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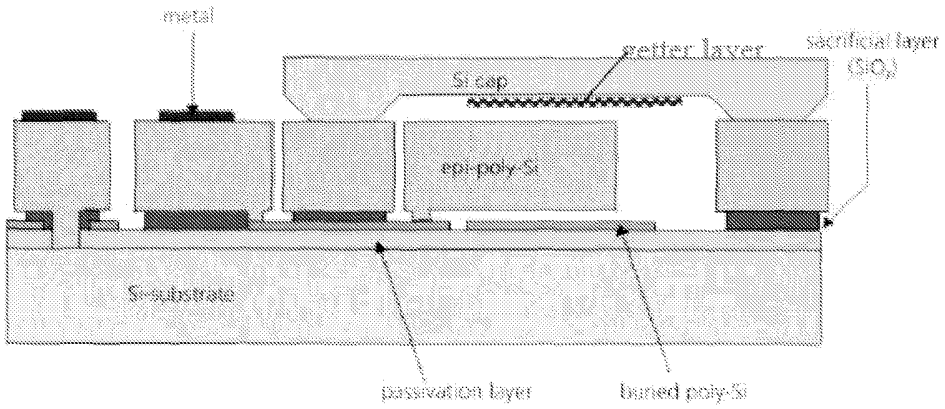
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(54) **Title:** METHOD FOR TESTING THE LEAKAGE RATE OF VACUUM CAPSULATED DEVICES



(57) **Abstract:** The present invention is directed to a method for testing the leakage rate of an encapsulated device, comprising the step: bombing the device with a Neon and/or Argon atmosphere using a bombing pressure of at least more than environmental pressure and measuring the quality factor before and after bombing. Preferably, the bombing time is about 10 to 100 hours, and the bombing pressure is 1,5 to 100 bar, more preferably 1,5 to 5 bar and most preferably about 4 bar. With this test, the leakage rate of fine leaks of the device may be determined. This test is helpful in determining statistical surface contaminations or defects caused by wafer processing that affect the seal integrity just enough to cause shorter lifetimes. Further, dicing, die assembly and transfer molding may also introduce physical defects which may be detected with the present method. Finally, the inventive test method may be useful for process optimization: Hermeticity tests are a great help to optimize sealing processes.

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Method for testing the leakage rate of vacuum capsulated devices

Vacuum wafer bonding technology provides a number of very effective techniques to produce low-cost, hermetic sealed packages for micromachined sensors and actuators. Besides the protection of the device from outside environmental stresses, the package must also provide a cavity ambient compatible with the device performance and reliability. This invention is directed to remove or alleviate the shortcomings of existing fine leak tests to assess the stability of the cavity atmosphere over long time. A new ultra-fine leak test based on quality factor (Q-factor) monitoring has been developed that has the potential to be used for in-line critical leak rate testing on wafer level before or after device singulation. With the example of a poly-silicon resonating microsensor, it is shown that the test is sensitive enough to predict the cavity pressure for a demanded device lifetime of 15 years, independent of whether or not an integrated thin film getter is used for stabilizing the cavity vacuum and extending device lifetime.

Microsensor packaging is one of the most important and challenging technology areas (W. Reinert et al., "Vacuum Wafer Bonding Technology", IMAPS Nordic 2004). In particular, hermetic packaging on wafer level is a key technology of many microelectromechanical systems (MEMS). The hermetic sealing protects them from harmful environmental influences, significantly increasing their reliability and lifetime. In addition some MEMS need a specific gas or pressure environment for damping of the resonating structure within the package to function as specified, see table 1. A number of technological topics are to be considered to produce hermetic sealed, micromachined devices on wafer level with controlled cavity pressures ("vacuum pressures") ranging from 10^{-4} mbar to 1000 mbar.

sensor/device type	vacuum level
accelerometer	300 – 700 mbar
absolute pressure sensor	1-10 mbar
resonator (angular rate)	10^{-1} mbar
bolometer	$< 10^{-4}$ mbar
RF-switch	$< 10^{-6}$ mbar

Table 1: Required vacuum level for different MEMS.

Wafer-level processes are particularly interesting for the MEMS packaging since they can reduce the fabrication costs and open up possibilities for batch processing. Various wafer level sealing technologies may be used, including wafer bonding, cavity sealing by thin-film deposition, and reactive sealing, see table 2.

Sealing technology	characteristics
Wafer bonding	Established, effective technologies Large cavity volume Damping atmosphere control Getter integration possible Robust cap withstands molding Limited device density on wafer
Thin film capping	Very high device density No getter integration possible Very small cavity volume No atmosphere control Cap may bend under molding press.
Cap transfer	Not an established technology Damping atmosphere control Getter integration possible Parallel process Thin caps reduce device thickness
Individual capping	Very large cavity volume possible Ceramic caps for RF applications Sequential placement process Getter integration possible

Table 2: Vacuum wafer level sealing technologies.

