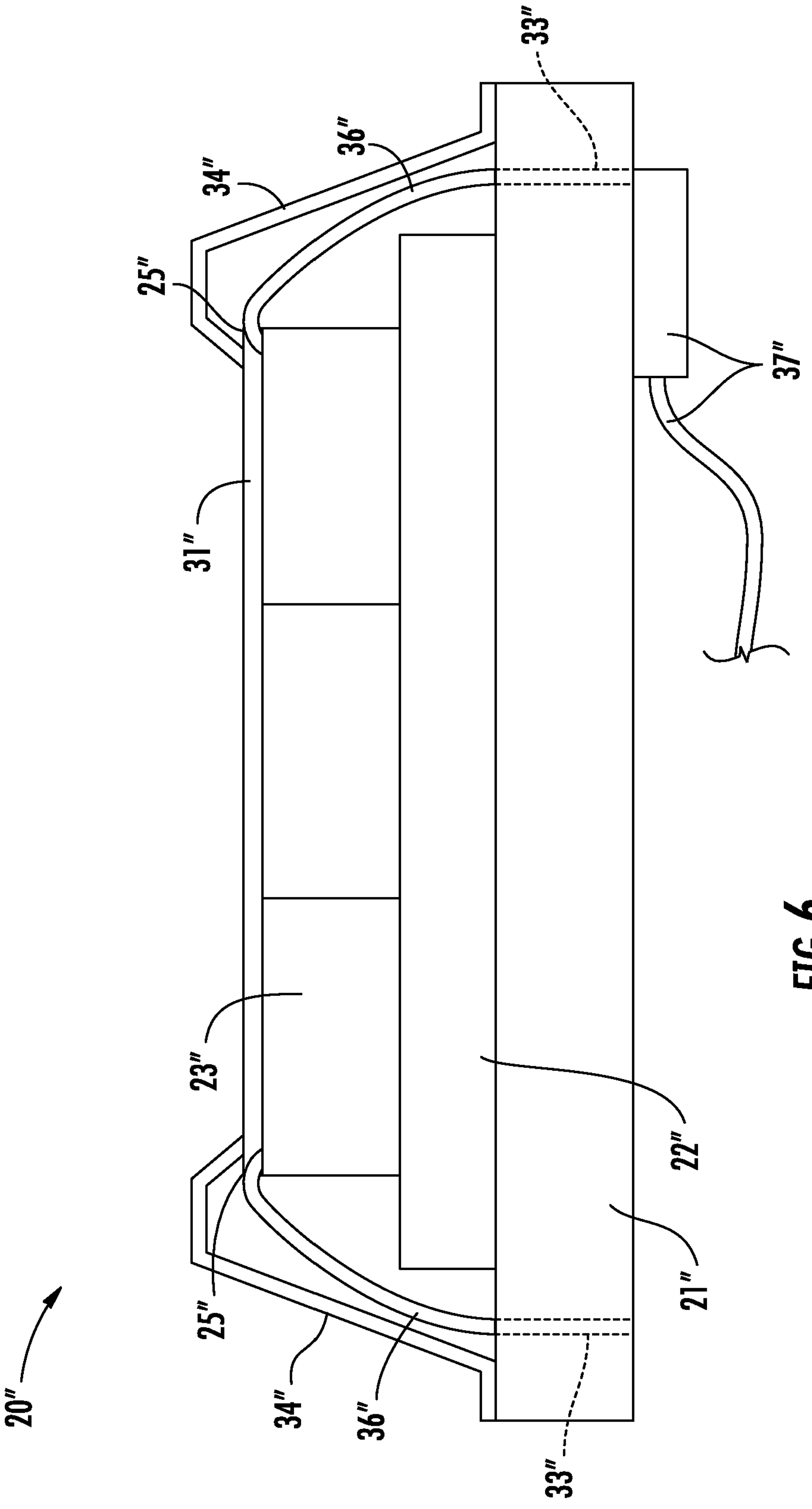

FIG. 6

