(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 3 465 188 B9

(12) **CORRECTED EUROPEAN PATENT SPECIFICATION**

(15) Correction information:
Corrected version no 1 (W1 B1)
Corrections, see
Claims EN 1, 6

(48) Corrigendum issued on:
21.12.2022 Bulletin 2022/51

(45) Date of publication and mention of the grant of the patent:
07.09.2022 Bulletin 2022/36

(21) Application number: **17719296.0**

(22) Date of filing: **28.04.2017**

(51) International Patent Classification (IPC):
G01N 27/12 *(2006.01)* ***G01N 33/00*** *(2006.01)*

(52) Cooperative Patent Classification (CPC):
G01N 27/124; G01N 33/0009; G01N 33/0016; G01N 33/0039; Y02A 50/20

(86) International application number:
PCT/EP2017/060244

(87) International publication number:
WO 2017/202571 (30.11.2017 Gazette 2017/48)

(54) **METHOD FOR DETERMINING AN ABSOLUTE GAS CONCENTRATION USING A GAS SENSOR ARRANGEMENT AND GAS SENSOR ARRANGEMENT FOR DETERMINING AN ABSOLUTE GAS CONCENTRATION**

VERFAHREN ZUR BESTIMMUNG DER ABSOLUTEN GASKONZENTRATION MITTELS EINER GASSENSORANORDNUNG UND ENTSPRECHENDE GASSENSORANORDNUNG

PROCEDE DE MESURE DE LA CONCENTRATION ABSOLUE D'UN GAZ MOYENNANT UN ARRANGEMENT DE CAPTEURS ET ARRANGEMENT DE CAPTEURS CORRESPONDENT

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR

(30) Priority: **27.05.2016 EP 16171757**

(43) Date of publication of application:
10.04.2019 Bulletin 2019/15

(73) Proprietor: **Sciosense B.V.**
5656 AE Eindhoven (NL)

(72) Inventors:
- **RAIBLE, Stefan**
  72070 Tübingen (DE)
- **SCHEURER, Simone**
  72770 Reutlingen (DE)
- **BITTERLICH, Christian**
  72147 Nehren (DE)

(74) Representative: **Epping - Hermann - Fischer Patentanwaltsgesellschaft mbH**
Schloßschmidstraße 5
80639 München (DE)

(56) References cited:
DE-U1- 9 313 992 US-A- 4 240 799
US-A- 5 811 662 US-A- 6 054 098

- **MARK BART ET AL: "High Density Ozone Monitoring Using Gas Sensitive Semi-Conductor Sensors in the Lower Fraser Valley, British Columbia", ENVIRONMENTAL SCIENCE & TECHNOLOGY, vol. 48, no. 7, 1 April 2014 (2014-04-01), pages 3970-3977, XP055384309, US ISSN: 0013-936X, DOI: 10.1021/es404610t**

(Cont. next page)

- **David E Williams ET AL: "Ozone sensors based on WO 3 : a model for sensor drift and a measurement correction method Modelling the response of a tungsten oxidesemiconductor Validation of low-cost ozone measurement instruments suitable for use in an air-quality monitoring network A simple equivalent circuit model to represent", Meas. Sci. Technol. Meas. Sci. Technol, 1 June 2001 (2001-06-01), pages 684-690, XP055384355, Retrieved from the Internet: URL:http://iopscience.iop.org/article/10.1088/0957-0233/12/6/305/pdf [retrieved on 2017-06-22]**

Description

[0001] This invention relates to a method for determining an absolute gas concentration using a gas sensor arrangement and to a gas sensor arrangement for determining an absolute gas concentration.

[0002] Gas sensors are used to detect the presence of gases in an area, often as part of a safety system. For example, one area of application includes the regular measurement of Ozone content in air and other media. Ozone is a powerful oxidizing agent and can cause a wide range of symptoms in humans, including lacrimation, irritation of the mucous membranes in the mouth, throat, and bronchial tubes, headaches, coughing and even deterioration in lung function. Gas sensors can be used to monitor gas concentration and content in environmental air and can be implemented into systems to alert a user when a gas concentration exceeds hazardous thresholds for humans.

[0003] There is an increasing demand to implement gas sensors into mobile applications such as Smartphones, tablets and mobile computers. Thus, gas sensor design seeks to come up with compact and affordable concepts. At the same time, however, the decreasing footprint of gas sensors should not be traded for accuracy. It remains a challenge to combine both compact design and accurate measurement of absolute gas concentration into a single mobile device.

[0004] Bart et al. "High Density Ozone Monitoring Using Gas Sensitive Semi-Conductor Sensors in the LowerFraser Valley, British Columbia" in ENVIRONMENTAL SCIENCE & TECHNOLOGY, vol. 48, no. 7,1 April 2014, pages 3970-3977 show a high density ozone monitoring semiconductor gas sensor. The sensor is based on conductivity changes of heated tungstic oxide. Figure 2 shows an instrument which is based on a gas sensitive substrate located in a plastic housing to accommodate airflow over the sensitive area of the gas sensor. The instrument implements a temperature step to reset the sensitive surface and an airflow step to modulate specifically the signal due to ozone. Two sensor resistance values are measured: during a low flow phase when ozone is significantly decomposed on warm plastic surfaces surrounding the sensor and during a high flow phase. The ozone concentration is derived from the measured sensor resistance using a nonlinear calibration loaded into the instrument. Williams et al. "Ozone sensors based on WO3: a model for sensor drift and a measurement correction method modelling the response of a tungsten oxide semiconductor validation of low-cost ozone measurement instruments suitable for use in an air-quality monitoring network A simple equivalent circuit model to represent" in Meas. Sci. Technol., 1 June 2001 (2001-06-01), pages 684-690 elaborates on the sensor design suggested by Bart. In section 3.2 a measurement method and response calculation is explained. Basically, the measurement method relies on stepping a temperature from a high-value, where an ozone signal is small but sensor response is fast, to a low value, where the ozone signal is large but the response is slow, and follow the time variation of the conductance at the low temperature for a short time, before returning to the high temperature, to "reset" the sensitive surface. The conductivity is determined by thermal ionization.

[0005] US 6,054,098 A shows an apparatus for measuring ozone. The apparatus shown in Figure 1 uses an ozone decomposer using silver wool as a catalyst. The ozone decomposer is usually heated using temperature control means in order to facilitate a catalyst reaction with the silver wool.

[0006] It is an objective of the present invention to suggest a method for determining an absolute gas concentration and a gas sensor arrangement for determining an absolute gas concentration that allow for higher accuracy of absolute gas concentration measurements using a more compact gas sensor arrangement.

[0007] These objectives are achieved by the subject matter of the independent claims. Further developments and embodiments are described in dependent claims.

