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(54) **SYSTEMS AND METHODS FOR A DUAL PURPOSE GETTER CONTAINER**

(57) Systems and methods for a dual purpose getter container are provided. In certain embodiments, an atomic sensor device comprises a sensor body, the sensor body enclosing an atomic sensor; a getter container coupled to an opening in the sensor body, wherein a first opening in the getter container is coupled to the opening in the sensorbody; and a second opening located on the getter container, wherein gas within the sensor body can pass through the second opening. Further, the device may include a getter enclosed within the getter container, the getter coating surfaces of the getter container, such that gas within the sensor body can enter the getter container and contact the getter.

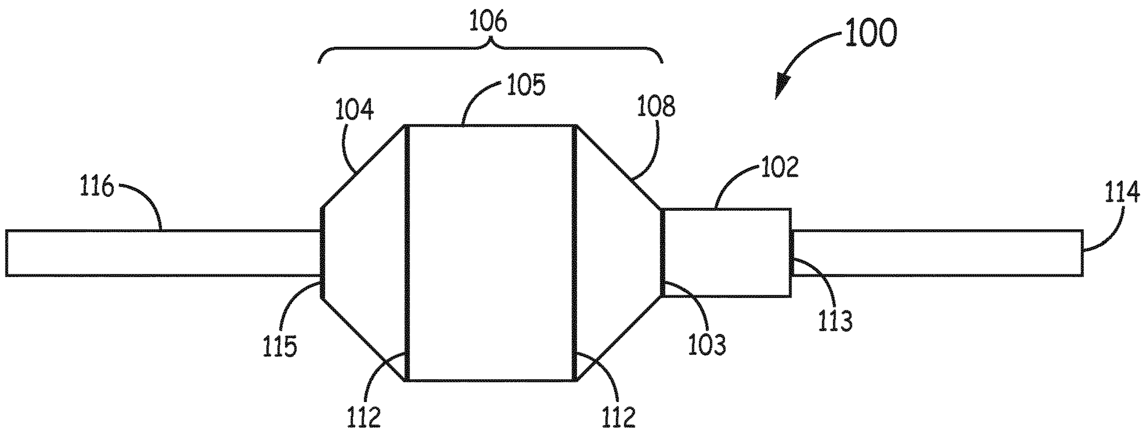


FIG. 1

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## Description

### BACKGROUND

**[0001]** Some atomic sensors require ultra-high vacuums to work properly. For example, air present within the body of a clock using cold atoms negatively impacts the functionality of the clock. To prevent air from entering the body of atomic sensors, the air within the body is removed using ion pumps, turbomolecular pumps, and the like. However, over time, small leaks or particle out-gassing allow air to slowly enter the sensor body. To maintain the required vacuum levels within the sensor body, non-evaporable getters are placed within a sensor to remove air that enters the sensor body. However, to have adequate pumping speeds and capacity, non-evaporable getters become relatively large and the size of the non-evaporable getter limits the possible size range of atomic sensors. In some applications, the size requirements of the atomic sensors prevents the use of non-evaporable getters to maintain a vacuum within an atomic sensor.

**[0002]** Further, in certain atomic sensors, air is pumped out to create a vacuum within the atomic sensor and other gasses may be introduced to enable the proper operation of the sensor. For example, in an atomic clock, a vacuum may be established within the body of the atomic clock and then a material is introduced into the body of the atomic clock, such as rubidium. In certain implementations, to establish the vacuum and introduce material into the sensor, access is provided to the inside of the sensor through a series of access ports. However, atomic clocks may be designed to occupy a small volume and multiple ports increase the size of the atomic clock and the multiple openings also may increase the fragility of the atomic clock, making the clock more susceptible to damage during fabrication and operation.

### SUMMARY

**[0003]** Systems and methods for a dual purpose getter container are provided. In certain embodiments, an atomic sensor device comprises a sensor body, the sensor body enclosing an atomic sensor; a getter container coupled to an opening in the sensor body, wherein a first opening in the getter container is coupled to the opening in the sensor body; and a second opening located on the getter container, wherein gas within the sensor body can pass through the second opening. Further, the device may include a getter enclosed within the getter container, the getter coating surfaces of the getter container, such that gas within the sensor body can enter the getter container and contact the getter.

### DRAWINGS

**[0004]** Understanding that the drawings depict only exemplary embodiments and are not therefore to be considered limiting in scope, the exemplary embodiments will be described with additional specificity and detail through the use of the accompanying drawings, in which:

Figure 1 is a diagram of one embodiment of a system for maintaining a vacuum in an atomic sensor;

Figures 2A and 2B are diagrams of different embodiments of a system for maintaining a vacuum in an atomic sensor;

Figure 3 a diagram of a getter securer according to one embodiment;

Figure 4 is a diagram of an activation device for a getter, where the getter is placed within a getter container according to one embodiment; and

Figure 5 is a flow chart diagram describing the fabrication of an atomic sensor having a dual purpose getter according to one embodiment.

**[0005]** In accordance with common practice, the various described features are not drawn to scale but are drawn to emphasize specific features relevant to the exemplary embodiments.

### DETAILED DESCRIPTION

**[0006]** In the following detailed description, reference is made to the accompanying drawings that form a part hereof, and in which is shown by way of illustration specific illustrative embodiments. However, it is to be understood that other embodiments may be utilized and that logical, mechanical, and electrical changes may be made. Furthermore, the method presented in the drawing figures and the specification is not to be construed as limiting the order in which the individual steps may be performed. The following detailed description is, therefore, not to be taken in a limiting sense.

