



US006647794B1

(12) **United States Patent**
Nelson et al.

(10) **Patent No.:** **US 6,647,794 B1**
(45) **Date of Patent:** **Nov. 18, 2003**

(54) **ABSOLUTE PRESSURE SENSOR**

(75) Inventors: **Daniel S. Nelson**, Chaska, MN (US);
David J. Hillman, Prescott, WI (US);
John McIntire, Chanhassen, MN (US)

(73) Assignee: **Rosemount Inc.**, Eden Prairie, MN (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **10/139,892**

(22) Filed: **May 6, 2002**

(51) Int. Cl.⁷ **G01L 9/12**

(52) U.S. Cl. **73/718; 73/724**

(58) Field of Search **73/718, 724, 756, 73/708; 361/283.1–283.4**

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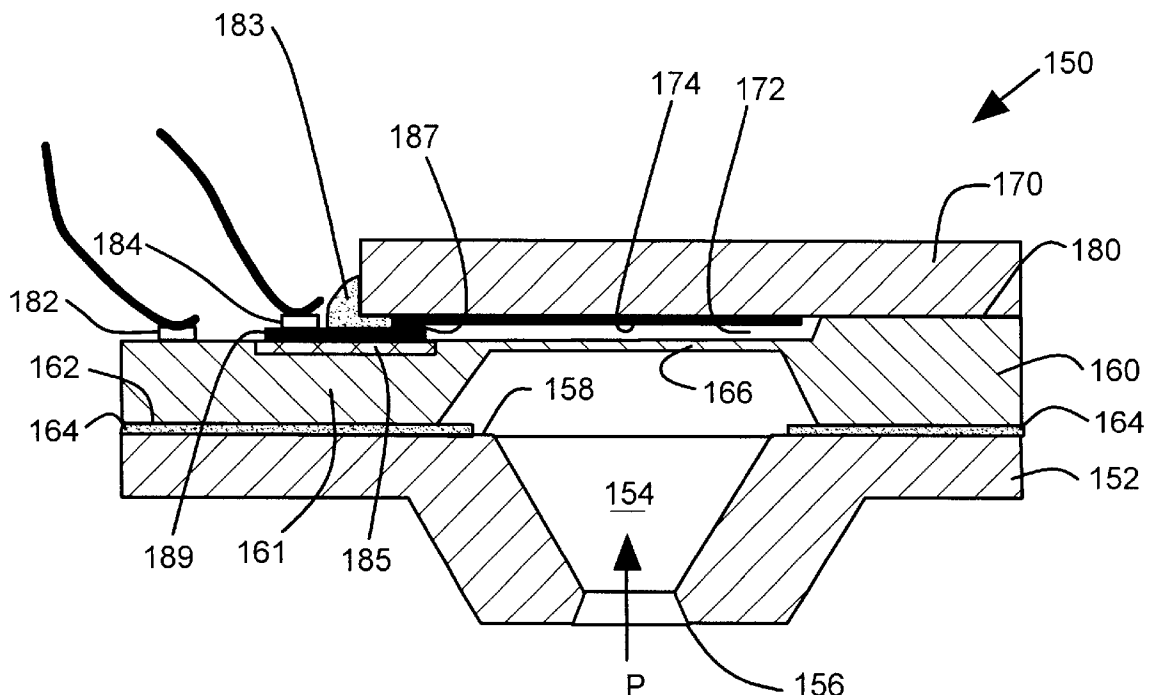
Primary Examiner—William Oen

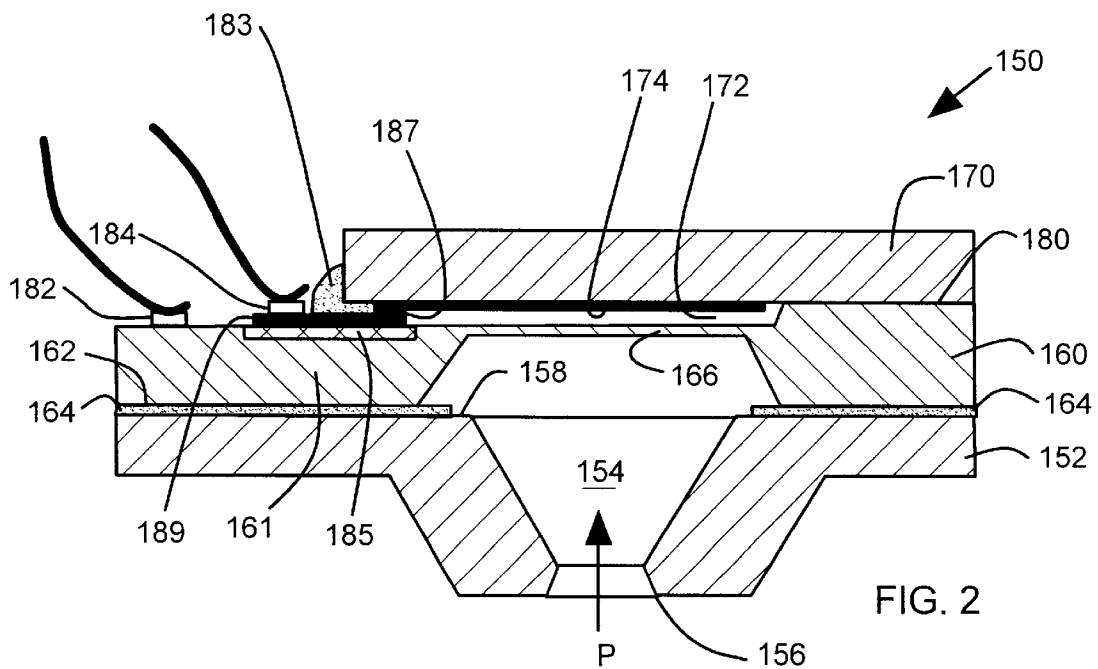
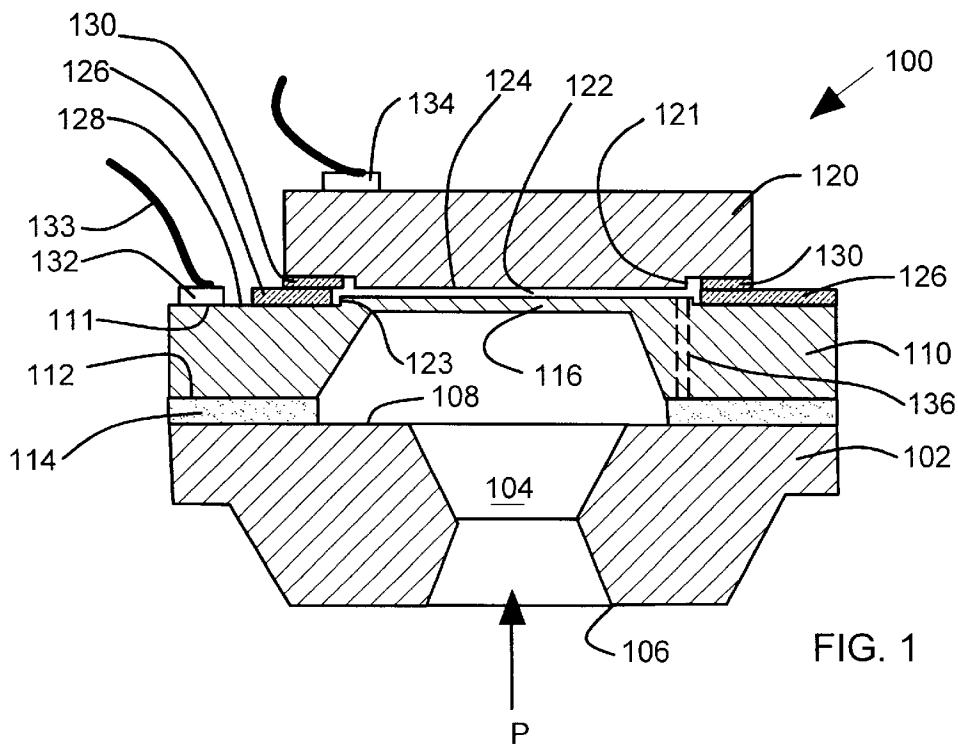
(74) *Attorney, Agent, or Firm*—Westman, Champlin & Kelly

(57) **ABSTRACT**

A barometric pressure sensor including a base layer, a sensor layer and a reference layer. The base layer has a passageway between a pressure inlet and a mounting face. The sensor layer is bonded by an insulating bond to the mounting face and includes a conductive diaphragm. The reference layer is mounted on the sensor layer to form a reference vacuum cavity. The reference layer includes a conducting surface facing the conductive diaphragm across the reference vacuum cavity to form a pressure sensing capacitor.

