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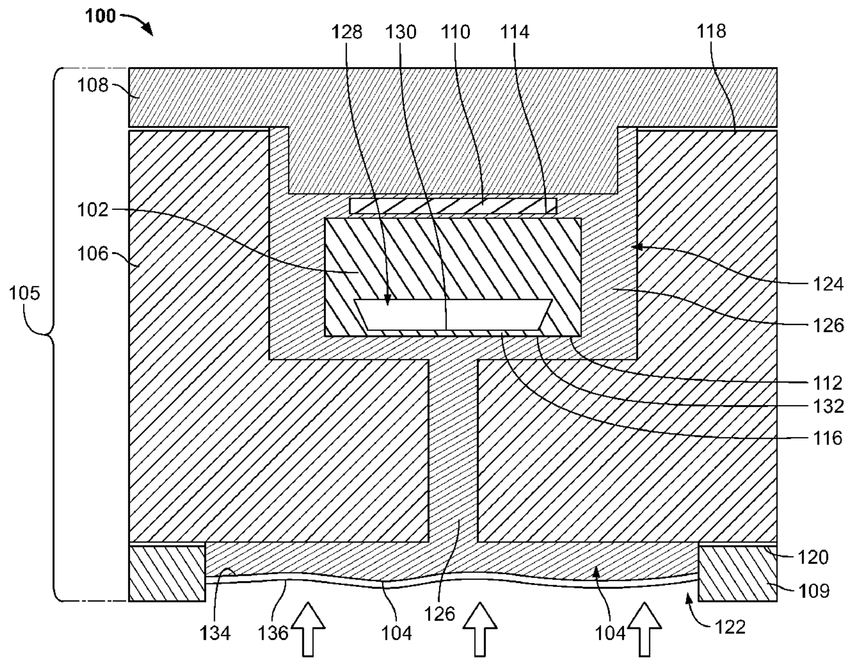

Fig. 1

(57) **Abstract:** A pressure sensing device includes a support structure 105, an isolated diaphragm 104, a working oil 126, and a MEMS die sensing element 102. The support structure 105 defines a portion of a sealed cavity 124. The isolated diaphragm 104 is mounted to the support structure 105. The isolated diaphragm 104 has in inner side 134 that defines an end of the sealed cavity 124 and an outer side 136 opposite the inner side 134. The working oil 126 is contained within the sealed cavity 124. The MEMS die sensing element 102 is enclosed within the support structure 105. A pressure exerted on the outer side 136 of the isolated diaphragm 104 by a fluid medium is transferred via the working oil 126 to the MEMS die sensing element 102 to measure the pressure of the fluid medium.

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*[Continued on next page]*

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# VACUUM-RESISTANT PRESSURE SENSING DEVICE

[0001] The subject matter herein relates generally to pressure sensing devices for measuring the pressure of fluid media, and more specifically to pressure sensing devices capable of operating within high vacuum environments.

[0002] Pressure sensors or transducers are devices that convert pressure forces into electrical signals that can be interpreted to measure the pressure exerted on the pressure sensor. Some known pressure sensors incorporate micro-electro-mechanical system (MEMS) technology which allows the pressure sensors to have a small, compact size while maintaining high accuracy. However, when exposed to high vacuum conditions for extended periods of time, the accuracy of the pressure sensors suffers. For example, it has been observed that when known pressure sensors are exposed to high vacuum (e.g., very low pressure) and high temperature conditions (e.g., 0.001 Pa pressures and 90 degrees C), the pressure sensors experience an output shift that affects the measurement readings. The extent of the output shift and time before the output shift occurs varies, which makes it difficult to calibrate or accommodate the output shift. Furthermore, in high vacuum conditions, the construction and composition of known pressure sensors may also suffer.

[0003] The problem to be solved is to provide a pressure sensing device that can operate within high vacuum environments without experiencing an output shift that exceeds a designated tolerance threshold or range to provide accurate pressure measurements.

[0004] According to the invention, a pressure sensing device is provided that includes a support structure, an isolated diaphragm, a working oil, and a MEMS die sensing element. The support structure defines a portion of a sealed cavity. The isolated diaphragm is mounted to the support structure. The isolated diaphragm has in inner side that defines an end of the sealed cavity and an outer side opposite the inner side. The working oil is contained within the sealed cavity. The

MEMS die sensing element is enclosed within the support structure. The MEMS die sensing element is exposed to the working oil within the sealed cavity. A pressure exerted on the outer side of the isolated diaphragm by a fluid medium is transferred via the working oil to the MEMS die sensing element to measure the pressure of the fluid medium. The working oil has a low vapor pressure and a low volatility content.

[0005] The invention will now be described by way of example with reference to the accompanying drawings in which:

[0006] Figure 1 is a cross-sectional illustration of a pressure sensing device according to an embodiment.

[0007] Figure 2 is a perspective view of the pressure sensing device according to an embodiment.

[0008] Figure 3 is a cross-sectional view of the pressure sensing device according to the embodiment shown in Figure 2.

[0009] Figure 4 is a cross-sectional view of the pressure sensing device according to another embodiment.