**[0007]** Embodiments described herein provide solutions for establishing and maintaining a vacuum within an atomic sensor through the use of a dual purpose getter container. To establish and maintain a vacuum such as an ultra-high vacuum within a clock body, a tube having an evaporable getter is attached to an opening in the body of an atomic clock. When the tube is attached, the tube is used for cleaning out the interior of the body and also for the introduction of material such as rubidium. When the body is evacuated and filled with rubidium, the tube may be sealed and then an evaporable getter placed within the tube may then be activated. By using the same opening for the evacuation of the body, filling of the body, and activation of the getter, the number of openings needed to fabricate the clock are reduced, thus enabling a smaller body that is more resistant to damage.

**[0008]** Figure 1 is a diagram illustrating a sensor 100 that is able to maintain a vacuum in an atomic sensor body 106 using two fill tubes 114 and 116 and a getter

102. In certain implementations, the atomic sensor 100 is an atomic clock, a gyroscope, an accelerometer, and the like. Further, the atomic sensor 100 includes a sensor body 106, where the sensor body 106 is a structure that isolates an interior volume from an exterior environment. In some implementations, gas present within a sensor body 106 (such as nitrogen, oxygen, argon, and the like) of the atomic sensor affects the ability of the atomic sensor 100 to perform its designed function. For example, cold atom clocks typically operate in an ultra high vacuum for proper operation. To prevent gas contamination from affecting the functionality of the atomic sensor, system 100 include a gas evacuation devices 114 attached to gas evacuation site 113. Gas evacuation sites 113 provides a location where gas evacuation device 114 attaches to the sensor body 106 to evacuate gas from within the sensor body 106. Multiple methods may be used to evacuate gas through gas evacuation site 113. For example, thermal vacuum sealing, gettering, fill/evacuation cycles, temperature bakes, oxygen discharge, pumping and other techniques may be used to evacuate the gas from within the sensor body through the gas evacuation site.As illustrated, and in certain embodiments, gas evacuation device114 may be a fill tube that is attached to gas evacuation site 113 on sensor body 106.

**[0009]** Further, the sensor 100 may also include a fill tube 116 attached to an access point 115, where the fill tube 116 through access point 115 may be used toprovide access to the interior of sensor body 106. Through the fill tube 116, an alkalimetal (such as rubidium, cesium, or any other suitable alkalimetal) used for operation of the atomic sensor within sensor body 106 may be placed within the sensor body 106 after the gas is evacuated out through the gas evacuation site 113. Also, ion pumps or turbo-molecular pumps can also attach to the fill tubes to remove air from within sensor body 106 through the fill tubes 114 and 116. When the air is evacuated from within sensor body 106 through the fill tubes 114 and 116, the fill tubes 114 and 116 are sealed to obtaina vacuum tight seal and maintain the vacuum using varioustechniques, including, for example, pinching and welding or valves. In some implementations, the chamber is evacuated to produce a vacuum and sealed. Then the alkali metal is released into the chamber undervacuum by crushing a capsule that was inserted into the fill tube 116 that contains the alkali metal (or by another suitable technique). In an alternative implementation, the chamber is sealed after the alkali metal is released into the chamber. In other words, the sealed, self-contained alkali metal is introduced into thechamber before evacuation, but the alkali atoms are notreleased until after vacuum evacuation. In a further embodiment, if metallic but electrically isolated from each other, the fill tubes serve as electrodes forforming a plasma for discharge cleaning of sensor body 106 and to enhance vacuum properties and vacuum bake out (that is, heating the sensor body 106 to hastenevacuation) of the of sensor body 106.The fill tubes are further described in United States patent application serial number 12/484,878 (attorney docket number H0020713-5609) entitled "PHYSICS PACKAGE DESIGN FOR A COLD ATOM PRIMARY FREQUENCY STANDARD" filed on 6/15/2009 and which is referred to herein as the ’878 application. The ’878 application is incorporated herein by reference.

**[0010]** When gas is removed from within sensor body 106, atomic sensor material is placed in sensor body 106. For example, when atomic sensor 100 is an atomic clock, rubidium or cesium is placed in the evacuated sensor body 106 through gas evacuation site 115. In some implementations, when the atomic sensor material is placed in sensor body 106, gas evacuation sites 113 and 115 are sealed. However, gas,such as cesium or rubidium and other contaminant gasses, may remain in sensor body 106, may enter sensor body 106 after fabrication through a break in bonding materials like sodium silicate or a frit fracture, or may develop within sensor body 106 due to out-gassing of interior materials. To create and maintain the vacuum within sensor body 106, a getter may further remove remnant air and air that enters sensor body 106.