The selection of a sealing technology for a device requiring a vacuum environment has to be the best compromise between the demands for low cost, high reliability, device thickness, robustness for handling and packaging, outgassing, control of bond material flow, tolerated sealing temperature, chemical material compliance, damping pressure, sensitivity to surface defects and contamination and to surface topography. The bond technology may also affect the electrical performance of the device, e.g. for RF-switches. Besides maintaining vacuum, encapsulation on wafer level solves the problem of device protection during the wafer dicing operation. The improved robustness of capped devices allows MEMS devices to be handled in existing standard semiconductor backend processes.

In an important embodiment of the present invention, it focuses on hermeticity tests performed on microresonating devices sealed on wafer level, using eutectic AuSi wafer bonding with integrated thin film getter from SAES getters to produce low-cost and long-term reliable hermetic MEMS packages. However, the results are of general nature and therefore can be taken to test and optimize all resonating and other devices regardless of the used sealing technology.

The present invention will be explained partly referring to the attached figures, wherein

Figure 1 shows a MEMS construction with getter,

Figure 2 shows a commercial (PaGeWafer®) cap wafer with deposited getter layers,

Figure 3 shows the sorption characteristics for H_2 and CO per cm^2 of getter film after a SC-1 and SC-2 treatment.

Figure 4 is a diagram indicating the dependency of the Q-factor versus cavity pressure [N2] for a typical surface micro machined resonator,

Figure 5 indicates the effects degrading the cavity pressure in a MEMS structure,

Figure 6 shows the pressure distribution after Neon bombing,

Figure 7 gives the initial air leak rate for gyroscope sensors,

Figure 8 is a wafermap example wherein 1020 dies of different quality are arranged. With the quality inspection using the present invention, 94 % good dies (grey) are discovered, the remaining are to be aborted, and

Figure 9 is a diagram indicating the calculated relationship between bombing time and reliable operation time.

Figure 1 shows the main functional elements of a conventional surface micromachined MEMS device with a structured getter film in the cap. The effective cavity volume is 260 nL. The structured poly silicon layer is around 10 µm thick.

AuSi eutectic bonding is a technology using eutectic formation at 363°C between a silicon wafer and gold deposited on another silicon substrate. The bond temperature used is in the range of 380-400°C. This is compatible with Al device metallizations. Due to the liquid formed, this technology tolerates wafer topography coming from previous processing operations. The technology is also compatible with extended outgassing cycles and the activation requirements in case a deposited getter layer is present in the device cavity. Compared to glass frit bonding, AuSi eutectic bonding does not outgas remarkably during the wafer bonding cycle, and requires only very small bondframe widths, typically in the range of 60 – 100 µm (M. Nese et al., "New method for testing hermeticity of silicon sensor structures", Sensors and Actuators A, 1996, Vol. 53, p. 349-352). This increases the device density on the wafer, which is a major parameter for low-cost production. Therefore, AuSi eutectic bonding is a suitable (although not necessary) technology for the bonding of MEMS to be tested according to the method of the present invention.

The use of Non Evaporable Getter (NEG) material (preferably Zr based alloy) is often required to ensure suitable vacuum (total pressure under $1x10^{-3}$ mbar) and long-term

stability in MEMS devices (M. Moraja et al., "Impact of cleaning procedures on getter films", Proceeding of SPIE Vol.5343 (2004) p. 87- 93). NEG can chemically sorb all active gases, including H_2O, CO, CO_2, O_2, N_2 and H_2. The main constraints imposed by the device design and process are the compatibility of the getter with the fabrication process, the thickness of the getter film and an activation temperature compatible with the bonding process. Besides this, SAES Getters laboratories offer a patterned deposition of the getter material on the cap wafer by a proprietary technology named PaGeWafer®. The thick getter film can be selectively placed into the cavities without affecting the lateral regions of the wafer where the hermetic sealing is to be performed. The typical pattern lateral dimensions are in the range of the millimeter, while the getter film can be placed in the cavities with any depths, ranging from few microns up to hundreds of microns. Figure 2 shows the precise deposition of the getter material inside the cavities. The getter film consists of a special Zr alloy or the like whose composition is optimized to maximize sorption performance or to maximize performance in specific sealing or bonding processes. Thus, MEMS with integrated NEGs can successfully be tested using the method of the present invention, but, of course, the method is likewise applicable to devices without such NEGs.