[0008] It is to be understood that any feature described below in relation to any one embodiment may be used alone, or in combination with other features described hereinafter, and may also be used in combination with one or more features of any other of the embodiments, or any combination of any other of the embodiments, unless explicitly described as an alternative. Furthermore, modifications not described below may also be employed without departing from the scope of the method for determining an absolute gas concentration and the gas sensor arrangement for determining an absolute gas concentration as defined in the accompanying claims.

[0009] In at least one embodiment a method for determining an absolute gas concentration uses a gas sensor arrangement which comprises at least one gas sensor and means for decomposing a gas to be measured. The gas sensor is arranged to generate a sensor signal in response to a gas to be measured. The means for decomposing a gas to be measured is arranged to decompose the gas to be measured into components such as molecules, atoms or ions, for example. The means for decomposing a gas to be measured can be integral or external part of the gas sensor.

[0010] Furthermore, the method comprises the following steps. First, a first sensor signal is acquired using the gas sensor. At least one initial data point is determined from the first sensor signal. For example, the data point comprises a resistance value and a time value, which correspond to a resistance measured by the gas sensor at the given time. This examples holds for the case that a resistive gas sensor is used. However, other types of gas sensors can be used as well. Generally, the data points discussed hereinafter comprise a time-resolved measurement value derived from a sensor signal which is provided by the particular gas sensor.

[0011] In a next step, the gas to be measured is decomposed using the means for decomposing the gas into chemical components, e.g. components which are not detected by the gas sensor. Then, a second sensor signal is acquired, which is different from the first sensor signal due to the decomposition or decay of the gas into one or more components. From the second sensor signal a series of decay data points is determined. For example, the decay data points comprise a resistance value and a timestamp, respectively, which correspond to a resistance measured by the gas sensor at various times, for instance. The decay data points reflect the process of decomposition or decay of the gas into its components.

[0012] The initial data point and the series of decay data points correspond to different sensor signals at different times during the decomposition of the gas to be measured.

[0013] Finally, an absolute gas concentration is determined from a gas concentration function. This is done by evaluating the gas concentration function at least for the initial data point and the series of decay data points. The term "gas concentration function" relates to a mathematical function by which the data points, determined from the sensor signals, can be evaluated. The evaluation of this function results in a measure for the absolute gas concentration.

[0014] The decomposition of the gas is monitored using the gas sensor and by determining a series of decay data points from the acquired sensor signals. The gas concentration function is evaluated by fitting a decay function to a series of data points comprising the series of decay data points and the initial data point.

[0015] For example, the gas concentration function may be a difference function. A difference of decay data points and the initial data point, as a reference, may be proportional to the absolute gas concentration. It may be necessary that additional constraints are met in order to derive an accurate absolute gas concentration from the gas concentration function. For example, the difference gives a more reliable measure of gas concentration if a certain time period lies between acquiring the first and second sensor signals. For example, the second sensor signal could be acquired after the decomposition of the gas reaches a characteristic half-value period or a time period at which the decay of gas has reached a certain level.

[0016] In general, the term "decomposition of a gas" relates to a process by which the gas is decomposed into components, such as chemical components. For example, Ozone can be chemically decomposed into molecular and atomic oxygen. A decomposition process can be described as a decay and typically is characterized by a certain decay rate. For example, the decomposition of gas may be subject to an exponential decay and the amount of initial gas decreases at a rate proportional to its current value or a characteristic half-value period.

[0017] Furthermore, some decomposition or decay processes can be described as a dynamical equilibrium and the decomposition induced by the means for decomposing seeks to intentionally push the equilibrium to a decay side.

[0018] The term "gas sensor arrangement" is used to indicate that the gas sensor and the means for decomposing the gas can be separate or external units. For example, the gas sensor could be implemented as an integrated circuit and the means for decomposing the gas is connected to the integrated circuit. However, there may be embodiments where both components are implemented in one single device such as an integrated circuit comprising both the gas sensor and the means for decomposing the gas.

[0019] In at least one embodiment the method for determining an absolute gas concentration is executed in measurement cycles, and the corresponding steps are repeated in each measurement cycle.

[0020] In at least one embodiment an absolute Ozone measurement is implemented with an Ozone sensor as gas sensor, in particular with a metal oxide or WO3 gas sensor. The method utilizes Ozone stability during the duration of the measurement.

[0021] In at least one embodiment the means for decomposing a gas to be measured comprise a light source. For example, the light source may be an ultra violet light source. The gas is decomposed by means of light to be emitted from the light source. For example, a gas such as Ozone may be formed in an exothermic chemical reaction. The light source may provide sufficient energy to revert forming the gas and decompose the gas into its chemical components.

[0022] In at least one embodiment the means for decomposing the gas to be measured comprise a heat source. The gas is decomposed by means of heat to be radiated from the heat source. The heat source could be a component external to the gas sensor, such as an infrared source. Alternatively, or in addition, the gas sensor may have a heater such that can be altered in temperature. The temperature should be set high enough to provide sufficient energy to revert forming of the gas and decompose the gas into its chemical components. For example, a gas such as Ozone may be formed in an exothermic chemical reaction as discussed above and the decomposition is possible if the means for decomposing provide the amount of exothermic energy.

[0023] In at least one embodiment the gas concentration function is evaluated by taking a difference between the at least one initial data point and a series of decay data points. In this embodiment the gas concentration function is a difference function and its arguments are data points derived from the gas sensor signals. For example, the initial data point defines a reference point to which the decay data points are compared. The resulting delta, i.e. difference, can result in a value that is proportional or equal to the absolute gas concentration.

[0024] In at least one embodiment the gas concentration function is evaluated by interpolating a series of data points. The series of data points is constrained by the initial data point and the series of decay data points.

[0025] The initial data point and the series of decay data points correspond to different sensor signals at different times during the decomposition or decay of the gas to be measured. Data points lying (in time) between (or being constrained by) these points, can be interpolated by means of an interpolation function. Examples include a linear or exponential function. These interpolation functions can be used as gas concentration functions, for example. One possible way to evaluate these functions is to determine their gradients for a given argument. The gradient can result in a value that is proportional or equal to the absolute gas concentration.

[0026] The decomposition of the gas is monitored using the gas sensor. By monitoring the gas decay the series of decay data points are determined from the sensor signals. Monitoring the decomposition or decay of the gas results in collecting a series of data points which depend on the decay process. For example, the series of decay data points may resemble an exponential decay or a chemical reaction rate equation.

[0027] The gas concentration function is evaluated by fitting the decay function to the series of data points. The series of data points comprises the series of decay data points and the initial data point. The resulting decay function may resemble an exponential decay or a chemical reaction rate equation, for example. The fitting function can be evaluated, e.g. by determining gradients, slope, etc., in order to determine a value that is proportional or equal to the absolute gas concentration.