**[0011]** In this embodiment, an evaporable getter may maintain the vacuum within sensor body 106 after the fabrication of atomic sensor 100 finishes. During fabrication, the fabrication process may placeevaporable gettermaterial (also referred to as a flashable getter) within sensor body 106, but during fabrication the evaporable getter is not yet flashed. As used herein, before flashing, the evaporable getter includes a reservoir of reactive getter material such as barium, aluminum, magnesium, calcium, sodium, strontium, cesium, phosphorus, and the like. In some implementations, when a pump removes the air from within sensor body 106 and the fabrication process seals sensor body 106, the fabrication process places a getter activation device around a portion of the sensor body 106 that is proximate to the evaporable getter material and activates the getter material by heating the reservoir of getter material. Alternatively, sensor body 106 is sealed after the activation of getter material. The heat applied to the getter material causes the getter material to evaporate and coat an inside surface of sensor body 106. After the activation of the getter material, gas within sensor body 106, gas that has outgassed from material within sensor body 106,and gas that enters sensor body 106 after fabrication chemisorbs to the coating of getter material on the inside of sensor body 106. For example, the fabrication process places an evaporable getter that includes a reservoir of barium within sensor body 106. The getter activator heats the barium, which evaporates and coats an inside surface of sensor body 106. Because of the reactive nature of barium, air within the body chemisorbs to the barium coating. However, the evaporation of the getter material could impair the functionality of atomic sensor 100 if the getter material were to interact with and/or coat other functional elements within the sensor body 106 that may include an optical surface, rubidium within the sensor body 106, and the like. Also, the heat used to activate the getter material, if applied to particular components within or on atomic sensor 100, could damage atomic sensor 100.

**[0012]** To prevent damage to or interference with the functionality of atomic sensor 100, the fabrication process places the evaporable getter material within a getter container 102 that is attached to agetter site 103 on the external surface of sensor body 106, getter site 103 being an opening in sensor body 106. Getter container 102 is an enclosure with an opening that attaches to an opening in sensor body 106. Getter container 102 encloses getter material such that the evaporation of getter material during activationprimarily coats inside surfacesof getter container 102 and other surfaces of atomic sensor 100 that are farther from the middle of the sensor body 106 than the getter material. Accordingly, the getter material is inhibited from coating an inside surface of sensor body 106. For example, in some implementations, the evaporable getter material is located within a flattened metal ring with a channel extending around one side of the ring. Further, the fabrication process fills the channel with pressed getter material. The fabrication process places the ring containing the getter material within getter container 102 such that the side of the getter that contains the channel faces away from getter site 103 in sensor body 106. Because the ring faces away from the opening, the getter material will evaporate away from sensor body 106 (which may contain sensitive optical components) and coat the interior surface of getter container 102 such that air circulating within the sensor body 106 will be chemisorbed by the getter on the interior surface of getter container 102. In an alternative implementation, evaporable getter is a pan filled with getter material. Similar to the ring, the side of the pan filled with getter material faces away from the opening in sensor body 106. As used herein, facing away from the sensor body 106 means that the evaporable getter stores the getter material in such a way that getter material evaporates away from sensor body 106 towards a distal end of the getter container 102 in relation to the center of the sensor body 106.

**[0013]** In a further embodiment, the opening at getter site 103 between the interior of sensor body 106 and getter container 102 allows any air remaining in sensor body 106 to circulate between getter container 102 and sensor body 106. For example, the fabrication process joins getter container 102 to sensor body 106 such that an opening in the getter container joins to an opening at getter site 103 in the sensor body 106. Further, any air remaining within the combination of getter container 102 and sensor body 106 circulates around the enclosed volume such that it comes into contact with and chemisorbs to the coating of getter material on the interior surface of getter container 102. In some implementations, getter container 102 is shaped like a cup, where the mouth of the cup attaches to an opening in the getter site 103 of sensor body 106 and the getter faces away from sensor body 106 so that the getter material coats the bottom of the cup like shape of getter container 102.

**[0014]** In at least one implementation, the getter container 102 is connected to one of fill tubes 114 or 116. For example, the gas evacuation site 113 is located on a side of the getter container 102 other than the location where the getter container 102 connects to the sensor body 106 at getter site 103. As illustrated in Figure 1, the fill tube 114 is attached to the evacuation site 113 on the getter container 102, where the evacuation site 113 is located on an opposite side of the getter container from the sensor body 106. When the fill tube 114 is attached to the getter container 102, as the getter within the getter container 102 is flashed away from the center of the sensor body 106, the flashed getter material may coat the interior of the fill tube 114. However, the getter is not flashed until after the gas has been evacuated from within the sensor body 106 and the sensor body 106 has been vacuum sealed. In an alternative implementation, instead of the gas evacuation fill tube 114 being attached to the getter container 102, the material introduction fill tube 116 is connected to the getter container 102 and the getter in the getter container 104 is activated after material is introduced into the sensor body 106. By connecting one of the fill tubes 114 or 116 to the getter container 102 rather than a separate appendage on the sensor body 106, the atomic sensor 100 may be fabricated in such a way that it is less fragile , reduced size, and more streamlined form-factor for packaging later in system integration.

**[0015]** In some implementations, getter container 102 is fabricated from an insulating material. The application of heat activates the getter material. If getter container 102 conducts the heat developed during the activation of the getter material to sensor body 106, the heat could damage the atomic sensor 100. Thus, the material used to fabricate getter container 102 insulates sensor body 106 from the heat developed in the activation of the getter material. For example, getter container 102 is fabricated from glass, ceramics, and the like, in such embodiments. In an alternative embodiment, when the getter material is heated using inductive heating and getter container 102 is thermally isolated from the getter material, getter container 102 is fabricated from a material that does not respond to inductive heating. For example, getter container 102 is fabricated from a non-ferromagnetic material such as aluminum.