Wafer cleaning of the cap wafer is usually required before bonding to remove organics from the gold bond frames. The getter layer must tolerate the cleaning chemicals. It has been discovered that a caustic chemical treatment of the getter film both cleans the film and enhances its performance without measurable degradation of its structural integrity. For example, caustic chemical treatment called SC1 (with $NH_40H/H_20_2/H_20$) and SC2 (with $HCl/H_20_2/H_20$) does not affect the morphology and the sorption capacities of the getter film and significantly increased the sorption capacity, measured after ASTM standard F 798-82 (Wolfgang Reinert, Dr. Dirk Kähler, Marten Oldsen, Dr. Peter Merz, "IN-LINE CRITICAL LEAK RATE TESTING OF VACUUM-SEALED AND BACKFILLED RESONATING MEMS DEVICES", 8th international symposium on semiconductor wafer bonding, May 15-20 2005, Quebec) .The getter film at wafer level can withstand also treatment with a highly aggressive HNO_3 process up to 65% at 120 °C. The full compatibility of the getter film towards both temperature and chemical treatment with regards to the activation and capacity of the getter film is demonstrated. Typical absorption speed and absorption capacity of the patterned getter film per unit area at room temperature for hydrogen and carbon monoxide are reported in Figure 3.

The getter film, if present, is supplied in a stable, passivated form to protect the getter and to ensure that it performs as specified. For example, the PaGeWafer® can be safely handled in clean room air (M. Moraja et al., see above). Once the getter film is in

a vacuum or noble gas environment, it needs to be activated. During the thermal activation process, adsorbed gases leave the passive getter surface and the passivation layer is diffused into the bulk, rendering the surface of the getter grains chemically active and ready to pump contaminants out of the MEMS package (Wolfgang Reinert, Dr. Dirk Kähler, Marten Oldsen, Dr. Peter Merz, see above).

The getter film activation can be achieved through three main scenarios: The classic scenario is activation of the getter as part of the wafer bonding process. The temperatures under vacuum reached in the bonding process will simultaneous activate the getter as well as bond the device and cap wafers. In this case, the getter film will also improve the process conditions, by achieving a higher vacuum between the two wafers in the cavity. The second scenario is to apply heat to the cap wafer after bonding. The third scenario is first to heat the cap wafer under vacuum and then to align the wafers and bond them.

To realize a defined gas damping for resonating sensors, a gas-filling procedure has to be established. Only inert gases or gases that do not consume the getter or alter the getter sorption performance may be backfilled in the device cavities.

Argon may be selected because of good damping characteristics and low outgassing. The backfill operation is typically one step in the wafer bond cycle. Figure 4 shows the dependency of the device Q-factor from cavity pressure for a typical yaw rate sensor. The cavity pressure can be tuned to any value between 10^{-4} hPa and 1000 hPa, even overpressure is possible depending on the wafer bonder infrastructure. Typical damping pressures for gyroscopes are in the range of 10 to 100 Pa (0.1 to 1 mbar).

With the so called ring-down method, the quality factors in the range of 1000 – 500.000 can precisely be measured. The measured quality factor does not give the atmosphere gas composition; merely it is a measure of the total pressure in the device cavity, derived from the damping properties of a resonating ring (measurement of decay curve upon stopping excitation of the resonating ring). The linear fit of the measured Q-factor vs. chamber pressure in figure 4 is the basis to calculate the cavity pressure inside a hermetically sealed resonating device of the same layout.

The pressure inside of the vacuum encapsulated devices depends mainly on the outgassing of the inner surfaces, the leakage rate through fine leaks and permeation through the walls, see figure 5.

The outgassing depends mainly on the fabrication process of cap and device wafer, which has to be optimized (Max Wutz, Hermann Adam, Wilhelm Walcher, Theorie und Praxis der Vakuumtechnik, 1988, Friedr. Vieweg & Sohn, Braunschweig). For a package encapsulating a hollow space in the range of some to some hundreds of nanoliters ("nL package"), the gas load inside the cavity is critical. The enclosed base pressure together with outgassing during heat up and bonding at peak temperature may be already too much to achieve low cavity pressure below 1 Pa (10^{-2} mbar). But outgassing is a phenomenon that also generates gases throughout the device lifetime, with decreasing outgassing rate, as the amount of solved gases in surface layers decreases.

Fine leaks arise from imperfect bonding or crack initiation. The pressure change per unit time in a device can be expressed as

$$dP/dt = L / V \qquad (1)$$

where L is the leak rate and V the cavity volume of the device. Typical cavity volumes of present devices range from 0.1 mm^3 to around 5 mm^3 with a clear trend towards decreasing cavity volumes.

Since fine leaks may always be present, a leak test is necessary to guarantee a leakage rate which is small enough, either without the aid of a getter or if compensated by the getter. This maximum allowable leak rate may be called the critical leak rate, as it defines the devices within the statistical cavity pressure distribution that fail the first after the guaranteed lifetime is reached.

As an example: for a device with a life time demand of 15 years and internal vacuum requirement better than 10 Pa (0.1 mbar) and a getter capacity of approximately 1.7×10^{-5} hP·l per cavity, equation (1) gives the maximum tolerable air leakage rate at ambient pressure; for a cavity volume of 0.26 mm^3 this is 3.6×10^{-14} hPa·l/s. Due to the high Helium diffusion in silicon dioxide a long-term stable, high vacuum better than 10^{-2} Pa (10^{-4} mbar) is very difficult to achieve.