[0010] One or more embodiments presented herein disclose a pressure sensing device that includes a MEMS die sensing element. The MEMS die sensing element is isolated from a fluid medium that is to be measured via an isolated diaphragm and a working oil that transfers energy (e.g., forces) from the isolated diaphragm to the MEMS die sensing element. For example, the fluid medium exerts a pressure on the isolated diaphragm, and a resulting deflection of the isolated diaphragm is transmitted via the working oil within a cavity to the MEMS die sensing element which generates an electrical signal proportional to the force exerted by the fluid medium on the isolated diaphragm. The pressure sensing device is also configured to operate in high vacuum environments, such as at pressures as low as 0.001 Pa or lower. For example, the working oil within the pressure sensing device may have a low vapor pressure and low volatility content to avoid (or at least reduce the extent of) outgassing of the working oil (e.g., releasing vapor bubbles) in high vacuum and high temperature conditions, which alters the pressure exerted on the MEMS die sensing element and causes a shift in the electrical signal that is generated.

[0011] Figure 1 is a cross-sectional illustration of a pressure sensing device 100 according to an embodiment. The pressure sensing device 100 includes a MEMS die sensing element 102, an isolated diaphragm 104, and a support structure 105. In the illustrated embodiment, the support structure 105 is represented by a housing 106, a header 108, and a port member 109. The MEMS die sensing element 102 (also referred to herein as sensing element 102) is mounted to the header 108 via a bonding layer 110. The bonding layer 110 may be an adhesive, a weld material, or the like. The pressure sensing device 100 according to one or more embodiments is a media isolated pressure sensor. For example, a working oil 126 is sealed inside the pressure sensing device 100 to isolate the MEMS die sensing element 102 from external media that is being measured.

[0012] The sensing element 102 has a sensing side 112 and a mounting side 114 opposite the sensing side 112. The mounting side 114 engages the bonding layer 110. The sensing side 112 includes a diaphragm 116. The diaphragm 116 (also referred to as a MEMS diaphragm 116) is thin and is defined by a pocket 128 within the sensing element 102. The MEMS diaphragm 116 includes an interior surface 130 that defines a portion of the pocket 128 and an exterior surface 132 opposite the interior surface 130. The exterior surface 132 defines a portion of the sensing side 112 of the sensing element 102. The sensing element 102 has resistors along the sensing side 112, such as along the exterior surface 132 of the MEMS diaphragm 116. The resistors are piezoelectric and exhibit an electrical resistance that changes based on mechanical strain applied to the sensing element 102. For example, when pressure is applied across the MEMS diaphragm 116, the diaphragm 116 flexes and the resistors that are sensitive to mechanical strain provide an electrical signal through associated circuitry. The electrical signal indicates a measure of the pressure applied across the MEMS diaphragm 116.

[0013] The housing 106 has a top side 118 and a bottom side 120 opposite the top side 118. As used herein, relative or spatial terms such as “top,” “bottom,” “front,” “rear,” “inner,” and “outer” are only used to identify and distinguish the referenced elements in the orientations shown in the illustrated figures and do not necessarily require particular positions or orientations relative to gravity and/or the surrounding environment of the pressure sensing device 100. The housing 106 is disposed between the header 108 and the port member 109. For example, the top side 118 of the housing 106 is mounted to the header 108, and the bottom side 120 of the housing 106 is mounted to the port member 109. The port member 109 may be connected to a conduit or reservoir that contains a fluid medium to be measured by the pressure sensing device 100. The port member 109 defines an opening 122 that receives the fluid medium.

[0014] The isolated diaphragm 104 is attached to the port member 109 and extends across the opening 122 to seal the opening 122. The isolated diaphragm 104 may be welded, soldered, brazed, or the like to the port member 109. Optionally, the isolated diaphragm 104 may be attached to the bottom side 120 of the housing 106 in addition to being attached to the port member 109 (or instead of attaching to the port member 109). The fluid medium engages the isolated diaphragm 104, which defines a partition that isolates the sensing element 102 from the fluid medium. The isolated diaphragm 104 has an inner side 134 and an outer side 136 opposite the inner side 134. The inner side 134 faces towards the MEMS die sensing element 102. The fluid medium engages the outer side 136 of the diaphragm 104. The properties of the fluid medium, such as corrosivity and/or conductivity, do not affect the sensing element 102 due to the isolation provided by the isolated diaphragm 104. The isolated diaphragm 104 may include one or more metals, such as stainless steel, nickel, brass, and/or the like.

[0015] The pressure sensing device 100 defines a cavity 124 that contains a working oil 126 for transmitting energy (e.g., forces) from the isolated diaphragm 104 to the sensing element 102. The sensing element 102 extends into cavity 124 in the illustrated embodiment such that the sensing side 112 engages the working oil 126. The cavity 124 extends through the housing 106 from the top side 118 to the bottom side 120. The cavity 124 is vertically defined between the header

108 and the isolated diaphragm 104. The cavity 124 is hermetically sealed. The working oil 126 is non-corrosive, non-conductive, and incompressible.