**[0016]** In certain embodiments, a seal secures getter container 102 to sensor body 106at getter site 103. The sealmay provide avacuum seal where getter container 102 is joined to sensor body 106. To secure getter container 102 to sensor body 106, a sealing material is applied around the getter site 103 where getter container 102 contacts sensor body 106. For example, frit is applied around the location where getter container 102 and sensor body 106abut against one another in some embodiments. In further implementations, a frit mixture is also applied around the gas evacuation site 113 and the access point 115 where the fill tubes 114 and 116 respectively contact the getter container 102 and the sensor body 106. Subsequently, the sensor body 106, fill tubes 114 and 116, and getter container 102 are heated. The heat causes the applied material (such as frit) to become a liquid and flow around the location where the different components abut against one another. When the liquefied material has flowed around the different joints in the different components, the liquefied material may cool and harden to form a vaccum seal around the different joints of sensor body 106 and getter container 102. In one exemplary implementation, the liquefied material is a liquefied frit that hardens to form a frit glass. For example, the applied frit is melted and cooled, forming a hardened, vacuum seal connection between sensor body 106 and getter container 102. In an alternative implementation, getter container 102 is manufactured from the same material as sensor body 106 such that getter container 102 and portions of sensor body 106 are a single piece of material. Conversely, the sensor body 106 may be manufactured from different sensor body components for example, the sensor body 106 may include a first end 104 and a second end 108 that connect to a center portion 105, where the different sensor body components are joined together with seals 112. Similar to other seals in atomic sensor 100, seals 112 may be fabricated through the application of frit and subsequent heating.

**[0017]** In some implementations, the sensor body 106may connect to multiple getter containers. For example, sensor body 106 connects to a first getter container 102 and a second getter container. Each of the multiple getter containers may include a getter, for instance, getter container 102 encloses a first getter and the second getter container may enclose a second getter. In some implementations, the multiple getter containers increase the surface area coated by the getter material. The increased surface area improves the ability of the multiple getters to maintain a vacuum within the sensor body 106. When there are multiple getter containers, the different fill tubes 114 and 116 may attach to different getter containers attached to the sensor body 106. Individual getter containers may contain differing types of gettering material to increase the pumping speed for different contaminants.

**[0018]** In some implementations, a getter securer secures the getter material at a desired location within getter container 102. The phrase "getter securer," as used herein, refers to a structure or device that secures the getter material at a location within getter container 102. For example, the getter material is attached to a snap ring. The snap ring is then pinched and inserted into getter container 102. When the snap ring is located at the desired location within getter container 102, the snap ring is released and the snap ring expands and applies pressure against the interior surface of getter container 102 to secure the unflashed getter material in place. Alternatively, the getter securer can be manufactured as part of getter container 102, or part of sensor body 106.

**[0019]** Figures 2A and 2B illustrate alternative embodiments to the atomic sensor 100 described above in Figure 1. For example, Figures 2A and 2B illustrate implementations where a single fill tube is used for both evacuating the interior of the sensor body and for the introduction of material into the sensor body. Further, the single fill tube is attached to a getter container that is attached to the sensor body. For example, Figure 2 illustrates an atomic sensor 200a that includes a sensor body 206 that is fabricated from a first end 204, a second end 208, and a center portion 205, where the different components of sensor body 206 are joined together by seals 212 in a similar manner as seals 112 join first end 104 and second end 108 to center portion 105 of Figure 1 as described above. Further, atomic sensor 200a includes a getter container 202a mounted to second end 208 at getters site 203a in a similar manner as described above with relation to getter container 102 and getter site 103 in Figure 1. In contrast to atomic sensor 100 in Figure 1, the fill tube 214a may be used for both gas evacuation and for the introduction of matter into the sensor body 206, where the single fill tube 214a is used for the combined uses of fill tubes 114 and 116 described above in Figure 1. As illustrated in Figure 2A, the fill tube 214a connects to a getter container 202a at access point/evacuation site 213a. Figure 2B illustrates a similar embodiment to atomic sensor 200A in Figure 2A. In particular Figure 2B illustrates a sensor 200b having a single fill tube 214b that connects to a getter container 202b at an access point/evacuation site 213b. However, in contrast to atomic sensor 200a, the getter container 202b connects to a getter site 203b that is located on the center portion 205 of sensor body 206 as compared to the location of getter site 203a on the second end 208 of sensor body 206. Alternatively, the getter container may also connect to the first end 204 of sensor body 206.

**[0020]** Figures 3 illustrates a snap ring 308 and a getterring 306 according to one embodiment. In certain embodiments, snap ring 308 is a metal spring like ring that can be deformed to fit inside a getter container. To aid in deforming snap ring 308, snap ring 308 includes, in this embodiment, holes 301 in tabs 303. A tool can be inserted through holes 301 in tabs 303 to either compress or extend snap ring 308. Pressing tabs 303 together decreases the diameter of snap ring 308, allowing it to fit within a getter container. When the tool places snap ring 308 within a getter container at a desired location, the tool releases snap ring 308, which springs against the sides of the getter container. The pressure from snap ring 308 against the sides of the getter container secures snap ring 308 in place.

**[0021]** In at least one embodiment, a connector 305 connects snap ring 308 to getter ring 306. The connector 305 allows the snap ring 308 to also secure getterring 306 in place within the getter container. Getterring 306 is a ring with a getter material channel 307. The getter material channel 307 holds getter material during assembly. For example, in some implementations, getter material channel 307 contains barium that has been pressed into getter material channel 307. The getter material in getter material channel 307 remains located within the getter material channel 307 until the gettermaterial is activated.