[0028] In at least one embodiment the gas sensor arrangement comprises one, or a single, gas sensor. The operation of the gas sensor arrangement comprises at least a first, a second and a third phase.

[0029] During the first phase the first sensor signal is acquired and from the first sensor signal the at least one initial data point is determined. During execution of the first phase the means for decomposing the gas to be measured are turned off or operated at an initial condition. For example, the initial condition determines a constant temperature or light output which do not yet decompose the gas.

[0030] During the second phase the gas to be measured is decomposed, the second sensor signal is acquired and from the second sensor signal the series of decay data points is determined. During execution of the second phase the means for decomposing the gas to be measured is turned on and operated at a decay condition. For example, at the decay condition the means for decomposing the gas is operated at a constant temperature or light output which is arranged to decompose the gas.

[0031] The third phase is executed after the second phase is terminated after a time period. During the third phase the gas is exchanged from the gas sensor arrangement by means of diffusion and/or active air movement. For example, the time period takes into account that decomposition or decay of the gas is not an instant process but rather needs time to reach a certain level or a steady state, for example. The means for decomposing the gas may be operated at the initial condition or any other condition that allows a temperature or light output which does not decompose the gas.

[0032] In at least one embodiment the gas sensor arrangement comprises a first gas sensor and a second gas sensor. The at least one initial data point is determined by means of the first gas sensor. The gas to be measured is decomposed at the second gas sensor using the means for decomposing the gas of the gas sensor arrangement. Then, the series of decay data points is determined by means of the second gas sensor.

[0033] Finally, the absolute gas concentration is derived from the gas concentration function by evaluating the gas concentration function at least for the initial data point of the first gas sensor and for the series of decay data points of the second gas sensor.

[0034] In at least one embodiment the means for decomposing the gas to be measured are provided at the second gas sensor. The first and second gas sensors are operated in different phases. During a first phase the first sensor signal is acquired and from the first sensor signal the at least one initial data point from the first gas sensor is determined. The means for decomposing the gas to be measured are turned off or operated at an initial condition, e.g. a constant temperature or light emission.

[0035] During a second phase the gas to be measured is decomposed. The second sensor signal is acquired from the second gas sensor. From the second sensor signal the series of decay data points is determined with the means for decomposing the gas to be measured turned on or operated at a decay condition e.g. a constant temperature or light emission sufficient to decompose the gas to be measured.

[0036] In at least one embodiment the means for decomposing the gas to be measured are provided at both the first and the second gas sensor, and may be activated independently or together. The first, second and third phases of operation are complemented with a fourth, fifth and sixth phase.

[0037] In the fourth phase the second gas sensor is used for acquiring the first sensor signal and another initial data point is determined from the first sensor signal. During the fourth phase the means for decomposing the gas to be measured are turned off or operated at an initial condition, e.g. a constant temperature or light emission which do not yet decompose the gas.

[0038] During the fifth phase the first gas sensor is used for decomposing the gas to be measured, the second sensor signal is acquired and from the second sensor signal the series of decay data points is determined. During the fifth phase the means for decomposing the gas to be measured are turned on and operated at a decay condition, e.g. a constant temperature or light emission sufficient to decompose the gas to be measured.

[0039] During the sixth phase the fifth phase is terminated after another time period. Then the gas is exchanged from the gas sensor arrangement by means of diffusion and/or active air movement.

[0040] In at least one embodiment the gas to be measured is Ozone and the gas sensor comprises an Ozone sensitive gas sensor.

[0041] In at least one embodiment a gas sensor arrangement for determining an absolute gas concentration comprises at least one gas sensor which is arranged to generate a sensor signal which is indicative of a gas to be measured. One or more means for decomposing the gas to be measured are provided. The control unit is arranged to operate the gas sensor and the means for decomposing the gas. The control unit is designed to execute the following steps.

[0042] The first sensor signal is acquired from the gas sensor and at least one initial data point is determined from the first sensor signal. The gas to be measured is decomposed using the means for decomposing the gas. A second sensor signal is acquired from the gas sensor and a series of decay data points is determined from the second sensor signal.

[0043] The initial data point and the series of decay data points correspond to different sensor signals at different times during the decomposition of the gas to be measured.

[0044] The gas sensor arrangement further comprises a processing unit which is arranged to determine an absolute gas concentration from a gas concentration function. The gas concentration function is evaluated at least for the initial data point and the series of decay data points

[0045] The processing unit is arranged to monitor the decomposition of the gas using the gas sensor and by determining a series of decay data points from the acquired sensor signals and to evaluate the gas concentration function by fitting a decay function to a series of data points comprising the series of decay data points and the initial data point.

[0046] In at least one embodiment the means for decomposing the gas to be measured comprises at least one of a heater, a hot plate of the gas sensor, a light source, an ultra violet light source, an infrared source. Furthermore, the gas sensor may comprise at least one of a semiconductor gas sensor, a metal oxide, MOX, gas sensor, a WO3 MOX gas sensor, a resistive gas sensor and/or a chemo-resistive gas sensor.

[0047] A semiconductor gas sensor as understood hereinafter is arranged to detect gases by a chemical reaction which takes place when the gas comes in direct contact with the sensor. Tin dioxide or tungsten trioxide are possible materials used in semiconductor gas sensors. For example, the gas sensor such as a semiconductor gas sensor is resistive gas sensor and/or a chemoresistive gas sensor. Semiconductor gas sensors employ a change in electrical resistance which typically is decreased when the gas sensitive part of the sensor comes in contact with the monitored gas. The resistance of tin dioxide is typically around 50 kΩ in air but can drop to around 3.5 kΩ in the presence of 1% methane. The change in resistance can be used to calculate the gas concentration. Semiconductor sensors are commonly used to detect various gases. One use includes detection of Ozone.

[0048] In at least one embodiment the gas sensor is located in a sensor package. The sensor package is designed to allow for passive diffusion of the gas to be detected into and/or out of the sensor package. Alternatively, or in addition, the gas sensor arrangement comprises means to provide an active air flow to exchange the gas to be detected away from the gas sensor. The means to provide an active air flow are controlled by means of the control unit.

[0049] The principles presented herein have a number of advantages, including:

- no fan is needed to measure absolute gas concentrations, such as Ozone concentration. Diffusion mechanism can be sufficient to exchange the gas to be measured after a measurement cycle is completed,
- light and/or temperature can be used to decompose the gas, e.g. to destroy Ozone,
- an absolute gas concentration such as Ozone can be determined by measuring a decay time to derive gas concentration,
- switching between the first and second gas sensor can be used to reduce the need of diffusion and reduce impact of sensor drift.