[0016] During operation, pressure applied by the fluid medium on the isolated diaphragm 104 within the opening 122 of the port member 109 causes the diaphragm 104 to slightly flex (e.g., deflect). The deflection of the diaphragm 104 is transferred through the working oil 126 to the MEMS diaphragm 116. The pressure on the MEMS diaphragm 116 is detected by measuring the resistance (or a change in the resistance) of the piezo-resistors on the sensing element 102. The pressure sensing device 100 is calibrated to determine the pressure of the fluid medium exerted on the isolated diaphragm 104 based on the measured resistance of the piezo-resistors.

[0017] The pressure sensing device 100 is configured to withstand harsh environments including high vacuum and high temperature conditions while maintaining accurate measurements within a designated tolerance threshold or range. For example, the designated tolerance range may be 1% of span at vacuum level. Known pressure sensors experience an output shift greater than the tolerance range when exposed to a high vacuum and high temperature environment for an extended period of time. For example, applying a negative pressure, such as 0.001 Pa, over an extended time period at a high temperature, such as at or above 90° C, causes the tested pressure sensors to experience an output shift. The output shift can exceed 2.5 mV, and it has been observed that greater vacuum conditions and higher temperatures accelerate the output shift. The accuracy of the pressure measurements suffer as a result of the output shift.

[0018] The pressure sensing device 100 according to the embodiments presented herein is able to withstand extended exposure to 0.001 Pa pressure and 90° C temperature without having an output shift greater than 1% span. As a result, the pressure sensing device 100 maintains measurement sensitivity and accuracy even in harsh environments. Due to the robustness of the pressure sensing device 100, the pressure sensing device 100 can be utilized in various harsh environment applications. For example, the pressure sensing device 100 can be utilized in semiconductor manufacturing applications, such as for flash memory production. The pressure sensing device 100 may be installed in a mass flow controller for semiconductor applications.

[0019] The working oil 126 of the pressure sensing device 100 has a lower vapor pressure and a lower volatility content (e.g., low concentration of volatile molecules), relative to oils utilized in known pressure sensors. The inventors of the present application have discovered that the composition of the oil within the pressure sensors is a contributing factor in the observed output shift when exposed to high vacuum and high temperature. For example, at high vacuum and high temperature conditions, some of the molecules of the oil transition to the gas phase, creating gas bubbles. The addition of the gas phase within the cavity 124 affects the pressure exerted on the MEMS die sensing element 102, causing or at least contributing to an output shift.

[0020] Even if oil is degassed by temperature and moderate vacuum conditioning of the oil prior to entering a known pressure sensor, the conditioning may not remove all volatile molecules that may outgas in high vacuum conditions. The volatility content of the working oil is an inherent material property. Known oils used in typical pressure sensors may have a large amount of volatile content with varying molecular sizes. Small volatile molecules of the oil may outgas during the conditioning process, which allows the oil to maintain the liquid state (e.g., without vapor bubbles) when the pressure sensor is subjected to moderate vacuum and temperature conditions. However, the conditioning process may not generate sufficient energy to cause larger volatile molecules within the oil to outgas, such that the larger volatile molecules remain within the oil. The larger volatile molecules that remain after the conditioning may outgas in high vacuum and high temperature conditions (e.g., pressures at or less than 0.001 Pa and temperatures at or greater than 90° C), producing the vapor bubbles that contribute to the output shift. The oils used as the working oil 126 of the pressure sensing device 100 according to the embodiments described herein have low vapor pressures and low volatility contents, which eliminates or at least reduces the occurrence of volatile molecules becoming vapors at harsh conditions (e.g., high vacuum and high temperature).

[0021] In one embodiment, the working oil 126 is a perfluoropolyether (PFPE) oil. The PFPE oil may have a low vapor pressure that may be less than 13.33 Pa (e.g., 0.1 Torr) at temperatures less than or equal to 100° C. The PFPE oil may have a minimum viscosity of 0.426 Pa*s at 1 rad/s. In non-limiting examples, the PFPE oil may be ECO-25/9 PFPE diffusion pump oil, available from Enparticles Diffusion Pump Oil. Optionally, diffusion pump oils other than PFPE oil may have sufficient properties (e.g., low vapor pressure, low volatility content, inert, etc.) to represent the working oil 126 of the pressure sensing device 100.

[0022] In another embodiment, the working oil 126 is a silicone oil that has a volatility content (e.g., volatile molecule count) that is less than $3 \times 10^6$ per 20 μL. For example, the silicone oil representing the working oil 126 may have a volatility content of approximately $2.5 \times 10^6$ per 20 μL. A second silicone oil that is commonly used in known pressure sensors was measured to have a greater volatility content than the other silicone oil, referred to as the first silicone oil. For example, the volatility content of the second silicone oil was measured to be greater than $5 \times 10^6$ per 20 μL, and roughly double the content of the first silicone oil. During testing, the use of the second silicone oil within a pressure sensor resulted in an output shift greater than the designated tolerance range of 1% span, while the use of the first silicone oil (with the lower volatility content) in the pressure sensor did not cause an output shift greater than the tolerance range. Thus, the first silicone oil with the lower volatility content may represent the working oil 126 within the pressure sensing device 100, while the second silicone oil does not represent the working oil 126.