There is a variety of reasons why hermeticity testing is required for MEMS and comparable devices. First, the testing may be needed for screening purposes: Wafer processing may cause statistical surface contaminations or defects that affect the seal integrity just enough to cause shorter lifetimes. Further, dicing, die assembly and transfer molding may also introduce physical defects. Second, a testing may be

required for process optimization: Hermeticity tests are a great help to optimize sealing processes.

The present invention is directed to the development of a preferably in-line, ultra-fine leak test, for example on wafer level for resonating and other devices based on the principle to determine the unknown leak conductance of an effective leak by the method described below. This inventive leak test is defined by claim 1.

For example, both lateral and rotational resonating devices can be tested. The leak rate of every single resonating device can be measured before shipping out. The in-line test is compatible with all existing vacuum wafer bonding technologies (e.g. glass frit bonding, metallic bonding, eutectic bonding, low temperature bonding and anodic bonding), and reactive and thin film sealing as well as transfer cap sealing technology. The test is not affected by the material selection of the device wafer. Lateral and vertical feed throughs are tolerated; even wireless resonator driving concepts in burst or constant driving mode are possible. The method of the present invention does not require any specific device sealing technologies, but is applicable independent on the sealing method. The single devices or MEMS tested with the present method are not affected by leaking neighbour devices. The method may be performed on the devices at any time as required or desired, and consequently there is no wait time effect before measurement. Thus, the present invention provides a fast feedback, e.g. for wafer bonding process control.

For determination of leak conductance, the following is to be considered: In principle, the number and geometry of fine leak channels in a leaking device is not known. It is convenient to sum up all physical leak channels and to treat them as one single effective leak channel. During the Neon (or Argon) bombing, the device will take up Neon (or Argon) gas through this effective leak. The molecular gas flow law describes the Neon gas flow into the evacuated cavity:

$$q_{gas} = L_{gas} \cdot (P_2 - P_1) \qquad (2)$$

$$L_{gas} = 8/3 \cdot \frac{r^3}{l} \cdot \sqrt{\frac{T}{M_{gas}}} \qquad (3)$$

The conductance L_{gas} is proportional to a geometry term 8/3 r^3/l, that describes the probability of a gas molecule to pass a straight leak channel with opening radius r and length l. The gas with the molecular weight M_{gas} passes the leak channel at temperature T with diffuse reflection after hitting the channel wall. The condition is that the gas does

not chemically react with the channel walls. The outside partial gas pressure is given by P2 and the cavity pressure is P1.

The geometry term is experimentally determined by the Neon (or Argon) bombing. From the monitored pressure increase ΔP in the device cavity volume V during the bombing at bombing pressure P_{bomb} for the time t, the conductance can be calculated by the equation:

$$L_{gas} = \frac{\Delta P \cdot V}{t \cdot P_{bomb}} \qquad (4)$$

With the known conductance of the leak channel for Neon (or Argon), the total gas flow for all air gases can be calculated by the sum of all partial flow rates. This assumes that all gas atoms in the air are small enough to pass the leak channel. The calculation can be approximated by taking the mean atom weight of air: M_{air} = 28.92 g/mol. From vacuum physics (Max Wutz, Hermann Adam, Wilhelm Walcher, see above), the conductance of air is calculated by:

$$L_{air} = L_{Ne} \cdot \sqrt{\frac{M_{Ne}}{M_{air}}} = L_{Ne} \cdot 0.8316 \qquad (5)$$

$$q_{air} = L_{air} \cdot P_{air} \qquad (6)$$

With the present invention, an air leak rate sensitivity of up to about 10^{-16} mbar l/s is detectable.

The ultra-fine leak test of the present invention overcomes the limitations of He and Kr^{85} fine leak testing. Neon has a small collision diameter and high particle velocity. Moreover, it has much lower solubility in SiO_2 than He. The sensitivity of the He fine leak test is limited by the capabilities of the mass spectrometer used. Typically, the sensitivity is up to 10^{-9} hPa·l/s, which is a factor of 100.000 below the necessary sensitivity to assess the hermeticity of modern inertial sensors. The He test can be performed on single devices or in batch mode, but is ineffective for device cavity volumes below 5 mm³. The Kr^{85} of the radioisotope method requires a long bombing time to achieve a leak rate sensitivity around 10^{-12} hPa·l/s, the high cost of test equipment and the interference during scintillator measurements of neighbouring devices on a wafer. Not to forget, both test methods have to be performed with an additional gross leak test to check for rough seal defects.

The Neon (or Argon) ultra-fine leak test of the present invention is based on high pressure bombing in Neon (or Argon) atmosphere and the measurement of the quality factor before and after the bombing. The test can be performed on single MEMS devices either encapsulated on wafer level or in discrete hermetic housings. It can also be used with a batch of devices or on wafer level, which is the most efficient form to reduce handling efforts. Automatic wafer probers may be used for testing after device sealing. From the electrical measurements, the actual cavity pressure and initial air leak rate can be directly computed and compared to a predefined acceptable air leak rate, see figures 6 and 7.