[0050] In at least embodiment Ozone is decomposed, e.g. via light and / or temperature to generate an Ozone free baseline.

[0051] Thus, Ozone decomposition can be used as a mechanism for absolute measurement. Hot plates may be used together with additional light and or temperature sources.

[0052] An absolute Ozone concentration can be monitored by a time measurement. No active flow is needed. This allows for minimising a device drift by alternative devices used for measurement.

[0053] Passive diffusion can be used by package design or active air flow to exchange decomposed Ozone by fresh Ozone. A use of two heaters such as hotplates can be used to compensate for drift and/or measure decomposed and fresh Ozone simultaneously at two different locations.

[0054] In the following, the principle presented above is described in further detail with respect to drawings, in which exemplary embodiments are presented.

[0055] In the exemplary embodiments and Figures below, similar or identical elements may each be provided with the same reference numerals. The elements illustrated in the drawings and their size relationships among one another, however, should not be regarded as true to scale. Rather individual elements, such as layers, components, and regions, may be exaggerated to enable better illustration or improved understanding.

Figure 1 shows an exemplary embodiment of a gas sensor arrangement having a single gas sensor and a heater,

Figure 2 shows another exemplary embodiment of a gas sensor arrangement having a single gas sensor and a UV light source,

Figure 3 shows an exemplary embodiment of a gas sensor arrangement having two gas sensors and a hot plate,

Figure 4 shows an exemplary embodiment of a gas sensor arrangement having two gas sensors and two hot plates, and

Figure 5 shows an exemplary embodiment of a gas sensor arrangement having a charcoal trap.

[0056] Figure 1 shows an exemplary embodiment of a gas sensor arrangement having a single gas sensor 1 and a heater 11. The drawing shows an exemplary use of heat to decay Ozone. For example, Ozone is decomposed by heat originating, e.g. from a sensor hotplate or an external heat source such as an IR source as heaters 11. A decay time t_{decay} characteristic of the Ozone decomposition can be used to derive the absolute Ozone concentration. After the Ozone decomposition the Ozone is exchanged by diffusion or active air movement to allow for the next measurement. Package design can support fast air exchange to allow a next cycle to begin.

[0057] In particular, the drawing depicts one possible method to determine an absolute Ozone concentration. The method is executed in two consecutive phases. In this particular embodiment, the method employs a resistive MOX gas sensor. The gas sensor 1 comprises a heater 11, e.g. a hotplate or an external heat source, which can be operated at different temperatures.

[0058] In a first phase PH1 the heater 11 is operated at an initial condition or at an initial temperature $T_{heater1}$. For example, the heater can be turned off and its temperature settles at ambient temperature T_{amb}. Instead the heater 11 can also be operated at a defined operating temperature T_{op}, at the operating temperature T_{op} the heater settles has a temperature which is not sufficient to decompose the gas to be measured, e.g. Ozone. The initial condition in the first phase PH1 can be summarized as $T_{heater\_} = T_{amb}$ or T_{op}.

[0059] In a second phase PH2 the heater 11 is turned on or operated at a decay condition, e.g. at a decay temperature T_{decay}. At the decay condition the temperature T_{decay} is set high enough to induce a decay or decomposition of Ozone gas, e.g. of gas that is in contact or near vicinity to the gas sensor 1. During the second phase PH2 the resistive MOX gas sensor 1 is used to monitor the Ozone decay. An exemplary measurement curve is depicted on the right side of the drawing. It shows a gas concentration function R(t) as a function of time t. The gas concentration function R(t) is represented by resistance values acquired by the gas sensor 1. The resistance values are data points derived from the sensor signal as a function of time. An initial data point corresponds to a first resistance value R1. Due to the gas decay or decomposition the initial data point decreases in value according to the gas concentration function R(t) and the sensor signal, or decay data points, decrease with time.

[0060] The data points collected by means of the resistive MOX gas sensor 1 are indicative of the decay of the Ozone gas and can be evaluated for an absolute ozone concentration. In an example not according to the invention, the Ozone gas concentration $c(O_3)$ is proportional to the difference of the first resistance value R1 and a final resistance value R2. The final resistance value R2 is determined after the decay has lasted for a characteristic period of time, such as one decay time t_{decay} or a multiple thereof. The final resistance value R2 can also be determined when the decay of Ozone has reached a steady state.

[0061] The first resistance value R1 and the final resistance value R2 can be combined to yield a measure of absolute Ozone gas concentration. For example:

$$c(O_3) \sim (R1 - R2).$$

[0062] In an embodiment according to the invention, the gas concentration function R(t) can also be evaluated by determining the characteristic decay time t_{decay}. This can be achieved by interpolation or fitting a gas concentration function to the data points collected during the decay. The evaluation results in the absolute ozone gas concentration:

$$c(O_3) \sim t_{decay}.$$

[0063] Figure 2 shows another exemplary embodiment of a gas sensor arrangement having a single gas sensor and a UV light source. The drawings depicts an exemplary use of light to decay Ozone. Operation of the gas sensor arrangement corresponds to the embodiment of Figure 1. However, in this embodiment a light source 12 is used for decomposing the gas instead of a heater 11. Ozone is decomposed by light originating from the light source, e.g. an external light source such as a UV-B light source or LED. The decay time t_{decay} of Ozone is used to derive the absolute Ozone concentration.

[0064] After the Ozone decomposition Ozone is exchanged by diffusion or active air movement to allow for the next measurement. Package design can support fast air exchange to allow a next cycle to begin.

[0065] Figure 3 shows an exemplary embodiment of a gas sensor arrangement having two gas sensors and a hot plate as heater. The drawings depicts an exemplary use of two gas sensors 1, 2 to measure Ozone. Ozone is decomposed by heat originating from a first sensor hotplate 11, which is integrated into the gas sensor. A second hotplate 21, which is integrated into the second gas sensor 2 is placed at a different location and is used to measure an undistracted Ozone concentration.

[0066] To derive the absolute Ozone concentration the sensor signals and corresponding data values of both gas sensors 1, 2 are used as opposed to using sensor signals and corresponding data values from a single gas sensor as discussed with respect to Figures 1 and 2. For example, the absolute Ozone gas concentration can be proportional to the delta, e.g. a difference, of resistance readings, for the two gas sensors 1, 2. After the Ozone decomposition the Ozone is exchanged by diffusion or active air movement to allow the next measurement. Package design can support fast air exchange to allow a next cycle to begin.

[0067] The gas sensor arrangement of Figure 3 is operated in different phases. In a first phase PH1 both gas sensors 1, 2 are set to an initial condition. For example, both gas sensors 1, 2, i.e. both heaters 11, 21, such as sensor hot plates, are turned off or operated at an initial operating temperature. The initial temperature could be equal to the ambient temperature T_{amb} or, alternatively, be equal to an operation temperature T_{op}. The latter could be established by regulating the heaters to a temperature which is not yet sufficient to decompose the gas to be measured. This can be summarized as $T_{heater1} = (T_{amb}, T_{op}) = T_{heater2}$. Both gas sensors remain in phase PH1 long enough that Ozone diffuses to the two gas sensors at two different locations.