[0023] The pressure sensing device 100 containing the working oil 126 according to the embodiments described herein is capable of providing pressure measurements of fluid media at harsh conditions including high vacuum and high temperature without resulting in an output shift greater than a designated tolerance threshold or range. For example, the pressure sensing device 100 has been exposed for prolonged periods of time to a pressure of 0.001 Pa and a temperature of 90° C, while maintaining the output within a tolerance range of 1% of span at vacuum level. The pressure sensing device 100 may be operable at lower pressures (e.g., higher vacuum) and greater temperatures than the tested conditions. The pressure sensing device 100 is able to measure fluid media at pressures between about 1.7 kPa and about 6.9 kPa (about 0.25 psi to about 100 psi). The pressure sensing device 100 is able to measure corrosive and/or conductive fluid media because the MEMS die sensing element 102 is isolated from the fluid media via the isolated diaphragm 104.

[0024] Figure 2 is a perspective view of the pressure sensing device 100 according to an embodiment. The support structure 105 of the pressure sensing device 100 includes the housing 106 coupled between the port member 109 and a spacer 210. The header 108 is not shown in Figure 2. The MEMS die sensing element 102 (shown in Figure 1) and the working oil 126 (Figure 1) are contained within the support structure 105 and are not visible in Figure 2. The pressure sensing device 100 includes metal pins 208 that pass through a spacer 210. The pins 208 are electrically connected to the MEMS die sensing element 102 either directly or via wires. The pressure sensing device 100 includes a circuit board 202 mounted on a top side 204 of the spacer 210. The top side 204 is opposite to the side of the spacer 210 that couples to the housing 106. The pins 208 extend through the circuit board 202. The circuit board 202 includes circuitry that is configured to receive and analyze the electrical signals generated by the piezo-resistors on the sensing element 102. The pressure sensing device 100 includes conductors 206, such as wires or rigid metal contacts, extending from the circuit board 202 to a remote device, such as a communication device, a display device, a control device, and/or a power source.

[0025] Figure 3 is a cross-sectional view of the pressure sensing device 100 according to the embodiment shown in Figure 2. The pressure sensing device 100 in Figure 3 may be similar to the illustrated embodiment of the pressure sensing device 100 shown in Figure 1. The housing 106 defines a recess 302 that is open along the top side 118 of the housing 106 and a channel 304 that is fluidly connected to the recess 302. The channel 304 extends from the recess 302 to the bottom side 120 of the housing 106. The channel 304 has a smaller diameter than the recess 302. Both the recess 302 and the channel 304 define portions of the cavity 124 that receives the working oil 126. The housing 106 includes stainless steel, but may include one or more other metals in an alternative embodiment. The MEMS die sensing element 102 is mounted to the header 108 via an adhesive, such as an epoxy or a room-temperature-vulcanizing (RTV) silicone. The MEMS die sensing element 102 projects into the recess 302 of the housing 106 from above, and the sensing side 112 of the sensing element 102 engages the working oil 126. For example, the exterior surface 132 of the MEMS diaphragm 116 is in contact with the working oil 126. The sensing element 102 may be a silicon chip. The embodiment shown in Figure 3 is a top-side MEMS die design (as well as the embodiment shown in Figure 1).

[0026] The isolated diaphragm 104 is mounted to the support structure 105 at or proximate to the interface between the housing 106 and the port member 109. The inner side 134 of the isolated diaphragm 104 defines an end of the cavity 124. The cavity 124 is sealed to prevent the ingress or egress of fluids. In the illustrated embodiment, the isolated diaphragm 104 includes stainless steel and nickel alloys, but may include one or more other metals in an alternative embodiment. The support structure 105 and the isolated diaphragm 104 may have a compact size, such that the diameter of the isolated diaphragm 104 may be approximately 12-13 mm (e.g., within 2%, 5%, or 10% thereof), such as 12.57 mm.

[0027] The header 108 defines a fill hole 310 therethrough that is open to the cavity 124. The fill hole 310 is used to fill the cavity 124 with the working oil 126. After filling is complete, the fill hole 310 is sealed by a ball seal 312. The ball seal 312 may be metallic, such as stainless steel, and may be sealed on the header 108 via welding, soldering, or the like. The pins 208 project from the header 108 to engage the circuit board 202 (shown in Figure 2), which is omitted in Figure 3, to provide an electrical connection between the MEMS die sensing element 102 and processing circuitry.

[0028] Optionally, the pressure sensing device 100 includes a ceramic insert 314 mounted to the header 108 and surrounding the MEMS die sensing element 102. The ceramic insert 314 projects into the recess 302 of the housing 106 with the sensing element 102, and engages the working oil 126 in the cavity 124. The pressure sensing device 100 optionally may include a compensation board to compensate the electrical sensor output.