Either by electronic mapping or device inking, the devices with too short lifetime expectation are marked, see figure 8. Other than with He or Kr^{85} test, no further gross leak test has to be performed to verify the measured leak rate. This is a very important advantage of the present invention.

Concerning the characteristics of the Neon ultra-fine leak test, it is to be noted that the test procedure is compatible with integrated getter films. The use of inert-gas is mandatory for the test as all other active air gases will be gettered and do not increase the cavity pressure. The new in-line ultra-fine leak test is not affected by the typically very small cavity volumes. Other than with all existing fine leak tests, the sensitivity of the test increases with decreasing cavity volume, as the pressure increase during the Neon exposure is larger in a smaller cavity for a given leak rate. It should be noted that on the other hand also the critical acceptable leak rate will decrease to the same amount the cavity volume shrinks, if the device lifetime is constant. The test is not limiting the lateral size and pitch of devices on a wafer. Only the ability to access the bond pad locations with a needle prober is required. The Q-factor measurement of every single device is highly selective and not affected by leaking neighboring devices. The Neon tracer gas is selected to achieve a high leak penetration rate but on the other side prevent permeation through the wall materials of hermetic devices. Helium as a tracer gas causes wrong leak rate measurements, since the diffusion of Helium in fused silica even at room temperature is around a factor of 1000 higher than for Neon. Experiments with Helium bombing show a Q-factor decrease of all hermetic bonded devices by Helium uptake, that can be verified by residual gas analysis. On the other side, the use of Argon or any other heavier inert gas will decrease the test performance due to the much smaller diffusion rates of these gases in nano-size leak channels, e.g. 40 % longer bombing time is necessary if Argon is used.

Therefore, in the case of Argon as the bombing gas, it is preferred to use higher bombing temperatures for compensating the lower diffusion rate thereof. However, use of Neon as bombing gas is preferred, due to its properties as outlined above, and because its uptake during bombing is not that harmful for the device lifetime as Argon uptake.

Of course, a mixture of Neon and Argon may be used for the method of the present invention, if required or desired e.g. for specific purposes, provided that either the ratio of the components of the mixture and/or the partial pressures of the single gases in the mixture are known.

The necessary bombing parameters (gas, time, pressure, temperature) for devices depending on their initial cavity pressure, requested pressure stability over lifetime, backfill gas, getter capacity, getter pre-saturation during bonding, cavity volume, operating lifetime at mean temperature, storage lifetime at mean temperature can be calculated. In principle, bombing times between 1 and up to 100 hours or even more should be contemplated, depending on temperature (usually <50° or even cooled conditions for Neon, e.g. down to liquid nitrogen (77K), about room temperature or even heated (for Argon) and pressure conditions. Usually, a bombing duration of about 24 hours will be sufficient for testing the pressure stability to the device for an intended life duration of about 15 years.

Example

With a bombing time of 30 h in Neon at 3 bar absolute pressure, devices with maximum allowable critical leak rates in the range of 10^{-14} hPa·l/s will be identified with a sensitivity demand of the quality measurement corresponding to 10^{-2} hPa pressure change. As the gas flow through a very small leak from a region of high pressure to a reservoir of very low pressure is based on the molecular flow condition. The gas flow is proportional to (T/M)½, where T is the gas temperature [K] and M is the molecular mass [g/mol]. Figure 9 shows the impact of an extended operation time at the maximum operation temperature of the device described in this paper. The sensitivity requirements for the identification of the initial leak rate can only be met by harsher bombing conditions.

In summary, a new in-line ultra-fine leak test has been shown to be very efficient for 100% fine leak test on resonating gyroscope sensors with integrated getter film (M. Moraja et al., see above). The test is performed e.g. on wafer level and was

evaluated for AuSi eutectic vacuum wafer bonded 6" silicon wafers with a chip density of more than 1600 sensor devices per wafer. The measured leak rate states the 0h hermeticity of the tested devices and does not guarantee the stability of the leak during aging. The influence of device aging on the leak rate may be investigated separately by the use of the same Neon ultra-fine leak test.

* * * * *

Claims

1. Method for testing the leakage rate of an encapsulated device, comprising the step: bombing the device with a Neon or Argon atmosphere using a bombing pressure of at least more than environmental pressure and measuring the quality factor before and after bombing.

2. Method according to claim 1, wherein the bombing time is about 10 to 100 hours.

3. Method according to claim 1 or 2, wherein the bombing pressure is 1,5 to 100 bar, preferably 1,5 to 5 bar and most preferably 3 to 4 bar.

4. Method according to any of the preceding claims, wherein the bombing is performed at a temperature below 50°C.

5. Method according to any of claims 1 to 3 wherein the bombing is performed in an Argon atmosphere and the temperature is between room temperature and 330°C.

6. Method according to any of the preceding claims, wherein from the quality factor before and after the bombing, the leakage rate is determined.