[0068] In a second phase PH2 both gas sensors measure a gas background at an operation temperature. Both heaters 11, 21, e.g. sensor hot plates, are set to the operation temperature T_{op}, i.e. $T_{heater1} = T_{op} = T_{heater2}$. The operation temperature T_{op} is not sufficient to decompose the gas to be measured. In this condition sensor signals are acquired by the gas sensors 1, 2, respectively. In this particular embodiment the resistive MOX gas sensors acquire from the sensor signals first resistance values R_{s1} and R_{s2}, respectively. Alternatively, the first and second phases PH1, PH2 could be combined into a single phase and the heaters 11, 21 set to an initial temperature $T_{heater1} = T_{heater2} = T_{amb}$ or T_{op}, which could be equal to the ambient temperature T_{amb} or, alternatively, be equal to the operation temperature T_{op}.

[0069] In a third phase PH3 the heater 11 of the first gas sensor 1 is set to a temperature high enough to induce decay or decomposition of the Ozone gas. Typically the decay temperature T_{decay} is set to a much higher value than the operating temperature T_{op}: $T_{decay} \gg T_{op}$. At the same time the temperature of the second gas sensor 2 is held at the operating temperature T_{op}. The gas sensor arrangement stays in phase PH3 for a certain time. The time may be determined by the decay process. For example, the gas sensor arrangement may proceed with a next phase after the decay has lasted for a characteristic period of time, such as one decay time t_{decay} or a multiple thereof. The next phase can also be entered when the decay of Ozone has reached a steady state.

[0070] In a fourth phase PH4 the gas sensor arrangement returns to the conditions defined for phase PH2. This effectively terminates the decomposition of Ozone. The resistive gas sensors 1, 2 measure the gas background at the operation temperature T_{op} and then acquire final resistance values R_{f1} and R_{f2}, respectively. The absolute Ozone concentration can be determined from the first resistance values R_{s1} and R_{s2} and final resistance values R_{f1} and R_{f2}. In an example not according to the invention, a resistance difference can be constructed and made proportional to the absolute Ozone concentration $c(O_3)$. This yields:

$$c(O_3) \sim (R_{s1} - R_{f1}) - (R_{s2} - R_{f2}).$$

[0071] After the fourth phase PH4 the gas sensor arrangement may return to the first phase and start another measurement cycle. After the Ozone decomposition the Ozone is exchanged by diffusion or active air movement the next measurement cycle can start. Typically, the gas sensor arrangement stays in phase PH1 for an off-time, Off, which is chosen long enough to allow Ozone diffusion to settle at environmental level again. Package design can support fast air exchange to allow a next cycle to begin.

[0072] Alternatively, the two gas sensors can be switched (see Figure 4) or light sources can be used instead, or in addition, to the heaters. The decay process is monitored and fitted by an appropriate gas concentration function. Exemplary parameters are T_{op} = optimum WO3 gas sensor temperature for operation, T_d = temperature to decay O3 concentration.

[0073] Figure 4 shows an exemplary embodiment of a gas sensor arrangement having two gas sensors 1, 2 and two hot plates 11, 21 (reference numerals are only shown for the phase PH2 for better representation). The drawing depicts an exemplary use of two sensors to measure Ozone and alternate sensor for decay to minimize drift. This embodiment corresponds to the one shown in Figure 3 only the gas sensors are alternatingly used to decompose the Ozone at different locations. This can be used to compensate for drift issues as both sensors see the same thermal history over time. This approach involves symmetric drift switch between gas sensors.

[0074] Briefly, the method in this embodiment involves eight phases. Phases PH1 to PH4 correspond to phases PH1 to PH4 of Figure 3. After phase PH4, however, the gas sensor arrangement does not return to phase PH1 directly. Instead a fifth, sixth, seventh and eights phase PH5, PH6, PH7, PH8 are consecutively executed. These phases PH5 to PH8 correspond to phases PH1 to PH4 but with the gas sensors exchanged, i.e. during the first four phases PH1 to PH4 the first gas sensor 1 is used for decomposing, and then the second four phases PH5 to PH8 the second gas sensor 2 is used for decomposing the gas.

[0075] Figure 5 shows an exemplary embodiment of a gas sensor arrangement having a charcoal trap. The drawing depicts an exemplary Ozone sensor comprising a first gas sensor 1 and a second gas sensor 1 which is arranged to destroy Ozone gas locally by heat.

[0076] In this particular embodiment the first gas sensor 1 is a MOX gas sensor which is based on a resistive operation principle. The gas sensor 1 is arranged inside the sensor package 13 having a first gas inlet 14. Ozone gas can diffuse into and out of the package 13 via the first gas inlet 14. The sensor package 13 has no dedicated ozone gas filter. The second gas sensor 2 is also a MOX gas sensor and detects the presence of gas by changing its resistance. The second gas sensor is also arranged inside a sensor package 23 and has a second gas inlet 24. Both the first and second gas sensors 1, 2 can be arranged in the same sensor package but separated from each other. However, the sensor packages 13, 23 can also be two seperated units. The gas sensors are embedded in respective cavities 15, 25 which are independent from each other. Furthermore, a charcoal trap 26 is arranged inside the sensor package 23 of the second gas sensor 2. Ozone gas entering or leaving the cavity 25 of the second gas sensor 2 needs to travel through the charcoal trap 26. The charcoal trap 26 can be activated (activated charcoal) and set to a certain operating temperature. This way the charcoal trap 26 can serve as a heater 21 as discussed in the embodiments above. The gas sensor arrangement of Figure 5 can thus be used as gas sensor arrangement in one or more of the embodiments of Figures 1 to 4 discussed above.

[0077] Resistive MOX gas sensors can be assumed to have a constant sensitivity over the time periods involved in measuring the absolute ozone gas concentration. This fact supports that a differential measurement conducted with the first and second gas sensors and respective resistance values can be used as a measure which is proportional to the absolute ozone gas concentration.

[0078] Ozone measurement cycle not according to the present invention could involve the following steps:

1. Both sensors off = off long enough that O3 diffuses to sensors (sensor 1 and 2 at two different locations).
2. Sensor 1 and 2 measure gas background at operation temperature.
3. Sensor 1 operates at high temp to destroy Ozone.
4. Sensor 1 and 2 measure gas background at operation temperature. Difference of resistance is proportional to the Ozone concentration.
5. Back to point 1

[0079] Two hotplates can be used. However, humidity and other environmental items are changed and power consumption needs to be provided. UV as a light source can be very specific and will only destroy O3, for example. Power consumption can be lower, e.g. using a LED. However, an UV source is needed.