25 Claims, 9 Drawing Sheets





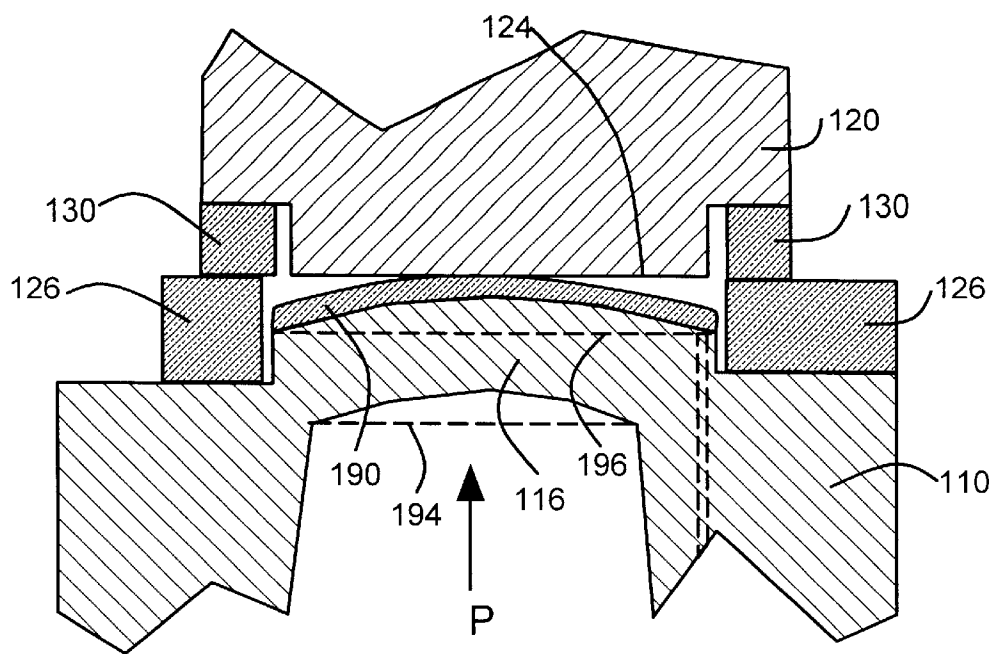


FIG. 3

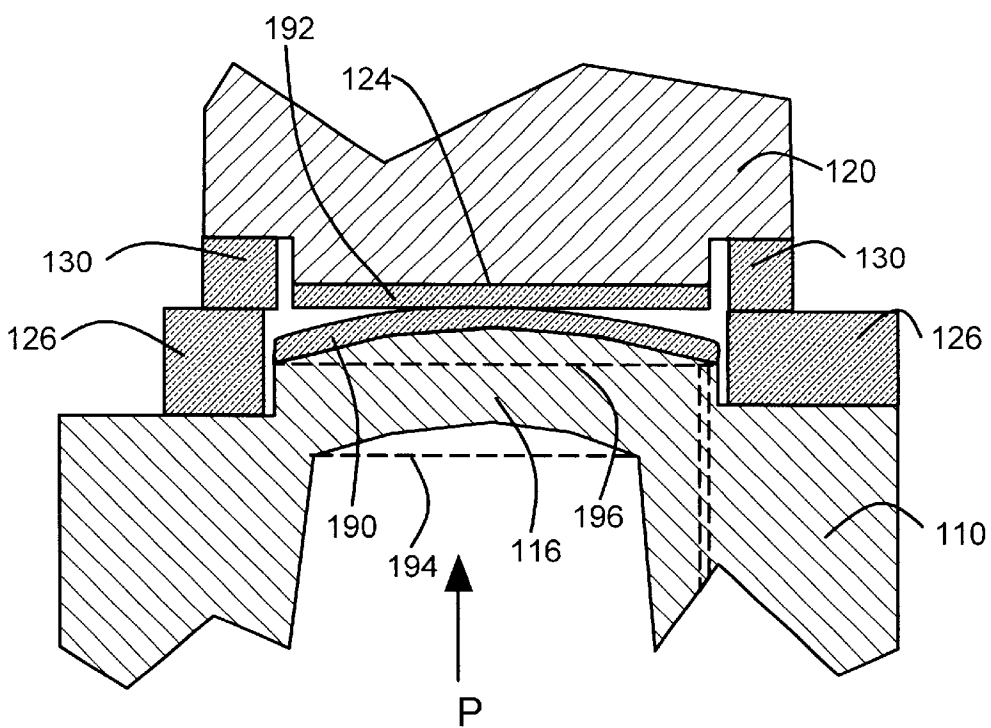


FIG. 4

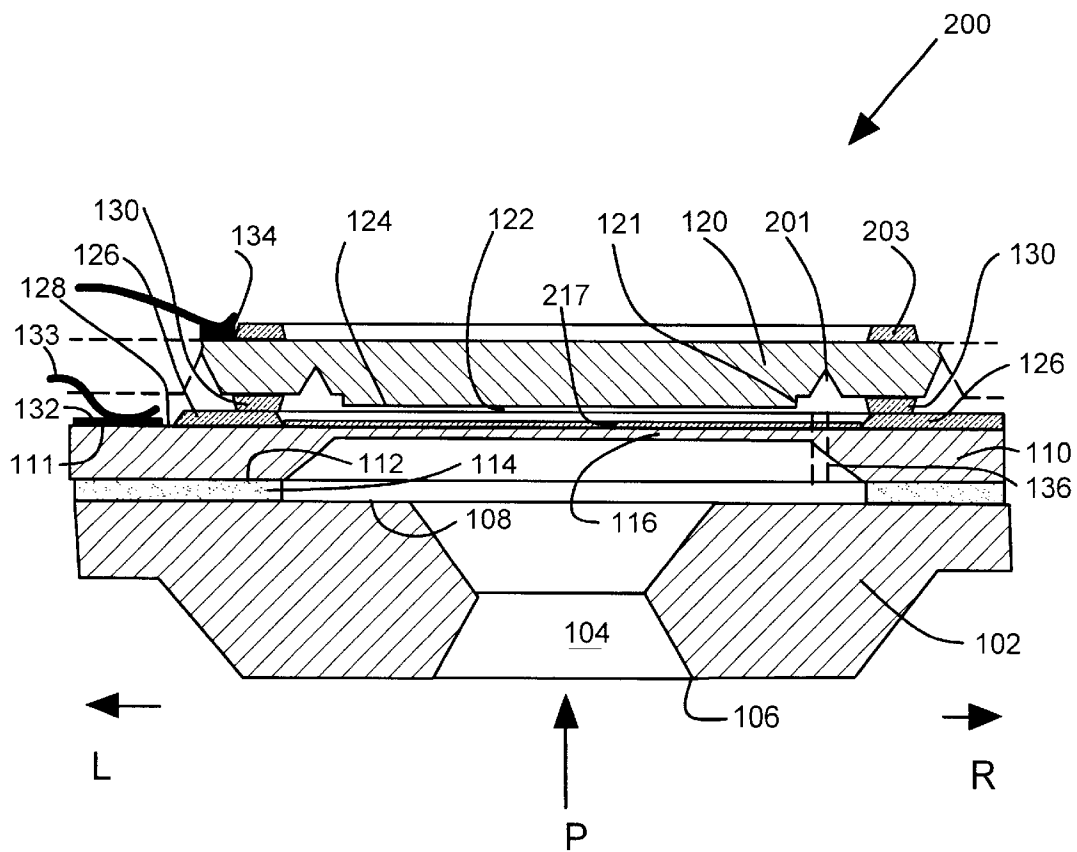


FIG. 5

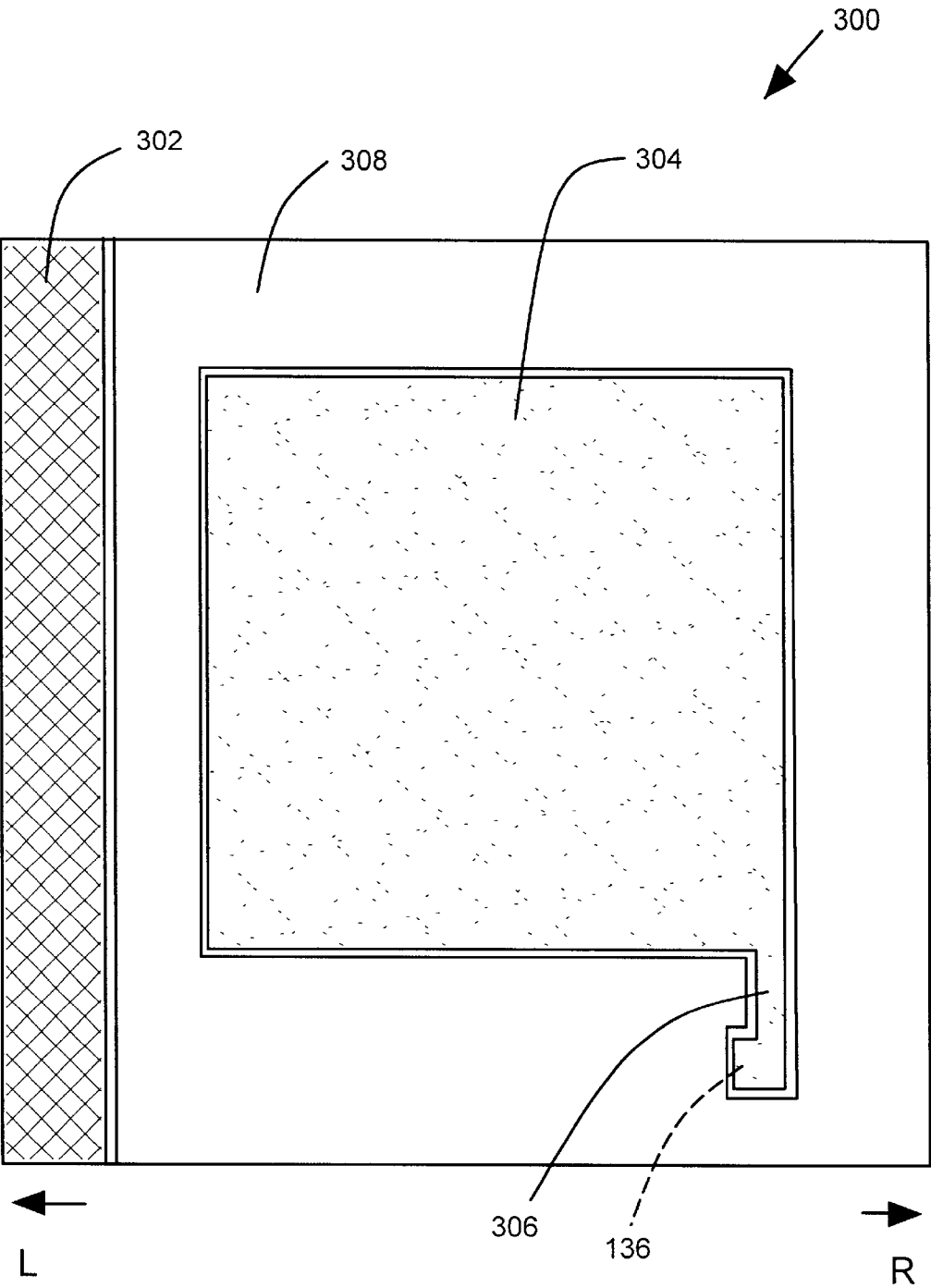


FIG. 6

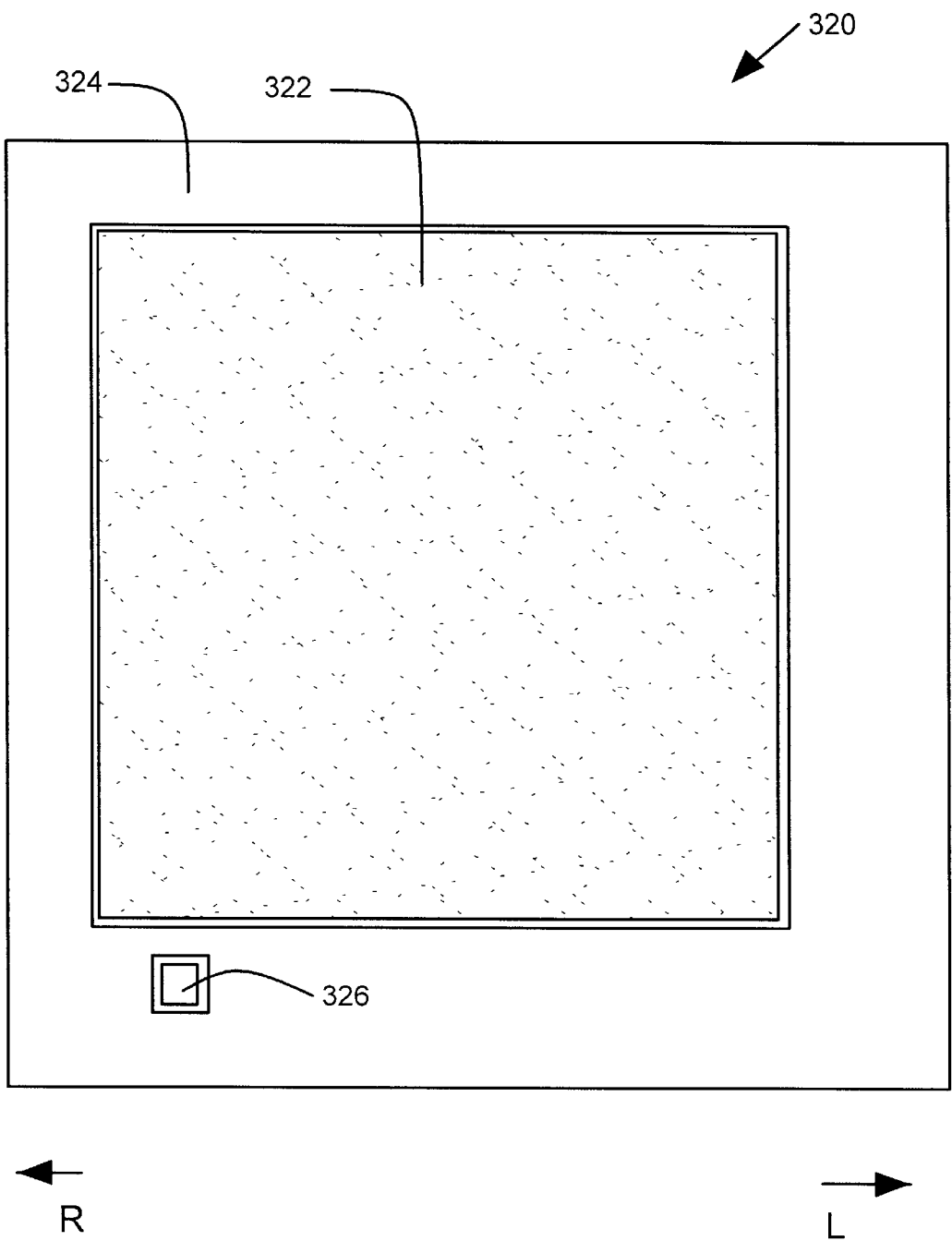


FIG. 7

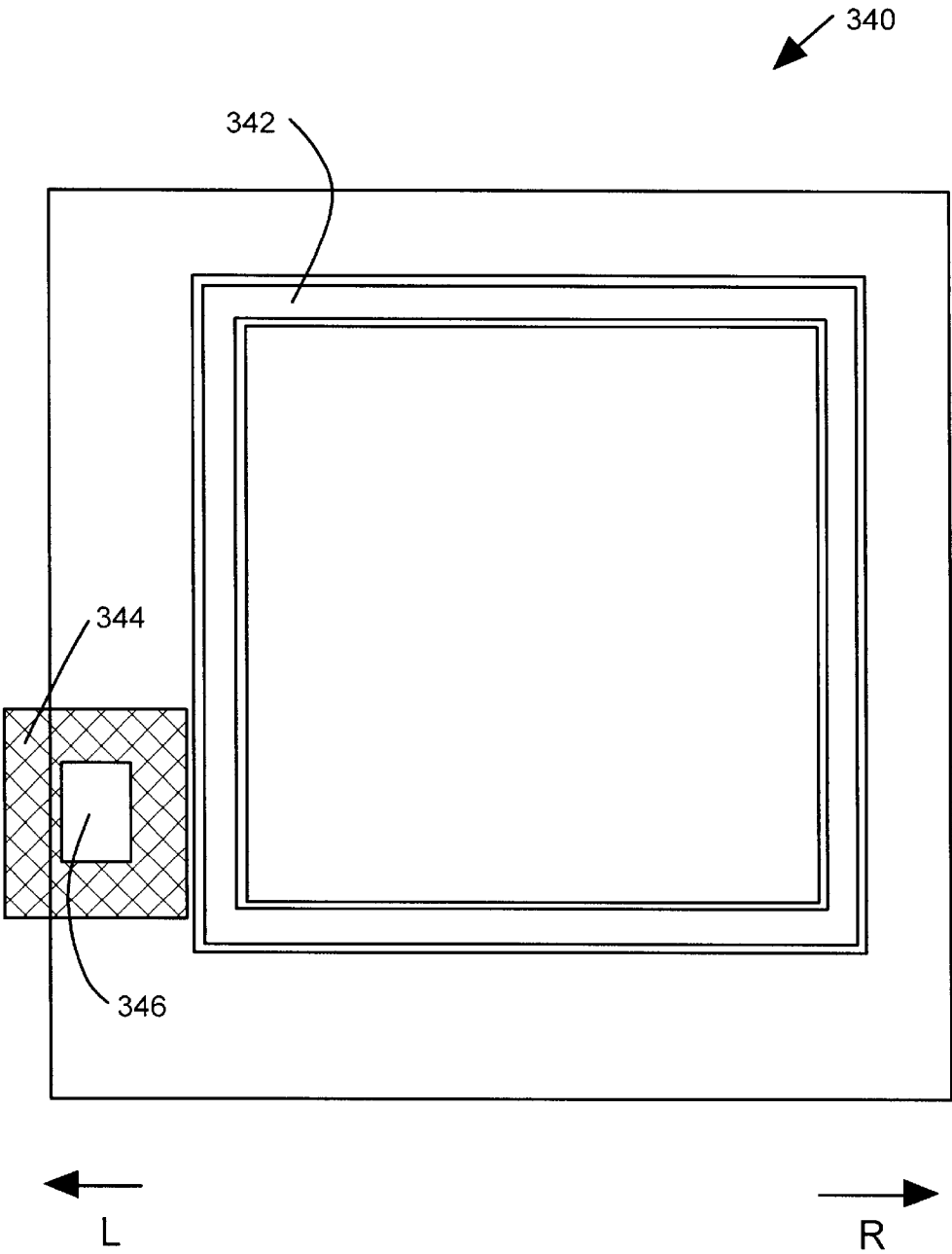


FIG. 8

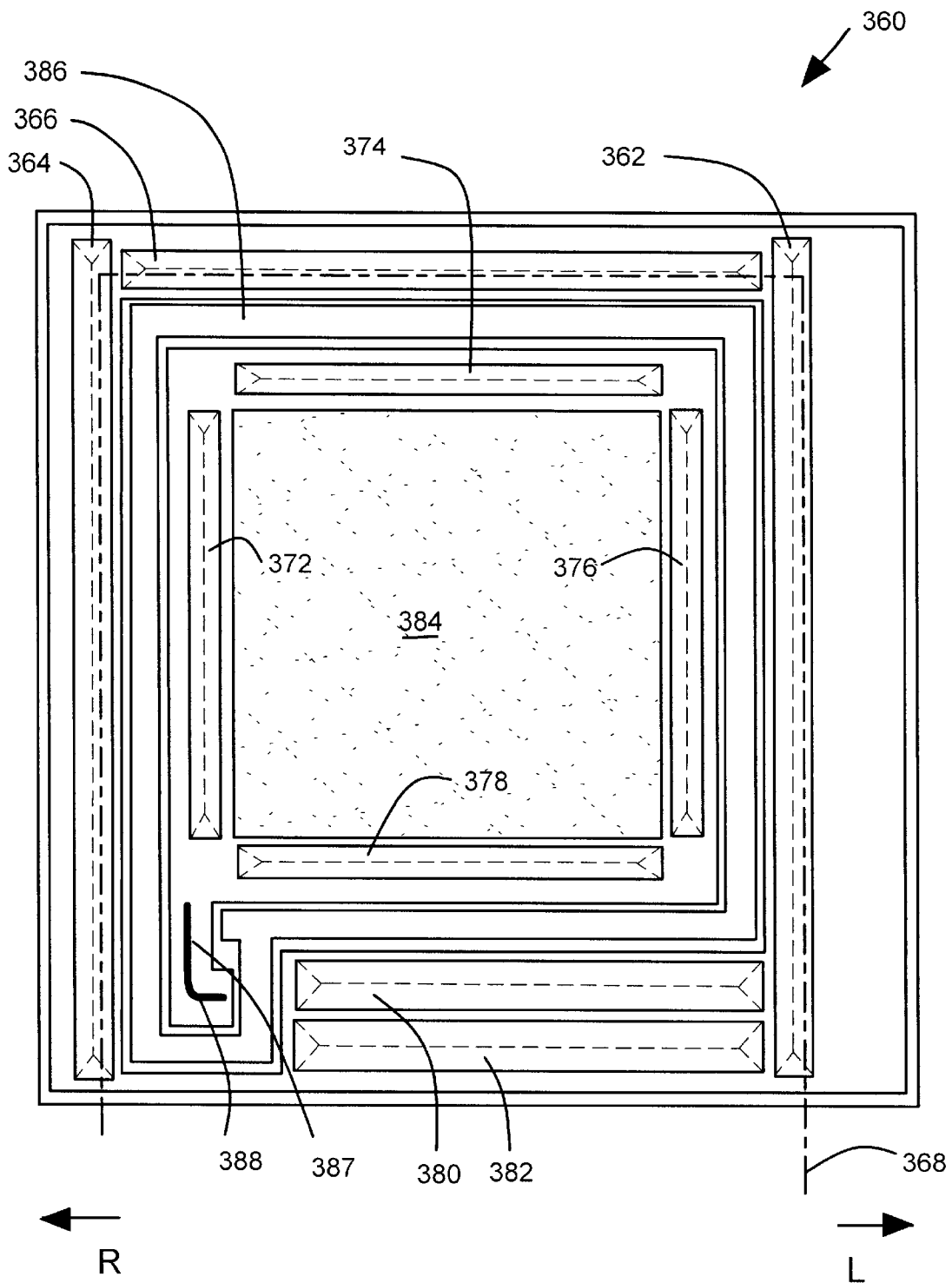


FIG. 9

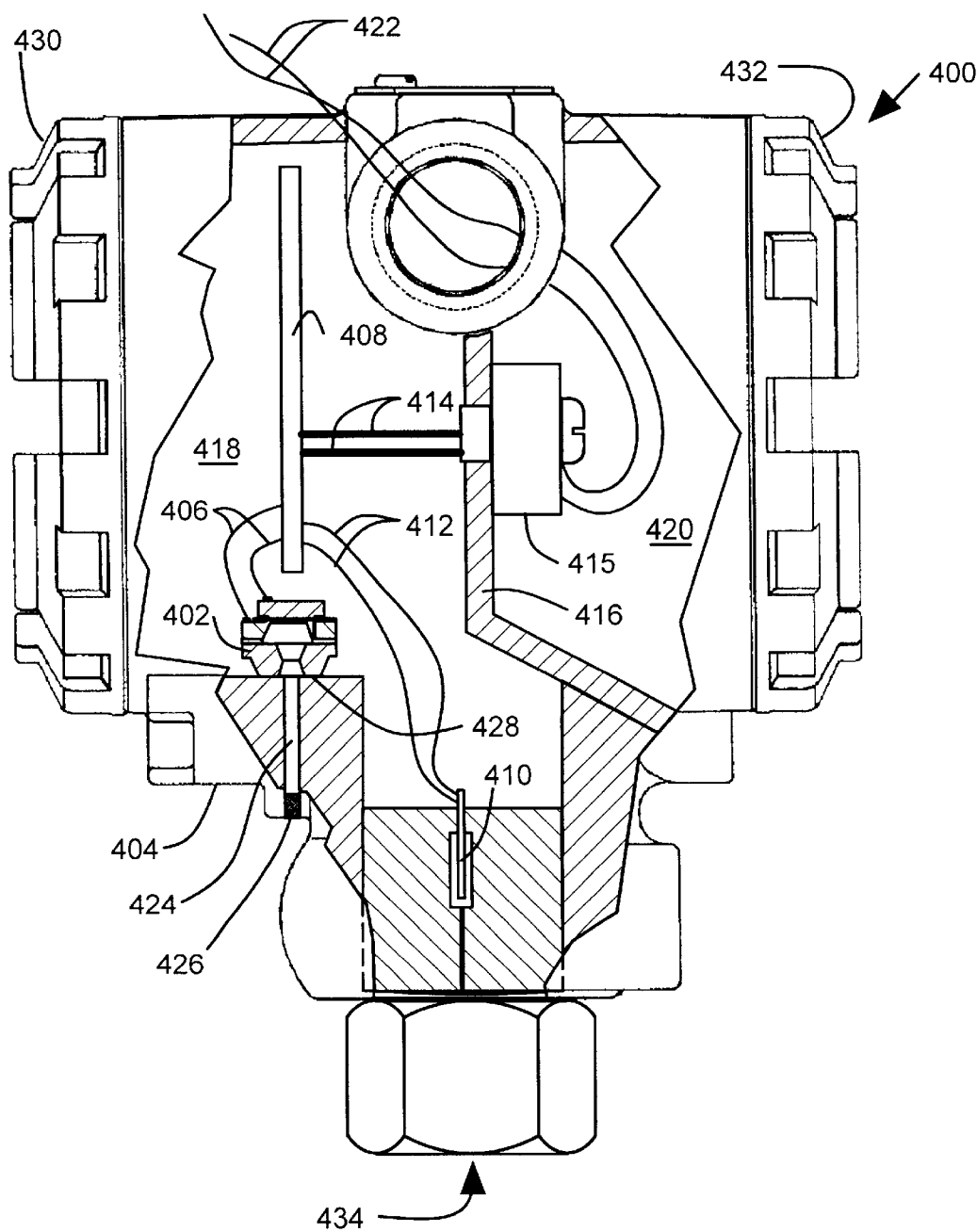


FIG. 10

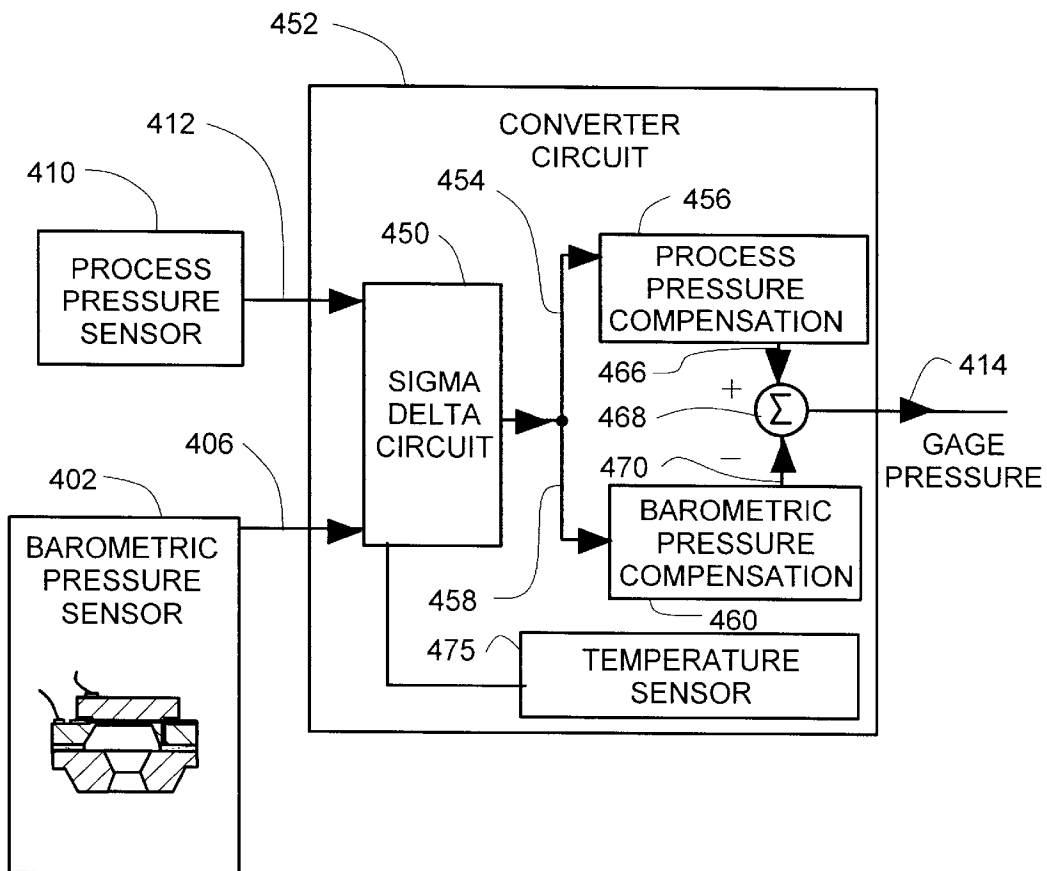


FIG. 11

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ABSOLUTE PRESSURE SENSOR

BACKGROUND OF THE INVENTION

In industrial transmitter applications, capacitive type sensors are typically used for sensing pressures. Capacitive sensors can be made highly accurate and repeatable. In gage transmitters that electronically calculate a pressure difference based on two absolute pressure sensor