**[0022]** Figure 4 illustrates a block diagram illustrating a system for activating evaporable gettermaterial in a getter ring 406 within a getter container 404 attached to a sensor body 402 and a fill tube 414. In one implementation, to activate the gettermaterial in the getter ring 406, a getter activation device 409 is temporarily attached to an outside surface of the getter container 404 proximate to the location of the getterring 406 within the getter container 404. The getter activation device 409, in this example, is an RF induction coil or other element that heats the gettermaterial within getter container 404. By placing the getter activation device 409 on the outside surface of getter container 404, where getter container 404 is outside the sensor body 402, getter activation device 409 activates getter 406 without damaging the interior of sensor body 402. Further, the getter container 404 is made from an insulating material like glass, in some embodiments, that does not heat up in response to an RF induction coil. In an alternative embodiment, other devices that heat the gettermaterial in the getter ring 406 are used for activation such as a laser heater. In another implementation the activation element could be permanently affixed to the getter container allowing for multiple re-activitations of the getter if necessary. Once the gettermaterial is activated, the getter can function to preserve the vacuum within the atomic sensor. It is important to note that the activation temperature of the getter is higher than any temperature used in previous process steps.

**[0023]** Figure 5 is a flow diagram of a method 500 for evacuating air from an atomic sensor. Method 500 can be performed to fabricate atomic sensor 100 described above in Fig. 1. The method 500 proceeds at 502, where evaporable getter material is secured within a getter container, the getter container having a first opening and a second opening. For example, getter material may be placed on a getter securer, like a snap ring, and then placed within the getter container.The method 500 proceeds at block 504, where the first opening of the getter container is attached to an opening in a sensor body such that the evaporable getter material faces away from the sensor body. Alternatively, the evaporable getter is secured within the getter container after the getter container is attached to the sensor body. The method 500 proceeds at 506, where the getter container is sealed to the sensor body such that the getter container and sensor body connect to one another with a vacuum seal.

**[0024]** The method 500 proceeds at 508, where the air is evacuated from inside of the sensor body through the second opening of the getter container. For example, a fill tube may be attached to the second opening in the getter container. An air evacuation device may be attached to the fill tube that evacuates the air from the inside of the sensor body by extracting the air from the fill tube. Further, an alkali metal may also be introduced into the sensor body through the fill tube. The method 500 then proceeds at 510, where the interior of the sensor body is vacuum sealed. For example, the fill tube attached to the second opening of the getter container with a vacuum seal may be temporarily connected to an external vacuum pump for initial evacuation and then after evacuation, the fill tube may be permanently vacuum sealed and then disconnected from the vacuum pump. Thus, interior of the sensor body may be vacuum sealed.The method 500, then proceeds at 512, where the evaporable getter material is activated to coat an interior surface of the getter container. For example, a heater, applied to the external surface of the getter container, heats the evaporable getter material. The reactive material evaporates and coats an inside surface of the getter container. The coating of getter material on the inside surface of the getter container chemisorbs air present within the sensor body.

<u>Example Embodiments</u>

**[0025]** Example 1 includes an atomic sensor device, the device comprising: a sensor body, the sensor body enclosing an atomic sensor; a getter container coupled to an opening in the sensor body, wherein afirst opening in thegetter container is coupled to the opening in the sensorbody; a second opening located on the getter container, wherein gas within the sensor body can pass through thesecond opening; a getter enclosed within the getter container, the getter coating surfaces of the getter container, such that gas within the sensor body can enter the getter container and contact the getter.

**[0026]** Example 2 includes the device of Example 1, further comprising a first fill tube connected to the second opening.

**[0027]** Example 3 includes the device of Example 2, further comprising a second fill tube connected to a further opening in the sensor body.

**[0028]** Example 4 includes the device of any of Examples 2-3, wherein the first fill tube is configured to evacuate gas from within the sensor body.

**[0029]** Example 5 includes the device of any of Examples 2-4, wherein the first fill tube is configured to allow the introduction of an alkali metal into the sensor body.

**[0030]** Example 6 includes the device of any of Examples 2-5, wherein the first fill tube is connected to the getter container with a vacuum seal.

**[0031]** Example 7 includes the device of Example 6, wherein the vacuum seal is formed using a frit.

**[0032]** Example 8 includes the device of any of Examples 1-7, wherein the sensor body is fabricated of a first end, a second end, and a center portion, wherein the first end and the second end are vacuum sealed to opposite ends of the center portion using a frit, wherein the first opening is located in one of the first end, the second end, and the center portion.

**[0033]** Example 9 includes the device of any of Examples 1-8, further comprising a getter securerconfigured to secure a reservoir of getter material at a location within the gettercontainer before activation of the getter material, wherein the reservoir of getter material faces away from the sensor body.

**[0034]** Example 10 includes the device of any of Examples 1-9, wherein the getter material in the reservoir is activated by inductive heating such that the gettermaterial evaporates away from the reservoir to form the getter.

**[0035]** Example11 includes the device of any of Examples 1-10, further comprising at least oneadditional getter container; wherein the sensor body isattached to the at least one additional getter container, the atleast one additional getter container containing an additionalgetter, wherein the at least one additional getter container is attached to at least one additional fill tube.