[0080] The proposed principles above can be miniaturised and used within low power measurement applications for consumer (IoT, wearables, mobile), industrial and automotive applications. With tailored package design a miniaturised device is seen possible.

[0081] The following items further support the proposed approach, for example:

- use O3 decay together with sensor, e.g. a WO3 sensor, to measure an absolute O3 concentration,
- WO3 MOx sensitivity may be stable over time,
- O3 typically decays faster and at known rate in air at higher temperatures or/and under UV B exposure in air,
- resistance delta can be used to measure Ozone concentration based on known decay rate.

[0082] The embodiments discussed above relate to measurement of an absolute Ozone as the gas to be measured. Ozone can be created by photochemical reactions involving molecular oxygen O2. For example, when diatomic oxygen absorbs ultraviolet radiation with wavelengths less than 240 nm, it breaks apart into two oxygen atoms:

$$O_2(g) \xrightarrow{UV\ light} 2 \cdot O(g).$$

[0083] The resulting oxygen atoms combine with O2 molecules to form Ozone:

$$O(g) + O_2(g) \xrightarrow{yields} O_3(g).$$

[0084] This reaction is exothermic. In turn, Ozone absorbs ultraviolet radiation with wavelengths as long as 290 nm. This radiation causes the Ozone to decompose into O_2 molecules and oxygen atoms:

$$O_3(g) \xrightarrow{UV\ light\ or\ heat} O(g) + O_2(g).$$

[0085] This, too, is an exothermic reaction. Thus, radiation and heat can be used to decompose Ozone into its components. This effect is employed in the method discussed so far. Nevertheless, the methodology is not restricted to Ozone but can be applied to all gases which can be decomposed by means of heat and/or radiation.

Claims

1. Method for determining an absolute gas concentration, using a gas sensor arrangement comprising a gas sensor (1) and means (11, 12) for decomposing a gas to be measured, the method comprising the steps of:

- acquiring a first sensor signal and determining from the first sensor signal at least one initial data point,

- decomposing the gas to be measured into chemical components using the means (11, 12) for decomposing the gas of the gas sensor arrangement,
- acquiring a second sensor signal and determining from the second sensor signal a series of decay data points wherein the initial data point and the series of decay data points correspond to different sensor signals at different times during the decomposition of the gas to be measured, and
- deriving an absolute gas concentration from a gas concentration function (R(t)) being a function of time by evaluating the gas concentration function (R(t)) at least for the initial data point and the series of decay data points;

wherein:

- the decomposition of the gas is monitored using the gas sensor (1) and by determining the series of decay data points from the acquired sensor signals and
- the gas concentration function (R(t)) is evaluated by fitting a decay function to a series of data points comprising the series of decay data points and the initial data point.

2. Method according to claim 1, wherein

- the means (11, 12) for decomposing a gas to be measured comprise a light source (12), in particular, an ultra violet light source, and
- the gas is decomposed by means of light to be emitted from the light source (12).

3. Method according to claim 1 or 2, wherein

- the means (11, 12) for decomposing a gas to be measured comprise a heat source (11) and
- the gas is decomposed by means of heat to be radiated from the heat source (11).

4. Method according to one of claims 1 to 3, wherein the gas concentration function (R(t)) is evaluated by taking a difference between the at least one initial data point and the decay data points.

5. Method according to one of claims 1 to 4, wherein the gas sensor arrangement comprises one gas sensor (1), and wherein:

- the acquiring the first sensor signal and determining from the first sensor signal the at least one initial data point is executed during a first phase with the means (11, 12) for decomposing the gas to be measured turned off or operated at an initial condition,
- the decomposing the gas to be measured, acquiring the second sensor signal and determining from the second sensor signal the series of decay data points is executed during a second phase with the means (11, 12) for decomposing the gas to be measured turned on and operated at a decay condition, and
- the second phase is terminated after a time period and the gas is exchanged from the gas sensor arrangement by means of diffusion and/or active air movement in a third phase.

6. Method according to one of claims 1 to 4, wherein the gas sensor arrangement comprises a first gas sensor (1) and a second gas sensor (2), and wherein

- the at least one initial data point is determined by means of the first gas sensor (1),
- the gas to be measured is decomposed at the second gas sensor (2) using the means (11, 12) for decomposing the gas of the gas sensor arrangement,
- the series of decay data points is determined by means of the second gas sensor (2), and
- the absolute gas concentration is derived from the gas concentration function (R(t)) by evaluating the gas concentration function (R(t)) at least for the initial data point of the first gas sensor (1) and for the series of decay data points of the second gas sensor (2).

7. Method according to claim 6, wherein the means (12) for decomposing the gas to be measured are provided at the second gas sensor (2), and wherein:

- the acquiring the first sensor signal and determining from the first sensor signal the at least one initial data point from the first gas sensor (1) is executed during a first phase with the means (11, 12) for decomposing the gas to be measured turned off or operated at an initial condition,
- the decomposing the gas to be measured, acquiring the second sensor signal from the second gas sensor (2) and determining from the second sensor signal the series of decay data points is executed during a second phase with the means (11, 12) for decomposing the gas to be measured turned on and operated at a decay condition, and
- the second phase is terminated after a time period and the gas is exchanged from the gas sensor arrangement by means of diffusion and/or active air movement in a third phase.

8. Method according to claim 7, wherein the means for decomposing the gas to be measured are provided at both the first and the second gas sensor (1, 2), and wherein the first, second and third phases are complemented with a fourth, fifth and sixth phases, wherein:

- in the fourth phase the second gas sensor (2) is used for acquiring the first sensor signal and determining another initial data point from the first sensor signal with the means (11, 12) for decomposing the gas to be measured turned off or operated at an initial condition,
- in the fifth phase the first gas sensor (1) is used for decomposing the gas to be measured, acquiring the second sensor signal and determining from the second sensor signal the series of decay data points with the means for decomposing the gas to be measured turned on and operated at a decay condition, and
- in the sixth phase the fifth phase is terminated after another time period and the gas is exchanged from the gas sensor arrangement by means of diffusion and/or active air movement.

9. Method according to one of claims 1 to 8, wherein the gas to be measured is Ozone and the gas sensor (1, 2) comprises an Ozone gas sensor.