outputs, accuracy and repeatability of the sensors are particularly important to avoid introducing errors in the subtraction process. The barometric pressure range is quite limited, typically 0.9–1.1 atmospheres, and there is a desire to use a relatively low cost absolute sensor for sensing barometric pressure. Low cost absolute pressure sensors, however, often do not have the accuracy and repeatability found in process fluid sensors. These low cost sensors can introduce undesired errors into the electronic subtraction process.

A barometric pressure sensor is needed that can be manufactured at a low cost and that has high repeatability in the limited barometric pressure range.

SUMMARY OF THE INVENTION

Disclosed is a pressure sensor comprising a base layer, a sensor layer and a reference layer. The base layer surrounds a passageway between an inlet adapted to receive a pressure and a mounting face on the base layer.

The sensor layer has a first face bonded by an insulating bond to the mounting face. The sensor layer includes a conductive diaphragm aligned with the passageway.

The reference layer mounts on the sensor layer to form a reference vacuum cavity that is aligned with the conductive diaphragm. The reference layer includes a conducting surface facing the conductive diaphragm across the reference vacuum cavity to form a pressure sensing capacitor.

These and various other features as well as advantages which characterize the present invention will be apparent upon reading of the following detailed description and review of the associated drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 illustrates a cross-sectional view of a first embodiment of a capacitive absolute pressure sensor.

FIG. 2 illustrates a cross-sectional view of a second embodiment of a capacitive absolute pressure sensor.

FIG. 3 illustrates a detailed cross-sectional view of a first diaphragm of a capacitive absolute pressure sensor.

FIG. 4 illustrates a detailed cross-sectional view of a second diaphragm of a capacitive absolute pressure sensor.

FIG. 5 illustrates a cross-sectional view of a third embodiment of a capacitive absolute pressure sensor.

FIG. 6 illustrates a mask for a top surface of the sensor layer shown in FIG. 5.

FIG. 7 illustrates a mask for a bottom surface of the sensor layer shown in FIG. 5.

FIG. 8 illustrates a mask for a top surface of the reference layer shown in FIG. 5.

FIG. 9 illustrates a mask for a bottom surface of the reference layer shown in FIG. 5.

FIG. 10 illustrates a partially broken away view of a gage pressure transmitter.

FIG. 11 illustrates a block diagram of a gage pressure transmitter.