[0029] Figure 4 is a cross-sectional view of the pressure sensing device 100 according to another embodiment. In the illustrated embodiment, the support structure 105 includes a housing 106, a spacer 210, and a port member 109, similar to Figure 2. The support structure 105 lacks the header 108 shown in Figures 1 and 3. The MEMS die sensing element 102 is mounted to the housing 106. The sensing element 102 is disposed within a recess 402 of the housing 106. Unlike the recess 302 shown in Figure 3, the recess 402 does not define a portion of the cavity 124 that contains the working oil 126. For example, the housing 106 defines a channel 404 and a fill hole 406 spaced apart from the channel 404. Each of the channel 404 and the fill hole 406 extends from the recess 402 to the bottom side 120 of the housing 106. The channel 404 aligns with and is fluidly connected to an aperture 410 in the mounting side 114 of the MEMS die sensing element 102. The aperture 410 extends from the mounting side 114 to the pocket 128. The fill hole 406 is plugged by a ball seal 312 that is within the recess 402. The cavity 124 that contains the working oil 126 extends from the fill hole 406 along the space between the bottom side 120 of the housing 106 and the inner side 134 of the isolated diaphragm 104 through the channel 404 and into the aperture 410 to the MEMS diaphragm 116 of the sensing element 102.

[0030] The working oil 126 engages the interior surface 130 of the MEMS diaphragm 116. The embodiment shown in Figure 4 is a back-side MEMS die design because the working oil 126 contacts the interior surface 130 instead of the exterior surface 132, as with the top-side MEMS die design shown in Figure 3. In Figure 4, the piezo-resistors along the exterior surface 132 of the MEMS diaphragm 116 are outside of the cavity 124 and therefore not exposed to the working oil 126. In the illustrated embodiment, the working oil 126 may be any of the working oils described with respect to the top-side embodiment shown in Figures 1 through 3. For example, the working oil 126 has a low vapor pressure and low volatility content.

[0031] The MEMS die sensing element 102 extends through, and is electrically connected to, a bond printed circuit board 420. The pressure sensing device 100 optionally includes a compensation board 422 to compensate the electrical sensor output. The compensation board 422 is mounted on the top side 204 of the spacer 210 in the illustrated embodiment, such that the spacer 210 is stacked between the compensation board 422 and the housing 106.

[0032] At least one technical effect of the pressure sensing device 100 according to the embodiments presented herein is the ability to maintain sensitivity even when exposed to harsh environments, such as high vacuum and high temperature conditions for extended periods of time. As a result, the pressure sensing device 100 may be employed for use in applications that conventional pressure sensors are not able to withstand, such as in various semiconductor manufacturing applications. Another technical effect of the pressure sensing device 100 is that the pressure sensing device 100 can be utilized to measure the pressure of fluid media that is corrosive and/or conductive without degradation due to the isolation provided by the isolated diaphragm 104. The pressure sensing device 100 has a relatively compact and small size, which also allows the pressure sensing device 100 to be mounted in locations that conventional pressure sensors may not fit, while providing accurate pressure measurements.

WHAT IS CLAIMED IS:

1. A pressure sensing device 100 comprising:

a support structure 105 defining a portion of a sealed cavity 124;

an isolated diaphragm 104 mounted to the support structure 105, the isolated diaphragm 104 having in inner side 134 that defines an end of the sealed cavity 124 and an outer side 136 opposite the inner side 134;

a working oil 126 contained within the sealed cavity 134; and

a MEMS die sensing element 102 enclosed within the support structure 105, the MEMS die sensing element 102 exposed to the working oil 126 within the sealed cavity 124, wherein a pressure exerted on the outer side 136 of the isolated diaphragm 104 by a fluid medium is transferred via the working oil 126 to the MEMS die sensing element 102 to measure the pressure of the fluid medium, wherein the working oil 126 has a low vapor pressure and a low volatility content.

2. The pressure sensing device 100 of claim 1, wherein the working oil 126 is a perfluoropolyether (PFPE) oil.

3. The pressure sensing device 100 of claim 1, wherein the working oil 126 has a vapor pressure less than 13.33 Pa at temperatures less than or equal to 100° C.

4. The pressure sensing device 100 of claim 1, wherein the working oil 126 has a minimum viscosity of 0.426 Pa*s at 1 rad/s.

5. The pressure sensing device 100 of claim 1, wherein the working oil 126 is a silicone oil that has a volatility content less than $3 \times 10^6$ per 20 µL.

6. The pressure sensing device 100 of claim 1, wherein the working oil 126 is a diffusion pump oil.

7. The pressure sensing device 100 of claim 1, wherein the isolated diaphragm 104 has a diameter of approximately 12-13 mm.

8. The pressure sensing device 100 of claim 1, wherein the pressure sensing device 100 is configured to operate at 0.001 Pa and 90° C without experiencing an output shift greater than 1% span.

9. The pressure sensing device 100 of claim 1, wherein the MEMS die sensing element 102 has a diaphragm 104, the diaphragm 104 has an interior surface 134 along a pocket defined within the MEMS die sensing element 102 and an exterior surface 136 opposite the interior surface 134, wherein the working oil 126 in the cavity 124 engages the exterior surface 136 of the diaphragm 104.

10. The pressure sensing device 100 of claim 1, wherein the MEMS die sensing element 102 has a diaphragm 104, the diaphragm 104 has an interior surface 134 along a pocket defined within the MEMS die sensing element 102 and an exterior surface 136 opposite the interior surface 134, wherein the cavity 124 extends through an aperture in the MEMS die sensing element 102 into the pocket such that the working oil 126 in the cavity engages the interior surface 134 of the diaphragm 104.