10. Gas sensor arrangement for determining an absolute gas concentration, comprising:

- at least one gas sensor (1, 2) arranged to generate a sensor signal indicative of a gas to be measured, in particular, indicative of an Ozone concentration,
- one or more means (11, 12, 21, 22) for decomposing the gas to be measured into chemical components, and
- a control unit arranged to operate the gas sensor (1) and the means (11, 12, 21, 22) for decomposing the gas such that:
- a first sensor signal is acquired from the gas sensor (1, 2) and at least one initial data point is determined from the first sensor signal,
- the gas to be measured is decomposed using the means (11, 12, 21, 22) for decomposing the gas,
- a second sensor signal is acquired from the gas sensor (1, 2) and a series of decay data points is determined from the second sensor signal, wherein the initial data point and the series of decay data points correspond to different sensor signals at different times during the decomposition of the gas to be measured; and the gas sensor arrangement further comprises:
- a processing unit which is arranged to determine an absolute gas concentration from a gas concentration function (R(t)) being a function of time by evaluating the gas concentration function at least for the initial data point and the series of decay data points and wherein the processing unit is arranged to:

- monitor the decomposition of the gas using the gas sensor (1) and by determining the series of decay data points from the acquired sensor signals and
- evaluate the gas concentration function (R(t)) by fitting a decay function to a series of data points comprising the series of decay data points and the initial data point.

11. Gas senor arrangement according to claim 10, wherein the means (11, 12, 21, 22) for decomposing the gas to be measured comprises at least one of:

- a heat source (11, 21), a heater, a hot plate of the gas sensor, a light source (12, 22), an ultra violet light source, an infrared source; and/or

wherein the gas sensor comprises at least one of:

- a semiconductor gas sensor, a metal oxide, MOX, gas sensor, a WO3 MOX gas sensor, a resistive gas sensor or a chemo-resistive gas sensor.

12. Gas sensor arrangement according to claims 10 or 11, wherein

- the gas sensor is located in a sensor package (13, 23) which is designed to allow for passive diffusion of the gas to be detected into and/or out of the sensor package, and/or
- means to provide an active air flow to exchange the gas to be detected away from the gas sensor and under the control of the control unit, and/or
- a charcoal trap (26) as heat source (11, 21).

Patentansprüche

1. Verfahren zur Bestimmung einer absoluten Gaskonzentration unter Verwendung einer Gassensoranordnung, die einen Gassensor (1) und ein Mittel (11, 12) zur Zerlegung eines zu messenden Gases umfasst,
wobei das Verfahren die Schritte umfasst:

- Erfassen eines ersten Sensorsignals und Bestimmen mindestens eines Anfangsdatenpunktes aus dem ersten Sensorsignal,
- Zerlegen des zu messenden Gases in chemische Komponenten unter Verwendung des Mittels (11, 12) zur Zerlegung des Gases der Gassensoranordnung,
- Erfassen eines zweiten Sensorsignals und Bestimmen einer Reihe von Abklingdatenpunkten

aus dem zweiten Sensorsignal, wobei der Anfangsdatenpunkt und die Reihe von Abklingdatenpunkten unterschiedlichen Sensorsignalen zu unterschiedlichen Zeiten während der Zerlegung des zu messenden Gases entsprechen, und

- Ableiten einer absoluten Gaskonzentration aus einer Gaskonzentrationsfunktion (R(t)), die eine Funktion der Zeit ist, durch Auswerten der Gaskonzentrationsfunktion (R(t)) zumindest für den Anfangsdatenpunkt und die Reihe von Abklingdatenpunkten; wobei:
- die Zerlegung des Gases unter Verwendung des Gassensors (1) und durch Bestimmung der Reihe von Abklingdatenpunkten aus den erfassten Sensorsignalen überwacht wird und
- die Gaskonzentrationsfunktion (R(t)) durch Anpassen einer Abklingfunktion an eine Reihe von Datenpunkten, die die Reihe von Abklingdatenpunkten und den Anfangsdatenpunkt umfassen, ausgewertet wird.

2. Verfahren nach Anspruch 1, wobei

das Mittel (11, 12) zur Zerlegung eines zu messenden Gases eine Lichtquelle (12), insbesondere eine ultraviolette Lichtquelle, umfasst, und das Gas mittels des von der Lichtquelle (12) zu emittierenden Lichts zerlegt wird.

3. Verfahren nach Anspruch 1 oder 2, wobei

das Mittel (11, 12) zur Zerlegung eines zu messenden Gases eine Wärmequelle (11) umfasst und
das Gas mittels der von der Wärmequelle (11) abzustrahlenden Wärme zerlegt wird.

4. Verfahren nach einem der Ansprüche 1 bis 3, wobei die Gaskonzentrationsfunktion (R(t)) durch Bildung einer Differenz zwischen dem mindestens einen Anfangsdatenpunkt und den Abklingdatenpunkten ausgewertet wird.

5. Verfahren nach einem der Ansprüche 1 bis 4, wobei die Gassensoranordnung einen Gassensor (1) umfasst, und wobei:

- das Erfassen des ersten Sensorsignals und das Ermitteln des mindestens einen Anfangsdatenpunktes aus dem ersten Sensorsignal während einer ersten Phase bei ausgeschalteten oder in einem Ausgangszustand betriebenen Mittel (11, 12) zur Zerlegung des zu messenden Gases durchgeführt wird,
- das Zerlegen des zu messenden Gases, das Erfassen des zweiten Sensorsignals und das Bestimmen der Reihe von Abklingdatenpunkten aus dem zweiten Sensorsignal während einer zweiten Phase ausgeführt wird, wobei das Mittel (11, 12) zur Zerlegung des zu messenden Gases eingeschaltet ist und in einem Abklingzustand betrieben wird, und
- die zweite Phase nach einer Zeitdauer beendet wird und in einer dritten Phase das Gas in der Gassensoranordnung durch Diffusion und/oder aktive Luftbewegung ausgetauscht wird.

6. Verfahren nach einem der Ansprüche 1 bis 4, wobei die Gassensoranordnung einen ersten Gassensor (1) und einen zweiten Gassensor (2) umfasst, und wobei

- der mindestens eine Anfangsdatenpunkt mittels des ersten Gassensors (1) ermittelt wird,
- das zu messende Gas am zweiten Gassensor (2) mit dem Mittel (11, 12) zur Zerlegung des Gases der Gassensoranordnung zerlegt wird,
- die Reihe der Zerfallsdatenpunkte mittels des zweiten Gassensors (2) ermittelt wird, und
- die absolute Gaskonzentration aus der Gaskonzentrationsfunktion (R(t)) abgeleitet wird, indem die Gaskonzentrationsfunktion (R(t)) zumindest für den Anfangsdatenpunkt des ersten Gassensors (1) und für die Reihe der Abklingdatenpunkte des zweiten Gassensors (2) ausgewertet wird.