**[0036]** Example 12 includes the device of any of Examples 1-11, wherein the additional getter contains different getter material from the getter.

**[0037]** Example 13 includes a method for evacuating gas from an atomic sensor, the method comprising: securing evaporable getter material within a getter container, the getter container having a first opening and a second opening; attaching the first opening of the getter container to an opening in a sensor body such that the evaporable getter material faces away from the sensor body; sealing the getter container to the sensor body; evacuating the gas from inside of the sensor body through the second opening of the getter container; vacuum sealing the interior of the sensor body; and activating the evaporable getter material to coat an interior surface of the getter container.

**[0038]** Example 14 includes the method of Example 13, wherein evacuating the gas from inside of the sensor body comprises: evacuating the gas through a fill tube attached to the second opening of the getter container; and sealing the fill tube.

**[0039]** Example 15 includes the method of Example 14, further comprising introducing alkali metal through the fill tube.

**[0040]** Example 16 includes an atomic sensor device, the device comprising: a sensor body, the sensor body enclosing an atomicsensor; a getter container coupled to an opening in the sensor body, the getter containercomprising: a first opening in the getter container coupled to the openingin the sensor body; a second opening located on the getter container, wherein gas within the sensor body can pass through the second opening; a getter enclosed within the getter container, the getter coating surfaces of the getter container, such that gas within the sensor body can enter the getter container and contact the getter; and a getter securer that secures the unflashed getter material within the gettercontainer such that the getter material faces away from the first opening; and a seal that seals the first opening to the opening inthe sensor body.

**[0041]** Example 17 includes the system of Example 16, further comprising a first fill tube connected to the second opening.

**[0042]** Example 18 includes the system of Example 17, further comprising a second fill tube connected to a further opening in the sensor body.

**[0043]** Example 19 includes the system of any of Examples 17-18, wherein the first fill tube is configured to evacuate gas from within the sensor body.

**[0044]** Example 20 includes the system of any of Examples 17-19, wherein the first fill tube is configured to allow the introduction of reactive material into the sensor body.

**[0045]** Although specific embodiments have been illustrated and described herein, it will be appreciated by those of ordinary skill in the art that any arrangement, which is calculated to achieve the same purpose, may be substituted for the specific embodiments shown. Therefore, it is manifestly intended that this invention be limited only by the claims and the equivalents thereof.

## Claims

1. An atomic sensor device (100), the device comprising:

   a sensor body (106), the sensor body (106) enclosing an atomic sensor;
   a getter container (102) coupled to an opening in the sensor body (106), wherein afirst opening in the getter container (102)is coupled to the opening in the sensorbody (106);
   a second opening located on the getter container (102), wherein gas within the sensor body (106) can pass through thesecond opening;
   a getter enclosed within the getter container (102), the getter coating surfaces of the getter container (102), such that gas within the sensor body (106) can enter the getter container (102) and contact the getter.

2. The device of claim 1, further comprising a first fill tube (114) connected to the second opening.

3. The device of claim 2, further comprising a second fill tube (116) connected to a further opening in the sensor body (106).

4. The device of claim 2, wherein the first fill tube (114) is configured to evacuate gas from within the sensor body (106).

5. The device of claim 2, wherein the first fill tube (114) is configured to allow the introduction of an alkali metal into the sensor body (106).

6. The device of claim 2, wherein the first fill tube (114) is connected to the getter container (102) with a vacuum seal.

**7.** The device of claim 1, wherein the sensor body (106) is fabricated of a first end (104), a second end (108), and a center portion (105), wherein the first end (104) and the second end (108) are vacuum sealed to opposite ends of the center portion (105) using a frit, wherein the first opening is located in one of the first end (104), the second end (108), and the center portion (105).

**8.** The device of claim 1, further comprising at least oneadditional getter container (102); wherein the sensor body (106) isattached to the at least one additional getter container (102), the atleast one additional getter container (102) containing an additionalgetter, wherein the at least one additional getter container (102) is attached to at least one additional fill tube.

**9.** The device of claim 1, wherein the additional getter contains different getter material from the getter.

**10.** A method for evacuating gas from an atomic sensor, the method comprising:

securing evaporable getter material within a getter container (102), the getter container (102) having a first opening and a second opening;
attaching the first opening of the getter container (102) to an opening in a sensor body (106) such that the evaporable getter material faces away from the sensor body (106);
sealing the getter container (102) to the sensor body (106);
evacuating the gas from inside of the sensor body (106) through the second opening of the getter container (102);
vacuum sealing the interior of the sensor body (106); and
activating the evaporable getter material to coat an interior surface of the getter container (102).