7. Method according to any of the preceding claims, wherein measurement of the quality factor is performed by measuring the damping properties of a resonating ring within the encapsulated device ("ring-down method").

8. Method according to any of the preceding claims, wherein the encapsulated device is a vacuum encapsulated device.

9. Method according to claim 7, wherein the device has been encapsulated under cavity pressures of between about 10^{-4} to 1000 mbar.

10. Method according to any of claims 1 to 7, wherein the device has been encapsulated under environmental pressure or overpressure.

11. Method according to any of the preceding claims, wherein the bombing is performed with a plurality of devices in a batch-wise mode.

12. Method according to any of the preceding claims, wherein the method is used for the identification of leaking devices, or for the identification of devices which are not sufficiently tight to provide a service life time as required, preferably of 5 to 15 years, or wherein the method is used for damages caused by further processing of the device, for example due to plastics encapsulation.

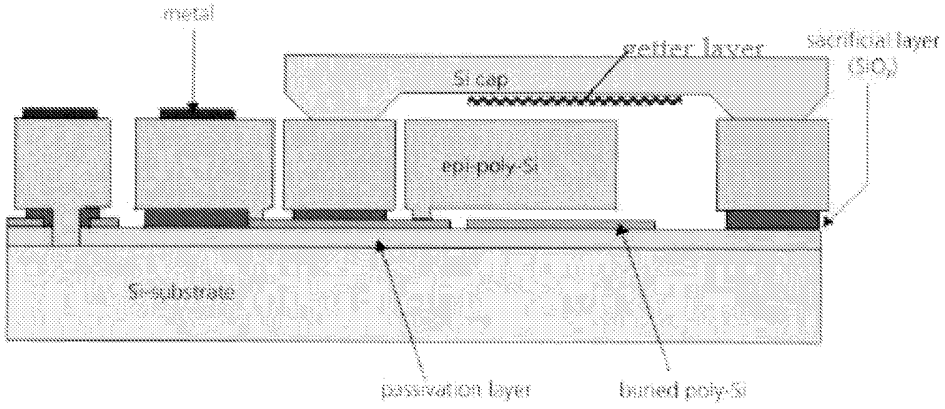


Fig. 1

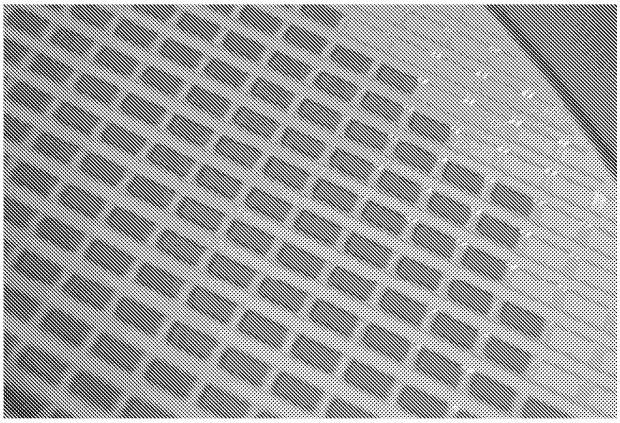


Fig. 2

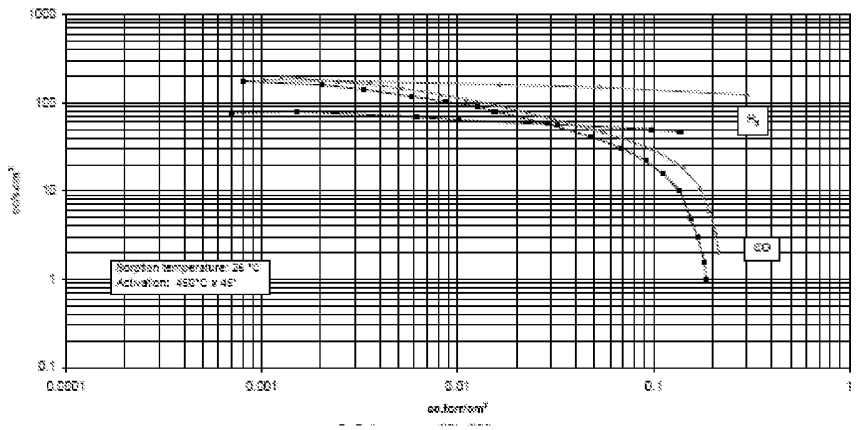


Fig. 3

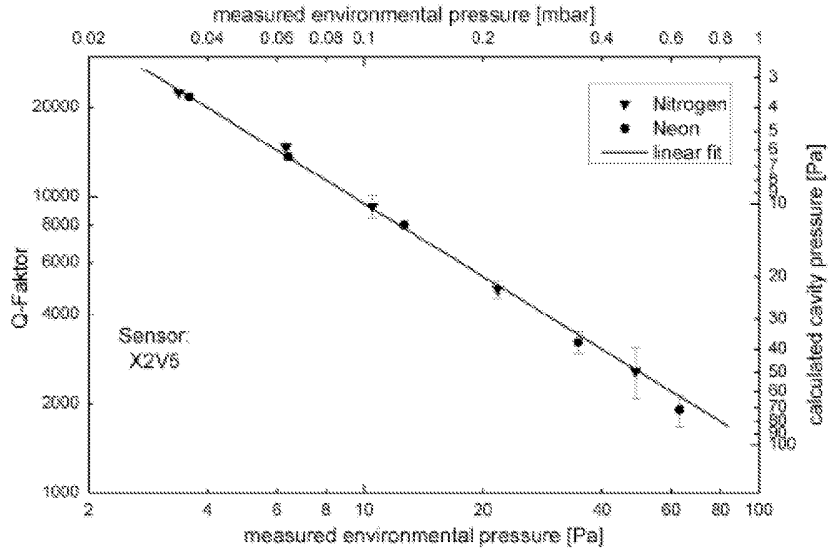


Fig. 4

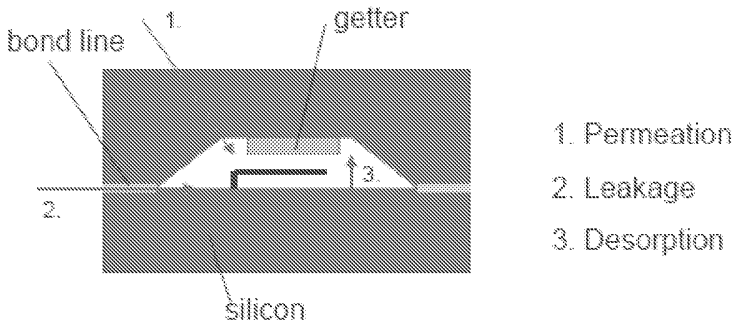


Fig. 5

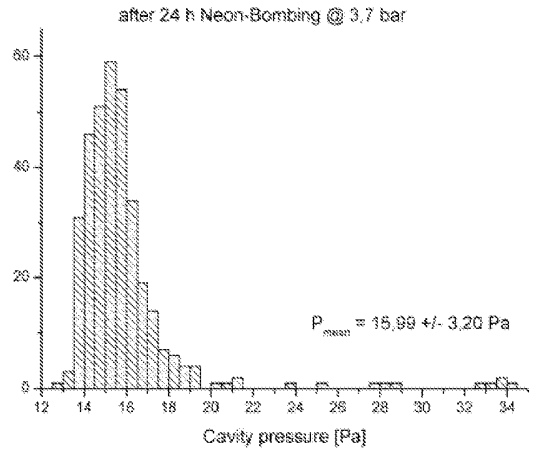


Fig. 6

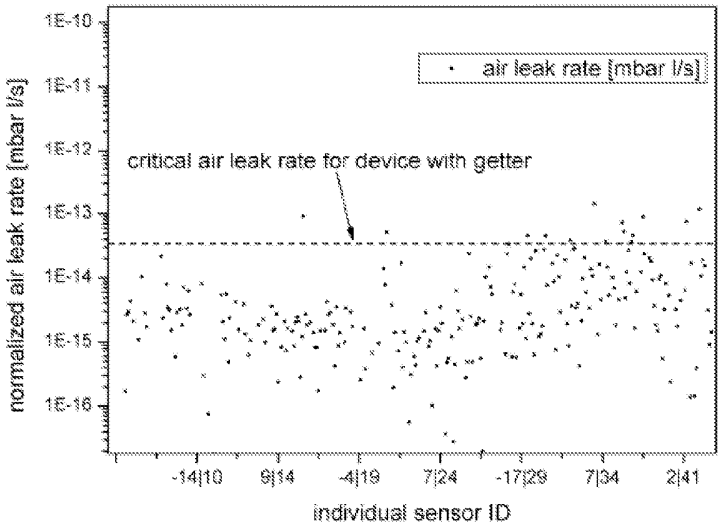

1E-10
1E-11
1E-12
1E-13
1E-14
1E-15
1E-16
normalized air leak rate [mbar l/s]
air leak rate [mbar l/s]
critical air leak rate for device with getter
-14|10
9|14
-4|19
7|24
-17|29
7|34
2|41
individual sensor ID