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DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Gage pressure transmitters are often used to measure a quantity of liquid stored in a tank. The gage pressure transmitter includes an electronic circuit that provides a transmitter output indicating gage pressure, or in other words, a difference between a sensed liquid pressure and a sensed barometric pressure. The gage pressure transmitter has a process pressure inlet that connects to an opening near the bottom of the tank. The gage pressure transmitter also has an atmospheric inlet or vent that is open to the atmosphere. The fluid level in the tank can be calculated from the transmitter's gage pressure output using well known formulae.

Gage pressure transmitters can be constructed using one differential pressure sensor that couples to both the process pressure and atmospheric pressure. Alternatively, two absolute pressure sensors can be used, with one absolute pressure sensor sensing the liquid pressure and the other absolute pressure sensor sensing the atmospheric pressure. When two absolute pressure sensors are used, a circuit in the transmitter calculates the pressure difference (gage pressure) electronically based on the two sensor outputs.

In industrial transmitter applications, capacitive type sensors are typically used for sensing pressures. Capacitive sensors can be made highly accurate and repeatable. In gage transmitters that electronically calculate a pressure difference based on two absolute pressure sensor outputs, repeatability of the sensors is particularly important to avoid introducing errors in the subtraction process. The barometric pressure range is quite limited, typically 0.9–1.1 atmospheres, and there is a desire to use a relatively low cost absolute sensor for sensing barometric pressure. Low cost absolute pressure sensors, however, often do not have the repeatability found in process fluid sensors. These low cost sensors can introduce undesired errors into the electronic subtraction process.

As illustrated below in FIGS. 1–11, barometric pressure sensors are provided that can be manufactured at a low cost and that have high repeatability in the limited barometric pressure range. The barometric pressure sensors can be conveniently batch fabricated with selected known processes of microstructure fabrication (also called microsystem technology (MST)) such as masking, doping, etching, thin film deposition and the like. These known processes include many adapted from the manufacture of integrated circuits.

FIG. 1 illustrates a pressure sensor 100 that is formed of multiple layers and that can be conveniently batch fabricated. The pressure sensor 100 includes a base layer 102 that surrounds a passageway 104 between an inlet 106 and a mounting face 108 on the base layer. Inlet 106 is adapted to bond to a gage transmitter housing internal surface surrounding a hole (as illustrated in FIG. 10) providing an atmospheric pressure P from outside a gage transmitter housing.

The pressure sensor 100 also includes a sensor layer 110 having a first face 112 bonded by an insulating bond 114 to the mounting face 108. The sensor layer 110 includes a conductive diaphragm 116 that is aligned with the passageway 104 to receive pressure P.

The pressure sensor 100 includes a reference layer 120 that is mounted on the sensor layer 110 to form a reference vacuum cavity 122 that is aligned with the conductive diaphragm 116. The reference layer 120 includes a conducting surface 124 facing the conductive diaphragm 116 across

the reference vacuum cavity **122** to form a pressure sensing capacitor. Reference layer **120** is sufficiently thick so that that reference layer **120** does not bend or deflect substantially with changes in atmospheric pressure around the sensor **100**. The reference layer **120** preferably includes a mesa **121** that protrudes slightly and that faces the conductive diaphragm **116**. The mesa **121** has a height that is selected to provide the desired spacing between capacitor plates in the vacuum cavity **122**. The height of mesa **121** can be selected to correct for the thickness of bonding layers **126**, **130**. In addition to the mesa **121**, or as an alternative to the mesa **121**, a second mesa **123** can be provided on the sensor layer **110** to provide capacitor spacing control.

The conductive diaphragm **116** serves as a first capacitor electrode or plate. The conducting surface **124** serves as a second capacitor electrode or plate. The vacuum cavity **122** provides a spacing between the generally parallel capacitor plates. The spacing between the capacitor plates varies as the diaphragm **116** is deflected by pressure **P**. The insulating bond **114** provides electrical insulation from the base layer **102** and preferably comprises a layer of glass frit.

The sensor layer **110** further includes a first insulating layer **126** surrounding the conducting diaphragm **116** on a second face **128**. The reference layer **120** includes a second insulating layer **130** bonded to the first insulating layer **126**. In one preferred arrangement, the reference layer **120** and the sensor layer **110** comprise silicon and the first and second insulating layers **126**, **130** comprise grown silicon dioxide and are fusion bonded together. The silicon in layers **110**, **120** is doped and electrically conductive. The insulating layers **126**, **130** insulate the conductive portions of the sensor layer **110** from the reference layer **120** so that the pressure sensing capacitor is not shorted out.

A first electrical bonding pad **132** is disposed on the sensor layer **110**. Bonding pad **132** is electrically in contact with and connected to the sensor layer **110** and thus provides one connection to a plate or electrode of the a pressure sensing capacitor. A second electrical bonding pad **134** is electrically in contact with and connected to the conducting surface **124** on the reference layer **120** and thus provides a connection to the other plate or electrode of the pressure sensing capacitor.

In a preferred arrangement, the sensor layer **110** includes a shelf portion **111** on one side that extends beyond the reference layer **120**, and at least one electrical bonding pad **132** is disposed on the shelf portion. The arrangement of this shelf portion **111** provides easy access for connecting a bond wire **133** and allows the bond pad **132** to be spaced away from the conductive diaphragm **116** so that stress transmission from the bond wire **133** to the conductive diaphragm **116** is reduced.

In a preferred arrangement, the sensor layer **110** further comprises a second passageway **136** extending from the reference vacuum cavity **122** to the insulating bond **114**. After the reference layer **120** and sensor layer **110** are bonded together, then the base layer **102** is bonded to the sensor layer **110** in a vacuum. The insulating bond or frit **114** seals the second passageway **136** to provide a permanent vacuum in reference vacuum cavity **122**. The second passageway **136** is preferably a laser drilled hole.

The pressure sensor **100** can be economically manufactured for use as a barometric pressure sensor having an operating range of about 0.9–1.1 standard atmospheres.

FIG. 2 illustrates a pressure sensor **150** that is similar to the pressure sensor **100** shown in FIG. 1, however, the pressure sensor **150** includes a reference layer **170** that is an

insulating glass anodically bonded to a sensor layer **160** by way of an anodic bond **180**.

In FIG. 2, a base layer **152** surrounds a passageway **154** between an inlet **156** that receives a pressure **P** and a mounting face **158** on the base layer **152**.

The sensor layer **160** has a first face **162** that is bonded by an insulating bond **164** to the mounting face **158**. The sensor layer **160** includes a conductive diaphragm **166** aligned with the passageway **154**. The insulating bond **164** preferably comprises a layer of glass frit.

The reference layer **170** is mounted on the sensor layer **160** to form a reference vacuum cavity **172** that is aligned with the conductive diaphragm **166**. The reference layer **170** includes a conducting surface **174** facing the conductive diaphragm **166** across the reference vacuum cavity **172** to form a pressure sensing capacitor. The bulk of the reference layer **170** preferably comprises pyrex glass, and the conducting surface **174** preferably comprises a deposition of nichrome. Reference layer **170** is anodically bonded to sensor layer **160** using the well known anodic bonding technique for bonding pyrex to silicon. After the anodic bond **180** is complete, then the sensor is heated in a vacuum to seal the reference vacuum cavity **172** with a small quantity of glass frit **183**. Glass frit **183** fills a small channel that is cut through the reference layer to allow an electrical feedthrough to a first electrical bonding pad **184** from the conducting surface **174**.

The first electrical bonding pad **184** is deposited on electrical conductor layer **189** that connects to the conducting surface **174** which forms a second plate or electrode of the pressure sensing capacitor. The first electrical bonding pad **184** and electrical conductor layer **189** are disposed on an isolation channel **185** on the sensor layer **160**. The electrical conductor layer **189** is in electrical contact with the conducting surface **174** by way of a metal bridge **187**.

A second electrical bonding pad **182** is disposed on the sensor layer **160** and thus connects to the conducting diaphragm **166** which forms one plate or electrode of the pressure sensing capacitor. The second electrical bonding pad **182** is in electrical contact with the sensor layer **160**.

The bonding pads **182**, **184** are preferably formed of aluminum. The isolation channel **185** is preferably formed of pyrolytic oxide. The metal bridge **187**, the electrical conductor layer **189** and the conducting surface **174** are all preferably formed of nichrome. The sensor layer **160** includes a shelf portion **161** that extends beyond the reference layer **170** and the electrical bonding pads **182**, **184** are disposed on the shelf portion.