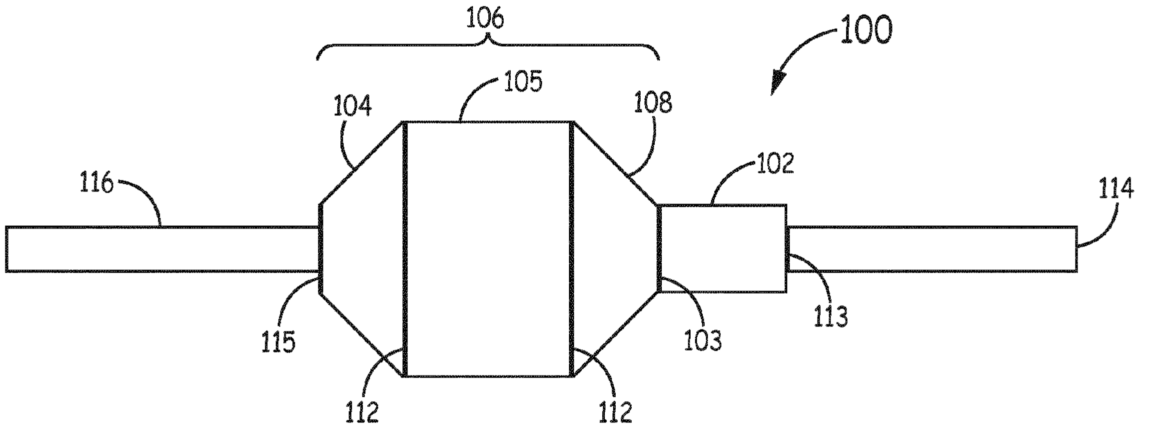
106
100
105
104
108
116
102
114
115
103
113
112
112

FIG. 1

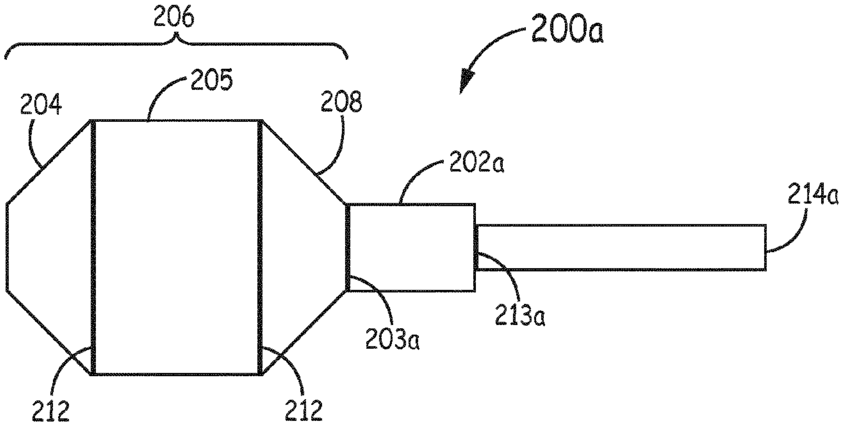
206
200a
205
204
208
202a
214a
213a
203a
212
212