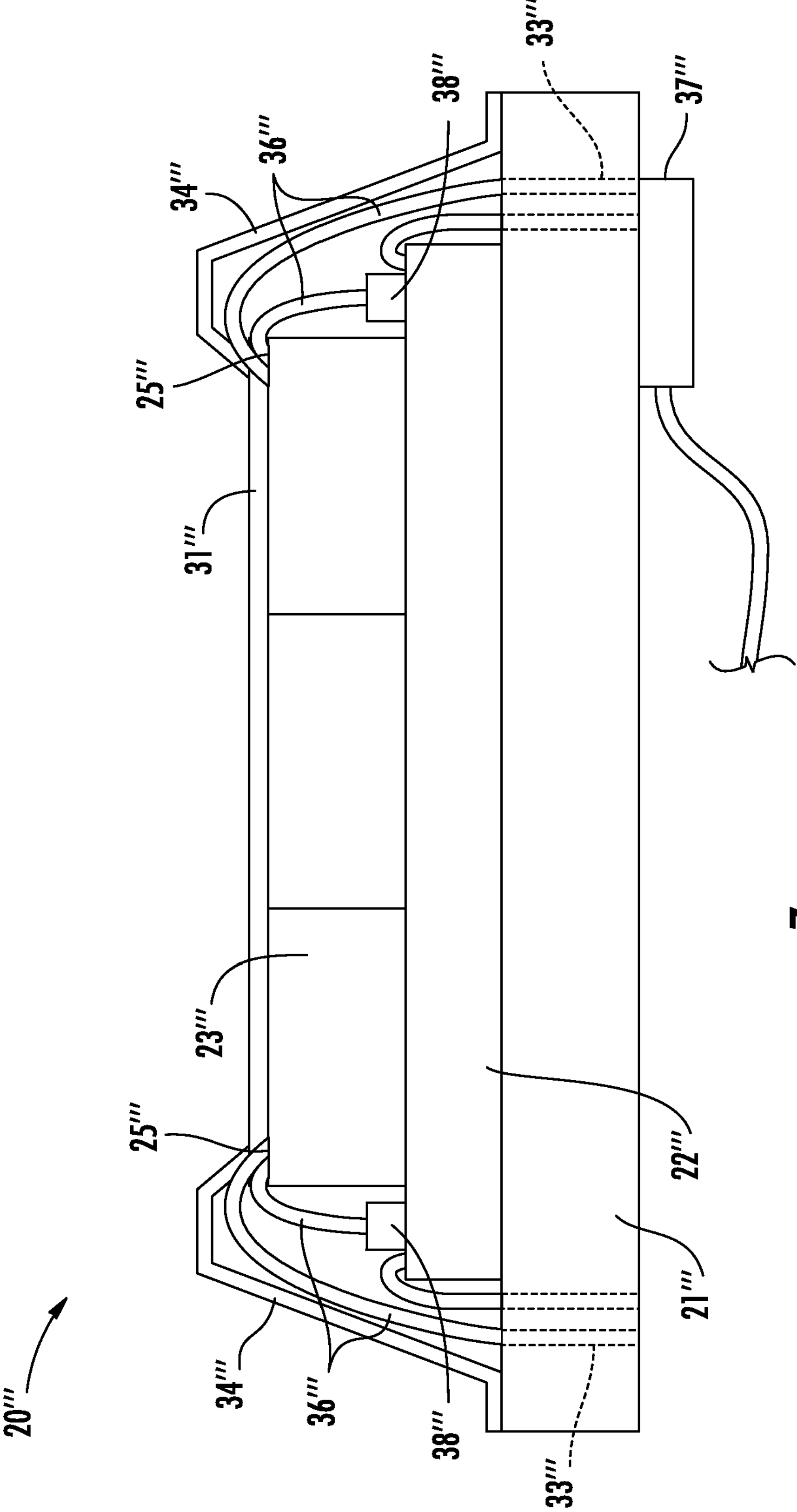

FIG. 7