The pressure sensor **150** is preferably a barometric pressure sensor having an operating range of about 0.9–1.1 atmospheres.

FIGS. 3–4 illustrate detailed cross-sectional views of two different embodiments of conductive diaphragms **116** of a capacitive absolute pressure sensor such as pressure sensor **100** illustrated in FIG. 1. FIGS. 3–4 are not drawn to scale, but have an expanded vertical scale to better illustrate certain features. Also, FIGS. 3–4 are illustrations of the conductive diaphragms **116** during overpressure conditions. An overpressure condition is a condition where the pressure **P** exceeds the nominal measurement range of the pressure sensor. Under overpressure conditions the conductive diaphragm **116** deflects away from its nominal flat shape (illustrated by dashed lines **194**, **196**) and rests against and is supported by the conducting surface **124** of reference layer **120**. In FIGS. 3–4, an oxide layer **190** is formed on the diaphragm surface. In addition, in FIG. 4 an additional oxide

layer 192 is formed on the conducting surface 124. The oxide layers 190, 192 prevent the conducting surface 124 from shorting out to the conductive diaphragm 116 during overpressure conditions. The conductive diaphragm 116 is supported during overpressure conditions so that it does not break, and the oxide layers 190, 192 prevent a short circuit during the overpressure condition.

FIGS. 5–9 illustrate a pressure sensor 200 that is similar to the pressure sensor 100 illustrated in FIG. 1, however the pressure sensor 200 includes some additional features. In particular, grooves 201, which can be used to reduce rest capacitance, are included. An additional masked insulating layer 203 can be included to provide enhanced performance over temperature extremes. A cul-de-sac shaped passageway (FIG. 6) can be added in reference layer 120 between the reference vacuum cavity 122 and the second passageway 136 to reduce movement of debris from laser drilling.

FIG. 5 illustrates a pressure sensor 200 that is formed of multiple layers and that can be conveniently batch fabricated using known processes of microstructure fabrication (also called microsystem technology (MST)) such as masking, doping, etching, thin film deposition and the like. The pressure sensor 200 illustrated in FIG. 5 is similar to the pressure sensor 100 illustrated in FIG. 1. The reference numerals used in FIG. 5 that are the same as reference numerals used in FIG. 1 identify the same or similar features.

In FIG. 5, the pressure sensor 200 includes multiple grooves 201 (also illustrated in FIG. 9 at 372, 374, 376, 378).

In a preferred embodiment, the second insulating layer 130 is masked to form a masked shape and the reference layer 120 also includes a third insulating layer 203 opposite the second insulating layer 130. The third insulating layer 203 is masked in substantially the same masked shape as the second insulating layer 130. The third insulating layer 203 is aligned with the second insulating layer 130. As temperature changes, the first and second insulating layers 203, 130 expand at a different rate than the expansion of the bulk material of reference layer 120. The difference in rates of expansion produces stress in reference layer 120, however, the stresses from the two substantially identical layers 203, 130 tend to cancel out. This feature of masking with substantially the same masked shape is described in more detail below in connection with FIGS. 8–9.

In another preferred embodiment, a thin oxide layer 217 is provided on sensor layer 110. Oxide layer 217 is similar to oxide layer 190 illustrated in FIGS. 3–4 and prevents shorting out during overpressure conditions.

FIGS. 6–9 illustrate various masks that are used in manufacture of the sensor 200 illustrated in FIG. 5. References L (left) and R (right) are included in FIG. 5 to identify left and right sides of the sensor 200. Corresponding references L and R are included in FIGS. 6–9 to indicate the orientation of the various masks relative to sensor 200 in FIG. 5. The masks illustrated in FIGS. 6–9 provide additional details on the shapes of various features shown in FIG. 5. The masks in FIGS. 6–9 are illustrative for manufacture of one sensor. It will be understood by those skilled in the art that a sensor can be batch fabricated with many other sensors on wafers and then diced. In the case of batch fabrication, the individual masks illustrated in FIGS. 6–9 are typically repeated in regular arrays on masks large enough to complete entire wafers.

FIG. 6 illustrates a mask 300 for a second face 128 (top surface) of the sensor layer 110 shown in FIG. 5. Mask 300 includes a generally rectangular region 302 that provides for

a correspondingly shaped surface of bare (unoxidized) silicon. The first electrical bonding pad 132 is later deposited on this bare silicon region 302. Mask 300 also includes a region 304 that overlies the conductive diaphragm 116 and also defines a cul-de-sac region 306 that is contiguous with the region 304. The cul-de-sac region 306 provides an open path between the second passageway 136 and the reference vacuum cavity 122. Mask 300 includes an irregular shaped region 308 that defines the first insulating layer 126 which surrounds the conductive diaphragm region 304 and the cul-de-sac region 306.

FIG. 7 illustrates a mask 320 for a bottom surface of the sensor layer 110 shown in FIG. 5. Mask 320 includes a region 322 that defines a region to be anisotropically etched on a (100) oriented crystal face of silicon to form the diaphragm 116. Mask 320 also includes a region 324 which is left oxidized and a region 326 which defines a location for the second passageway 136, typically a laser drilled hole.

FIG. 8 illustrates a mask 340 for a top surface of the reference layer 120 shown in FIG. 5. Mask 340 includes a region 342 that defines a masked insulating layer 203. Mask 340 also includes a region 344 that circumscribes a region 346 that defines the second electrical bonding pad 134.

FIG. 9 illustrates a mask 360 for a bottom surface of the reference layer 120 shown in FIG. 5. Mask 360 includes regions 362, 364, 366 that define anisotropically etched grooves. These anisotropically etched grooves provide a line 368 for stress concentration so that a batch fabricated sensor 200 can be conveniently diced free from a wafer of multiple sensors. In FIG. 5, the broken-away portions of reference layer 120 are illustrated in dashed lines.

Mask 360 also includes regions 372, 374, 376, 378, 380, 382 that define anisotropically etched grooves such as grooves 201 illustrated in FIG. 5. These grooves provide increased separation between surfaces of the sensor layer 110 and the reference layer 120. The reference layer 120 includes these grooves that face the sensor layer 110. The increased separation reduces “rest capacitance” of the capacitive pressure sensor. The rest capacitance of a capacitive pressure sensor is that value of the sensor’s capacitance when the sensor is at rest, or in other words, undeflected. The rest capacitance is unresponsive to pressure changes, and as such tends to undesirably reduce the percentage by which the capacitance changes over the nominal measuring range. Reducing the rest capacitance with grooves simplifies the design of electronic circuitry used with the pressure sensor 200.

Mask 360 also includes a region 384 which defines an etch stop layer forming mesa 121. Mask 360 further includes a region 386 that defines second insulating layer 130. It can be seen that region 342 in FIG. 8 defines masked insulating layer 203, and that region 386 in FIG. 9 defines second insulating layer 130 to have substantially the same shapes that are aligned with each other to provide mechanical stress isolation during temperature variations.

The mask 360 also includes a cul-de-sac region 387 that aligns with the cul-de-sac region 306 in FIG. 6. The reference vacuum cavity 122 is thus shaped to include a cul-de-sac leading to the second passageway 136, which is typically a laser drilled hole.

In one preferred embodiment, the cul-de-sac region 387 includes a turn 388 of at least 90 degrees as illustrated.

FIG. 10 illustrates a partially broken away view of a gage pressure transmitter 400 that includes a barometric sensor 402. Barometric sensor 402 can be constructed generally as described above in connection with FIGS. 1–9. The gage

pressure transmitter **400** includes a housing **404** that encloses the barometric sensor **402** that is connected by leads **406** to a printed circuit board **408** that includes a converter circuit. The converter circuit on printed circuit board **408** is explained in more detail below in connection with FIG. 11.

The gage pressure transmitter **400** also includes a process pressure sensor **410** that is connected by leads **412** to the converter circuit on printed circuit board **408**. Process pressure sensor **410** is an absolute pressure sensor that senses process pressure at a process pressure inlet **434**.