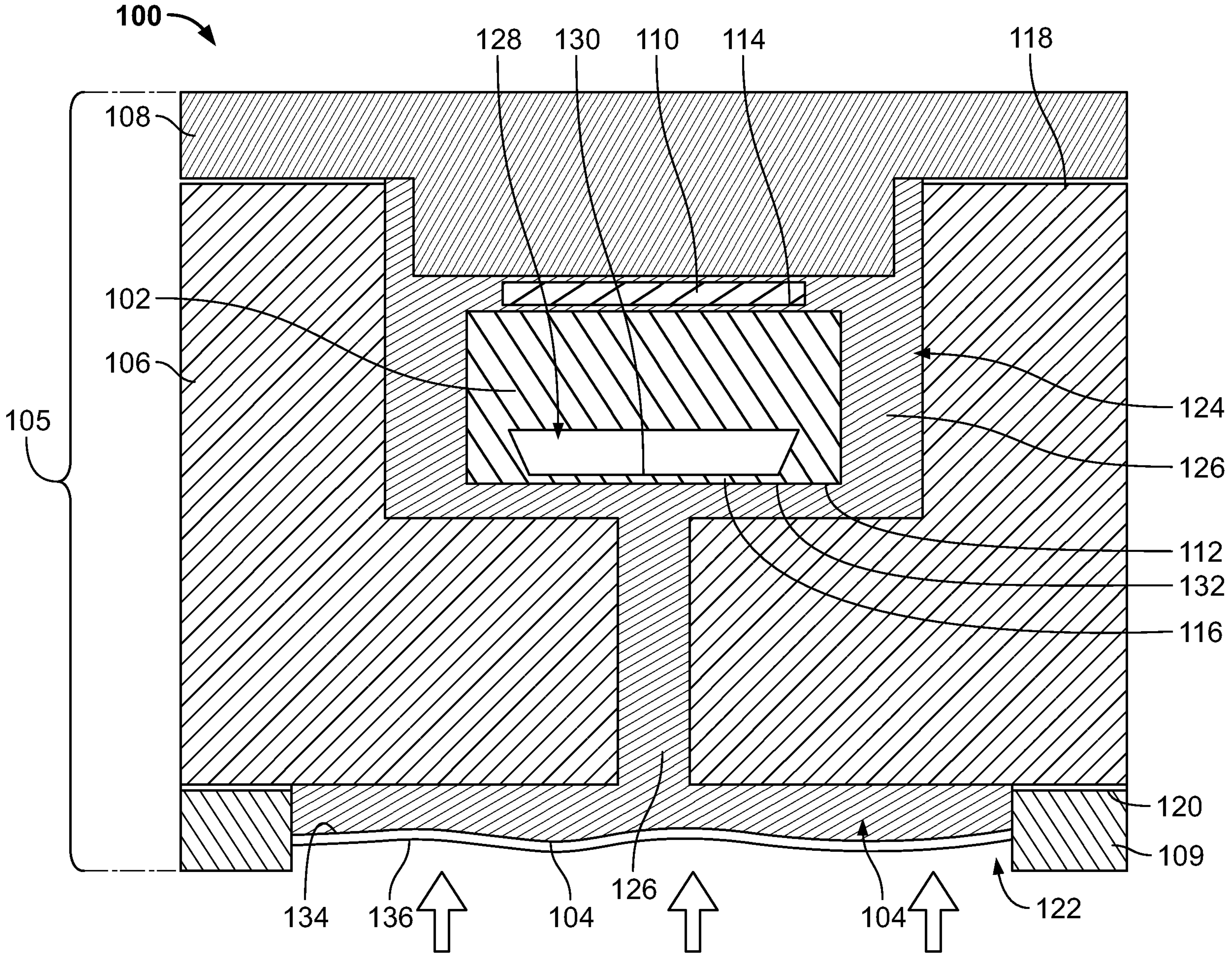
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Fig. 1

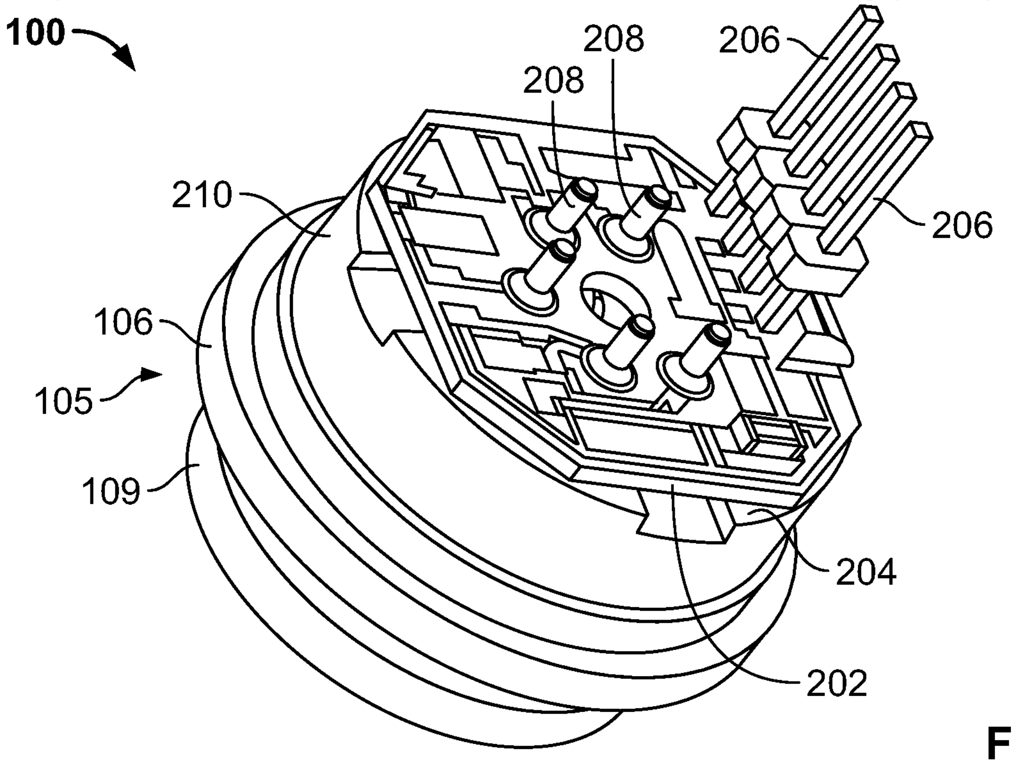
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Fig. 2