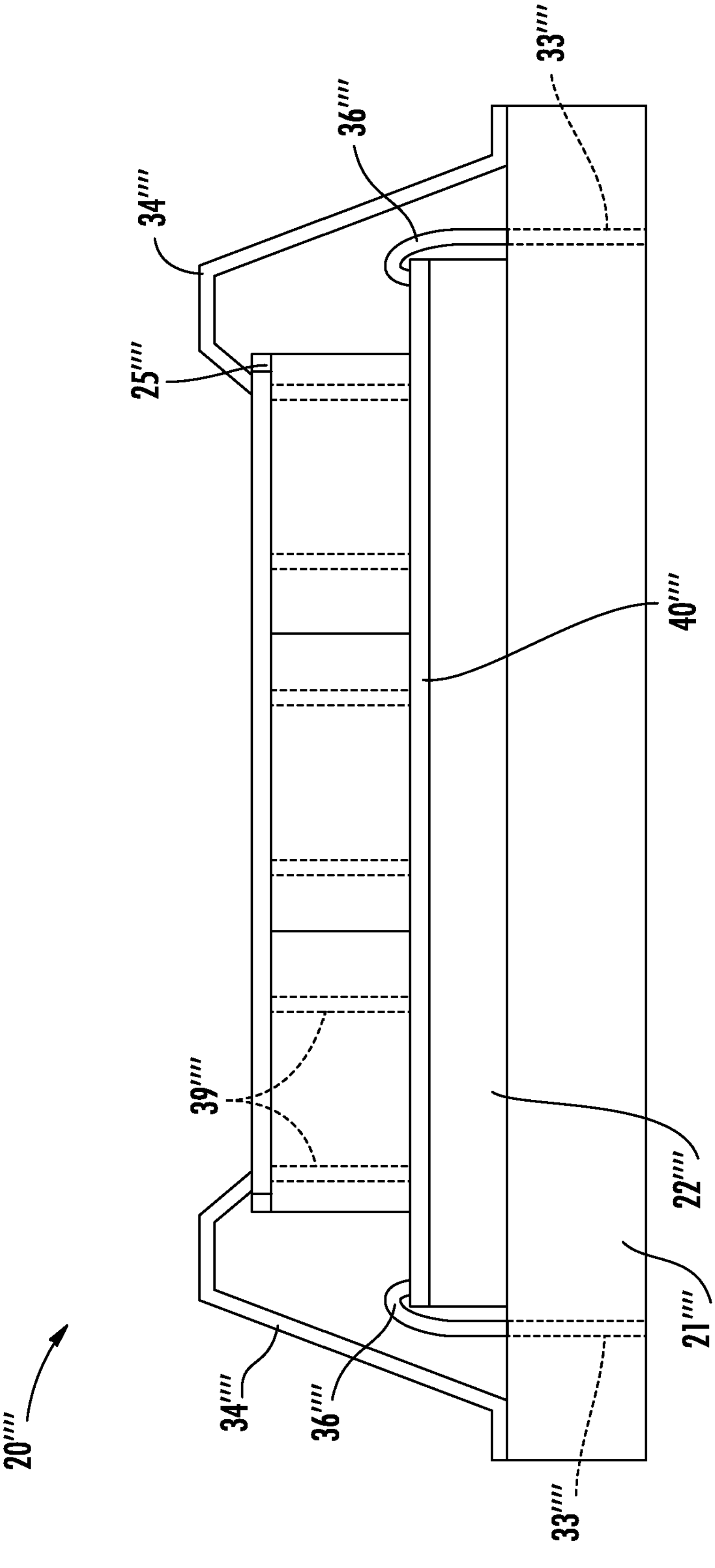

FIG. 8