Fig. 7

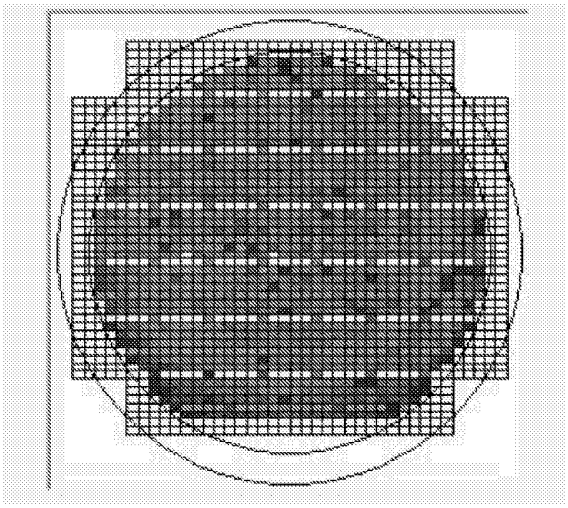


Fig. 8

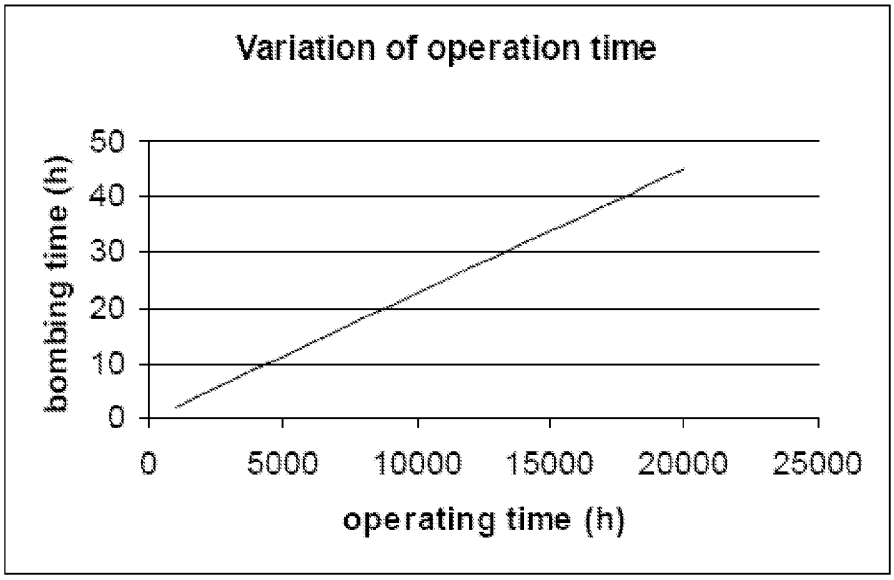

Variation of operation time
bombing time (h)
50
40
30
20
10
0
0
5000
10000
15000
20000
25000
operating time (h)

Fig. 9

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2005/055890

A. CLASSIFICATION OF SUBJECT MATTER
G01M3/18 G01M3/32 G01M3/22

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)
G01M

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

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)
EPO-Internal, WPI Data, PAJ, COMPENDEX, INSPEC, IBM-TDB

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	W. REINERT, G. LONGONI, S. ZERBINI, A. FOURRIER: "Long-term stability of vacuum-encapsulated MEMS devices using eutectic wafer bonding" VABOND PROJECT DELIVERABLE REPORT, March 2004 (2004-03), pages 1-26, XP002368245 http://www.vabond.com/public/reports/Deliverable%20D3_7-Public.pdf & http://icadc.cordis.lu/fep-cgi/srchidadb?CALLER=PROJ_IST&ACTION=D&RCN=62876&DOC=4&CAT=PROJ&QUERY=1 page 23, paragraph 4	1,3,6, 8-10,12
A	US 3 227 872 A (NEMETH ROBERT C) 4 January 1966 (1966-01-04) column 1, lines 10-15	1

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[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

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"E" earlier document but published on or after the international filing date

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
16 February 2006	07/03/2006

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Dogueri, A. K.

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2005/055890

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

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A	MAENAKA K ET AL: "Analysis of a highly sensitive silicon gyroscope with cantilever beam as vibrating mass" SENSORS AND ACTUATORS A, ELSEVIER SEQUOIA S.A., LAUSANNE, CH, vol. 54, no. 1-3, June 1996 (1996-06), pages 568-573, XP004077926 ISSN: 0924-4247 page 568, left-hand column, paragraph 1	11
A	SPARKS D ET AL: "Reliable vacuum packaging using NanoGetters(TM) and glass frit bonding" PROCEEDINGS OF THE SPIE, SPIE, BELLINGHAM, VA, US, vol. 5343, no. 1, 2003, pages 70-78, XP002360338 ISSN: 0277-786X pages 74-75	1-12
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C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	ITOH T ET AL: "Room temperature vacuum sealing using surface activated bonding method" TRANSDUCERS, SOLID-STATE SENSORS, ACTUATORS AND MICROSYSTEMS, 12TH INNATIONAL CONFERENCE ON, 2003, PISCATAWAY, NJ, USA,IEEE, vol. 2, 9 June 2003 (2003-06-09), pages 1828-1831, XP010647513 ISBN: 0-7803-7731-1 the whole document	1-12
A	BYEUNGLEUL LEE ET AL: "A study on wafer level vacuum packaging for MEMS devices" JOURNAL OF MICROMECHANICS & MICROENGINEERING, INSTITUTE OF PHYSICS PUBLISHING, BRISTOL, GB, vol. 13, no. 5, September 2003 (2003-09), pages 663-669, XP002359219 ISSN: 0960-1317 the whole document	1-12

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
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