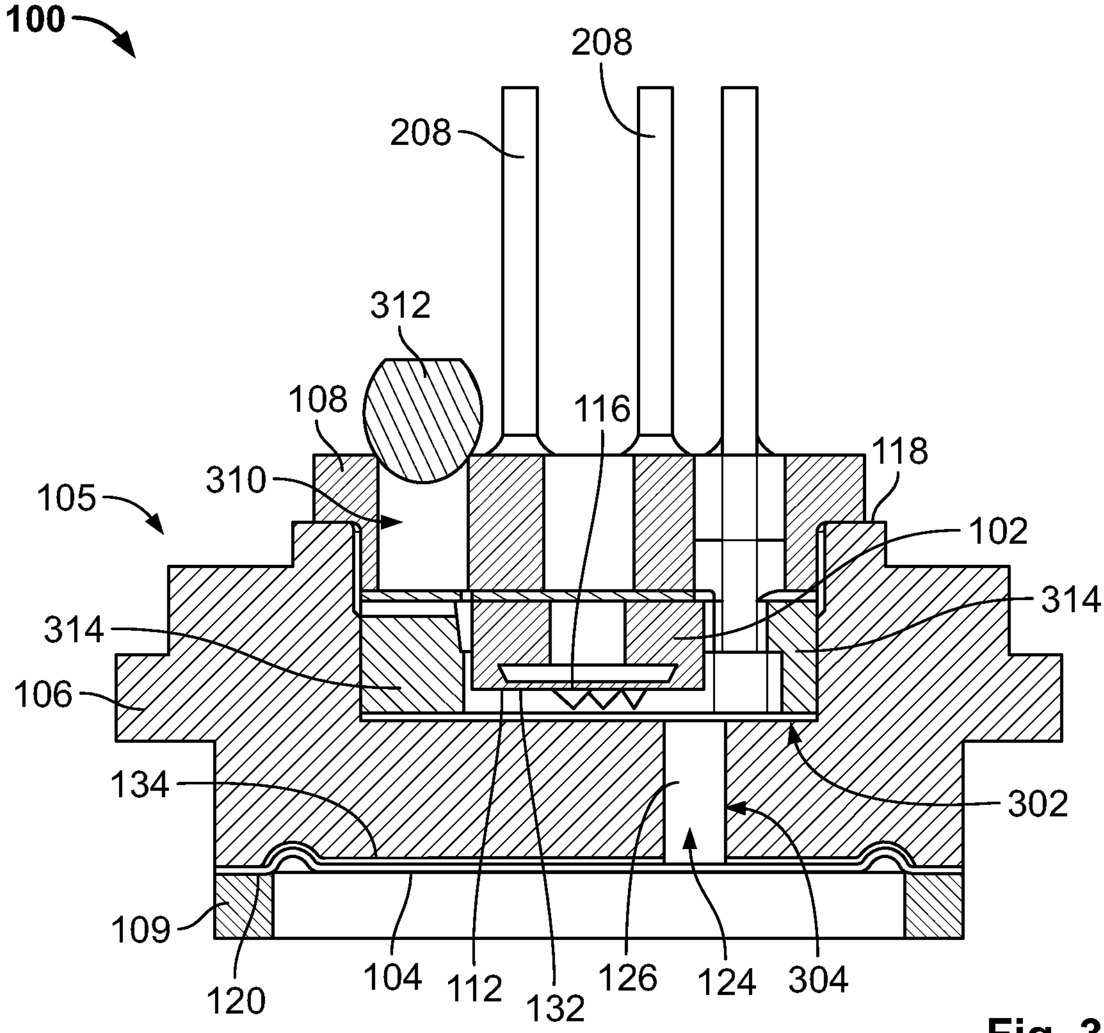
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Fig. 3