FIG. 2A

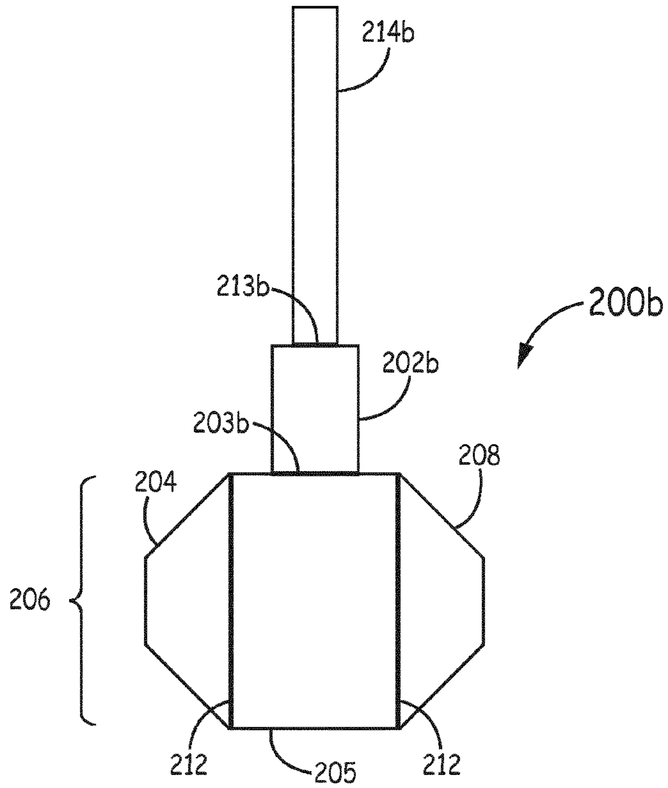


FIG. 2B

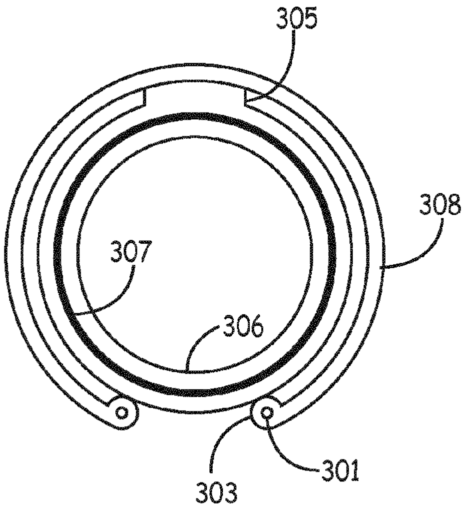


FIG. 3

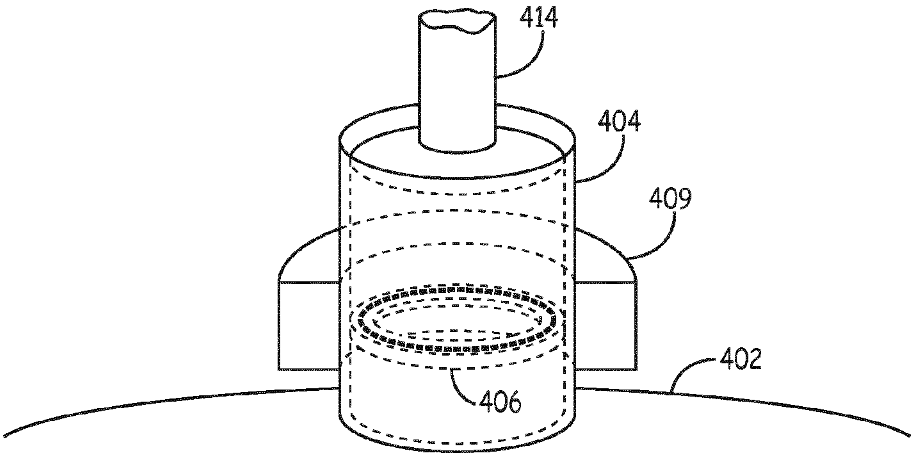


FIG. 4

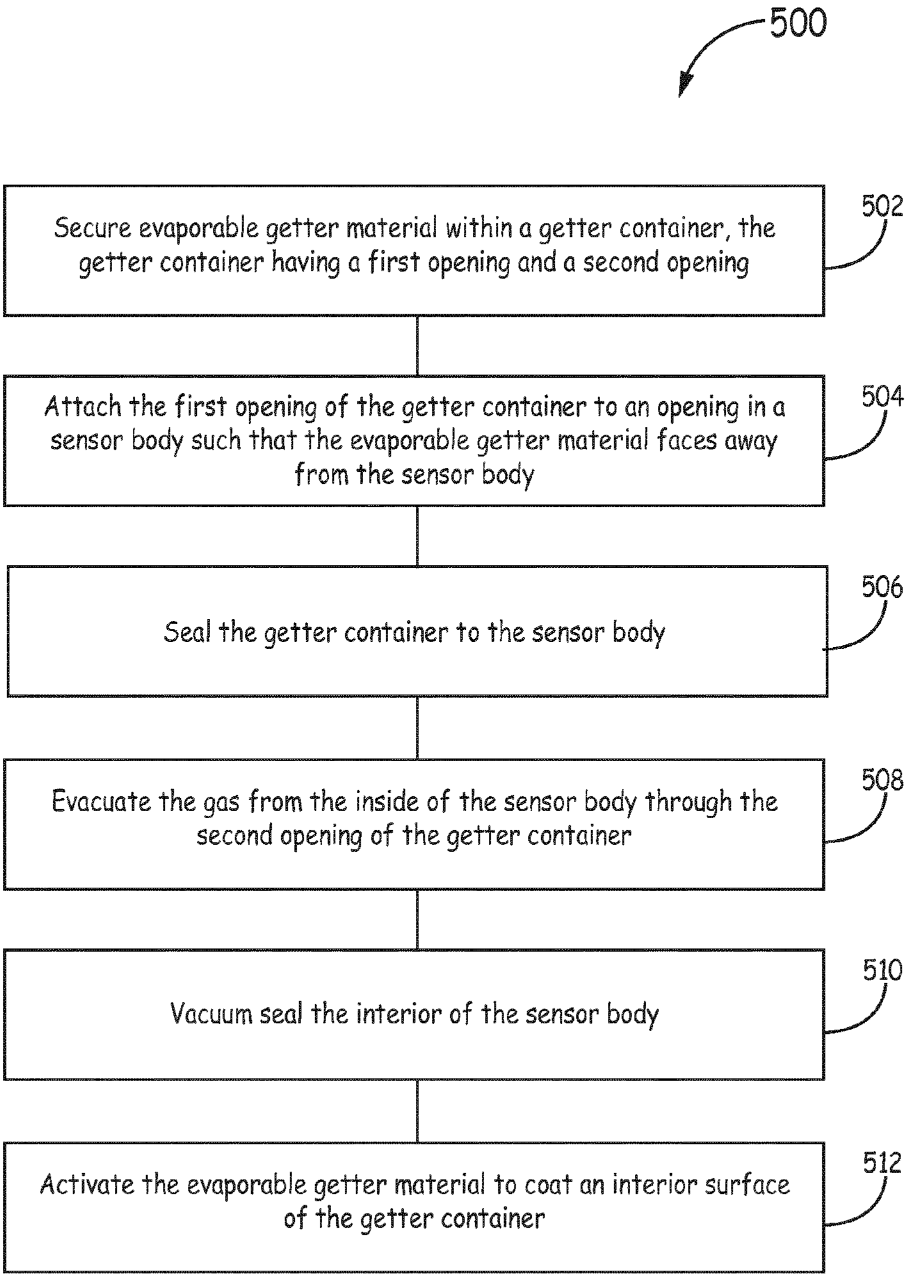
500
Secure evaporable getter material within a getter container, the getter container having a first opening and a second opening
502
Attach the first opening of the getter container to an opening in a sensor body such that the evaporable getter material faces away from the sensor body
504
Seal the getter container to the sensor body
506
Evacuate the gas from the inside of the sensor body through the second opening of the getter container
508
Vacuum seal the interior of the sensor body
510
Activate the evaporable getter material to coat an interior surface of the getter container
512

FIG. 5

## REFERENCES CITED IN THE DESCRIPTION



### Patent documents cited in the description

- US 12484878 B **[0009]**