The converter circuit on printed circuit board **408** generates an electrical output that represents gage pressure on leads **414**. Leads **414** connect to a terminal block **415** that also serves as sealed feedthrough. Housing **404** is a dual compartment housing with a barrier wall **416** separating an electronics compartment **418** from a field wiring compartment **420**. Each of compartments **418**, **420** is sealed by a corresponding threaded cover **430**, **432**. A cable **422** connects the terminal block **415** to a process control system (not illustrated) at a remote location. The electrical output is configured for long distance transmission, also called telemetry, and typically the output at terminal block **415** is in a standard format such as a 4–20 mA industrial process control loop that provides all of the energization for the gage transmitter **400**. The 4–20 mA industrial process control loop may include superimposed signals in a standard industry format such as the Hart protocol. Alternatively, the output at terminal block **415** can be in an industry standard fieldbus format such as Foundation Fieldbus, Profibus and the like.

The transmitter housing **404** includes a barometric pressure port **424** that is open to the atmosphere surrounding the housing **404**. an inlet of barometric pressure sensor **402** is bonded to the inside of the transmitter over the barometric pressure port. The barometric pressure port **424** preferably includes a porous teflon plug **426** disposed in the barometric pressure port **424**. The porous teflon plug **426** help prevent the entry of water in barometric pressure port **424**. The barometric pressure sensor **402** is preferably bonded to the housing **404** using a trimetal bond **428** such as Titanium-nickel-gold or Chromium-Nickel-Gold. Trimetal bonds are known for example from U.S. Pat. No. 5,695,590 Willcox et al.

FIG. 11 illustrates an exemplary block diagram of the gage pressure transmitter **400** in FIG. 10. The process pressure sensor **410** is coupled along leads **412** to a sigma delta circuit **450** in a converter circuit **452**. The barometric pressure sensor **402** is coupled along leads **406** to the sigma delta circuit **450** in the converter circuit **452**.

The sigma delta circuit **450** provides a digital signal representative of uncompensated process pressure along line **454** to a process pressure compensation circuit **456**. The sigma delta circuit **450** provides a digital signal representative of uncompensated barometric pressure along line **458** to a barometric pressure compensation circuit **460**. The process pressure compensation circuit **456** provides an output representing compensated process pressure on line **466** to a difference calculating circuit **468**. The barometric pressure compensation circuit **460** provides an output representing compensated barometric pressure on line **470** to the difference calculating circuit **468**. The difference calculating circuit **468** calculates a difference between compensated process pressure and compensated barometric pressure, which is an accurate indication of gage pressure **414**. The compensation performed by circuits **456**, **460** includes gain and linearity corrections.

In a preferred embodiment, the converter circuit also includes a temperature sensor **475** coupled to the sigma delta circuit **450**. In this preferred embodiment, the sigma delta circuit **450** provides an output representing temperature to both compensation circuits **456**, **460**. The compensations circuits **456**, **460** then additionally compensate for temperature changes.

In a preferred arrangement, the compensation circuits **456**, **460** and the difference calculating circuit **468** are realized as part of an embedded microprocessor system in the gage pressure transmitter **400**.

Sigma delta circuit **450** is preferably a sigma delta type analog to digital converter circuit. The converter circuit **452** compensates a reading from the process pressure sensor and compensates a reading from the barometric pressure sensor and calculates the difference by subtracting the compensated barometric pressure reading from the process pressure reading.

Although the present invention has been described with reference to preferred embodiments, workers skilled in the art will recognize that changes may be made in form and detail without departing from the spirit and scope of the invention.

What is claimed is:

1. An absolute pressure sensor, comprising:

a base layer surrounding a passageway between an inlet adapted to receive a pressure and a mounting face on the base layer;

a sensor layer having a first face bonded by an insulating bond to the mounting face, the sensor layer including a conductive diaphragm aligned with the passageway, forming a pressure cavity that is between the sensor layer and the base layer, the pressure cavity receiving the pressure; and

a reference layer mounted on the sensor layer to form a reference vacuum cavity that is aligned with the conductive diaphragm, the reference layer including a conducting surface facing the conductive diaphragm across the reference vacuum cavity to form a pressure sensing capacitor, the conductive diaphragm separating the reference vacuum cavity from the pressure cavity, the conductive diaphragm sensing absolute pressure.

2. The pressure sensor of claim 1 wherein the insulating bond comprises a layer of glass frit.

3. The pressure sensor of claim 1 wherein the conductive diaphragm includes an oxide layer.

4. The pressure sensor of claim 3 wherein the conducting surface supports the oxide layer under an overpressure condition.

5. The pressure sensor of claim 1 wherein the sensor layer further includes a first insulating layer on a second face surrounding the conducting diaphragm, and the reference layer further includes a second insulating layer bonded to the first insulating layer.

6. The pressure sensor of claim 5 wherein the second insulating layer is masked to form a masked shape and the reference layer also includes a third insulating layer opposite the second insulating layer, the third insulating layer being masked in substantially the same masked shape as the second insulating layer.

7. The pressure sensor of claim 5 wherein the reference layer and the sensor layer comprise silicon and the first and second insulating layers comprise silicon dioxide and are fusion bonded together.

8. The pressure sensor of claim 1 wherein the reference layer comprises pyrex glass and is anodically bonded to the sensor layer.

9. The pressure sensor of claim 1 further comprising a first electrical bonding pad disposed on the sensor layer and connected to the pressure sensing capacitor.

10. The pressure sensor of claim 9 further comprising a second electrical bonding pad connected to the pressure sensing capacitor. 5

11. The pressure sensor of claim 10 wherein the first electrical bonding pad is in electrical contact with the sensor layer, and the second electrical bonding pad is disposed on a pyrolytic oxide isolation channel on the sensor layer and is in electrical contact with the conducting surface. 10

12. The pressure sensor of claim 1 wherein the sensor layer further comprises a second passageway extending from the reference vacuum cavity to the insulating bond.

13. The pressure sensor of claim 12 wherein the second passageway is a laser drilled hole. 15

14. The pressure sensor of claim 13 wherein the reference vacuum cavity is shaped to include a cul-de-sac leading to the laser drilled hole.

15. The pressure sensor of claim 14 wherein the cul-de-sac includes a turn of at least 90 degrees. 20

16. The pressure sensor of claim 1 wherein the reference layer includes at least one groove facing the sensor layer.

17. The pressure sensor of claim 1 wherein the reference layer includes a mesa that faces the conductive diaphragm. 25

18. The pressure sensor of claim 1 wherein the sensor layer includes a shelf portion that extends beyond the reference layer, and at least one electrical bonding pad is disposed on the shelf portion.

19. The pressure sensor of claim 1 wherein the pressure sensor is a barometric pressure sensor having an operating range of at least 0.9–1.1 atmospheres. 30

20. A gage pressure transmitter that includes a barometric pressure sensor, the barometric pressure sensor comprising:

- a base layer surrounding a passageway between an inlet adapted to receive a pressure and a mounting face on the base layer; 35
- a sensor layer having a first face bonded by an insulating bond to the mounting face, the sensor layer including a

conductive diaphragm aligned with the passageway, forming a pressure cavity that is between the sensor layer and the base layer, the pressure cavity receiving the pressure; and

a reference layer mounted on the sensor layer to form a reference vacuum cavity that is aligned with the conductive diaphragm, the reference layer including a conducting surface facing the conductive diaphragm across the reference vacuum cavity to form a pressure sensing capacitor, the conductive diaphragm separating the reference vacuum cavity from the pressure cavity, the conductive diaphragm sensing absolute pressure.

21. The gage pressure transmitter of claim 20 further comprising:

a transmitter housing, the transmitter housing having a barometric pressure port bonded to the inlet.

22. The gage pressure transmitter of claim 21 further comprising a porous teflon plug disposed in the barometric pressure port.

23. The gage pressure transmitter of claim 20, further comprising:

- a process pressure sensor; and
- a converter circuit coupled to the process pressure sensor and the barometric pressure sensor, the converter circuit calculating a difference between process pressure and barometric pressure.

24. The gage pressure transmitter of claim 23 wherein the converter circuit includes a sigma delta analog to digital converter.

25. The gage pressure transmitter of claim 23 wherein the converter circuit compensates a reading from the process pressure sensor and compensates a reading from the barometric pressure sensor and calculates the difference by subtracting the compensated barometric pressure reading from the process pressure reading.

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