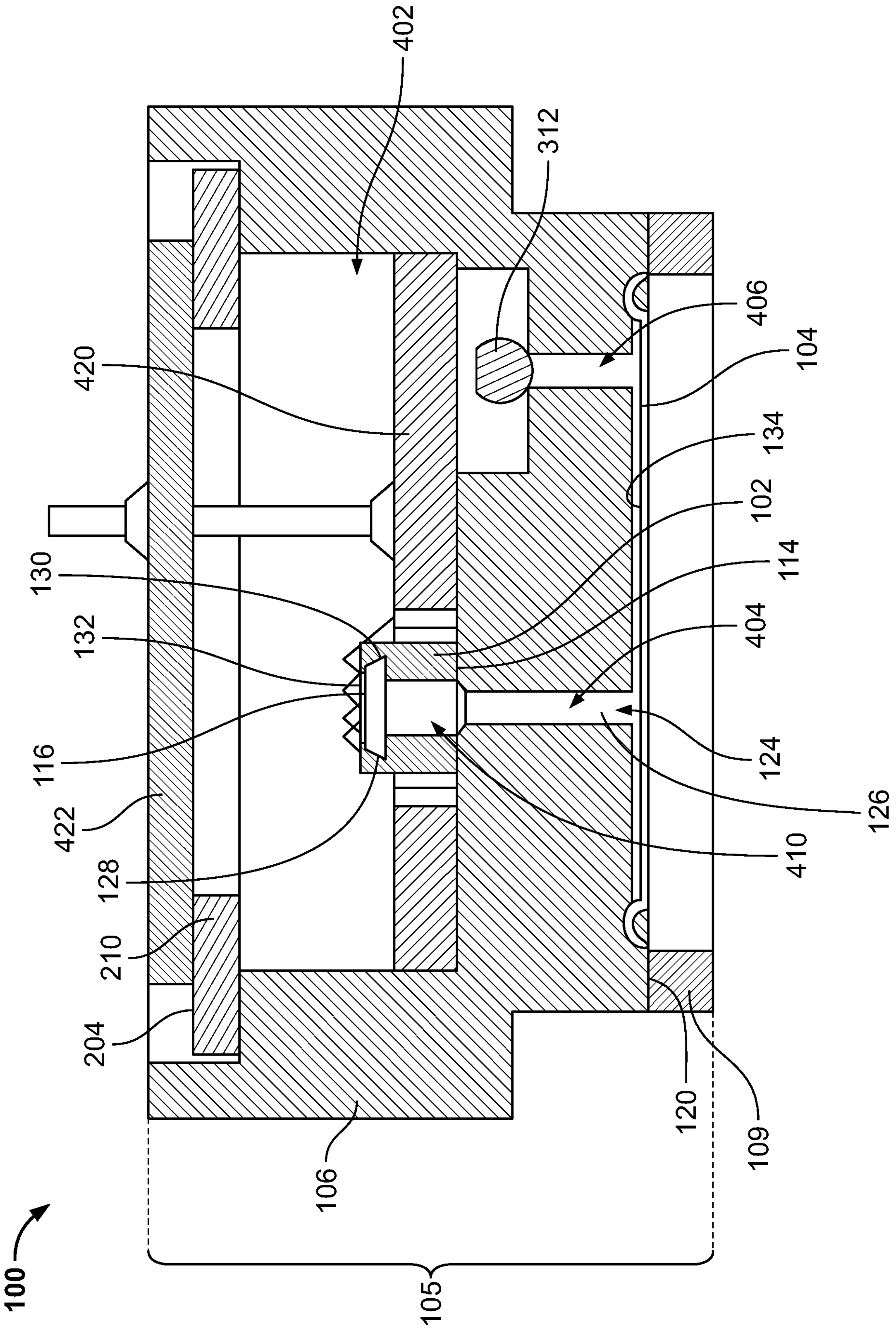
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Fig. 4

# INTERNATIONAL SEARCH REPORT

International application No
PCT/IB2019/052673

A. CLASSIFICATION OF SUBJECT MATTER
INV. G01L9/00 G01L19/00 G01L19/06
ADD.

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)
G01L

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 practicable, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

| Category* | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
|---|---|---|
| X | US 2007/095146 A1 (BROSH AMNON [US]) 3 May 2007 (2007-05-03)<br>abstract<br>paragraph [0031]<br>figure 1<br>----- | 1-10 |
| X | US 6 311 561 B1 (BANG CHRISTOPHER A [US] ET AL) 6 November 2001 (2001-11-06)<br>abstract<br>column 4, lines 45-50<br>----- | 1-10 |
| A | US 2018/134545 A1 (MORSINK FRANK [NL] ET AL) 17 May 2018 (2018-05-17)<br>paragraph [0020]; figure 5B<br>----- | 2-4 |
| A | US 2017/362083 A1 (YEE SEOW YUEN [US] ET AL) 21 December 2017 (2017-12-21)<br>paragraph [0028]<br>----- | 2-4 |
|  | -/-- |  |

☒ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

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| Date of the actual completion of the international search<br>17 July 2019 | Date of mailing of the international search report<br>26/07/2019 |
| Name and mailing address of the ISA/<br>European Patent Office, P.B. 5818 Patentlaan 2<br>NL - 2280 HV Rijswijk<br>Tel. (+31-70) 340-2040,<br>Fax: (+31-70) 340-3016 | Authorized officer<br>Grewe, Clemens F. |

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

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