7. Verfahren nach Anspruch 6, wobei das Mittel (12) zur Zerlegung des zu messenden Gases am zweiten Gassensor (2) vorgesehen ist, und wobei:

- das Erfassen des ersten Sensorsignals und das Ermitteln des mindestens einen Anfangsdatenpunktes des ersten Gassensors (1) aus dem ersten Sensorsignal in einer ersten Phase bei ausgeschaltetem oder in einem Ausgangszustand betriebenem Mittel (11, 12) zur Zerlegung des zu messenden Gases durchgeführt wird,
- das Zerlegen des zu messenden Gases, das Erfassen des zweiten Sensorsignals von dem zweiten Gassensor (2) und das Bestimmen der Reihe von Abklingdatenpunkten aus dem zweiten Sensorsignal während einer zweiten Phase ausgeführt wird, wobei das Mittel (11, 12) zur Zerlegung des zu messenden Gases eingeschaltet ist und in einem Abklingzustand betrieben wird, und
- die zweite Phase nach einer Zeitdauer beendet wird und in einer dritten Phase das Gas in der Gassensoranordnung durch Diffusion und/oder aktive Luftbewegung ausgetauscht wird.

8. Verfahren nach Anspruch 7, wobei das Mittel zur Zerlegung des zu messenden Gases sowohl am ersten als auch am zweiten Gassensor (1, 2) vorgesehen ist, und wobei die erste, zweite und dritte Phase durch eine vierte, fünfte und sechste Phase ergänzt werden, wobei:

- in der vierten Phase der zweite Gassensor (2) zur Erfassung des ersten Sensorsignals und zur Bestimmung eines weiteren Anfangsdatenpunktes aus dem ersten Sensorsignal verwendet wird, wobei das Mittel (11, 12) zur Zerlegung des zu messenden Gases ausgeschaltet ist oder in einem Anfangszustand betrieben wird,
- in der fünften Phase der erste Gassensor (1) verwendet wird, um das zu messende Gas zu zerlegen, das zweite Sensorsignal zu erfassen und aus dem zweiten Sensorsignal die Reihe von Zerfallsdatenpunkten zu bestimmen, wobei das Mittel zur Zerlegung des zu messenden Gases eingeschaltet ist und in einem Abklingzustand betrieben wird, und
- in der sechsten Phase die fünfte Phase nach einer weiteren Zeitdauer beendet wird und das Gas in der Gassensoranordnung durch Diffusion und/oder aktive Luftbewegung ausgetauscht wird.

9. Verfahren nach einem der Ansprüche 1 bis 8, wobei das zu messende Gas Ozon ist und der Gassensor (1, 2) einen Ozongassensor umfasst.

10. Gassensoranordnung zur Bestimmung einer absoluten Gaskonzentration, umfassend:

- mindestens einen Gassensor (1, 2), der so angeordnet ist, dass er ein für ein zu messendes Gas, insbesondere für eine Ozonkonzentration, indikatives Sensorsignal erzeugt
- ein oder mehrere Mittel (11, 12, 21, 22) zur Zerlegung des zu messenden Gases in chemische Komponenten, und
- eine Steuereinheit, die so angeordnet ist, dass sie den Gassensor (1) und das Mittel (11, 12, 21, 22) zur Zerlegung des Gases so betreibt, dass:
- von dem Gassensor (1, 2) ein erstes Sensorsignal erfasst wird und aus dem ersten Sensorsignal mindestens ein Anfangsdatenpunkt ermittelt wird,
- das zu messende Gas mit Hilfe des Mittels (11, 12, 21, 22) zur Zerlegung des Gases zerlegt wird,
- ein zweites Sensorsignal von dem Gassensor (1, 2) erfasst wird und aus dem zweiten Sensorsignal eine Reihe von Abklingdatenpunkten bestimmt wird, wobei der Anfangsdatenpunkt und die Reihe von Abklingdatenpunkten unterschiedlichen Sensorsignalen zu unterschiedlichen Zeitpunkten während der Zerlegung des zu messenden Gases entsprechen; und die Gassensoranordnung ferner umfasst:
- eine Verarbeitungseinheit, die eingerichtet ist, um eine absolute Gaskonzentration aus einer Gaskonzentrationsfunktion (R(t)), die eine Funktion der Zeit ist, zu bestimmen, indem die Gaskonzentrationsfunktion zumindest für den Anfangsdatenpunkt und die Reihe von Abklingdatenpunkten ausgewertet wird, und wobei die Verarbeitungseinheit eingerichtet ist, um:
- Überwachen der Zerlegung des Gases unter Verwendung des Gassensors (1) und durch Bestimmen der Reihe von Abklingdatenpunkten aus den erfassten Sensorsignalen und
- Auswerten der Gaskonzentrationsfunktion (R(t)) durch Anpassen einer Abklingfunktion an eine Reihe von Datenpunkten, die die Reihe von Abklingdatenpunkten und den Anfangsdatenpunkt umfasst.

11. Gassensoranordnung nach Anspruch 10, wobei das Mittel (11, 12, 21, 22) zur Zerlegung des zu messenden Gases mindestens eines der folgenden Elemente umfasst:

- eine Wärmequelle (11, 21), eine Heizung, eine Heizplatte des Gassensors, eine Lichtquelle (12, 22), eine ultraviolette Lichtquelle, eine Infrarotquelle; und/oder

wobei der Gassensor mindestens eines der folgenden Elemente umfasst:

- einen Halbleiter-Gassensor, einen Metalloxid, MOX, Gassensor, einen WO3-MOX-Gassensor, einen resistiven Gassensor oder einen chemoresistiven Gassensor.

12. Gassensoranordnung nach Anspruch 10 oder 11, wobei

- der Gassensor in einem Sensorgehäuse (13, 23) angeordnet ist, das so ausgelegt ist, dass es eine passive Diffusion des zu erfassenden Gases in das und/oder aus dem Sensorgehäuse ermöglicht, und/oder
- ein Mittel zur Bereitstellung eines aktiven Luftstroms zum Austausch des zu erfassenden Gases weg vom Gassensor und unter der Kontrolle der Steuereinheit, und/oder
- ein Kohlefilter (26) als Wärmequelle (11, 21).

Revendications

1. Un procédé pour déterminer une concentration absolue de gaz, en utilisant un arrangement de capteur de gaz comprenant un capteur de gaz (1) et des moyens (11, 12) pour décomposer un gaz à mesurer, le procédé comprenant les étapes suivantes:

- acquérir un premier signal de capteur et déterminer à partir du premier signal de capteur au moins un point de données initial,
- décomposer le gaz à mesurer en composants chimiques en utilisant les moyens (11, 12) de décomposition du gaz de l'arrangement de capteurs de gaz,
- acquérir un deuxième signal de capteur et déterminer à partir du deuxième signal de capteur une série de points de données de décomposition, le point de données initial et la série de points de données de décomposition correspondant à différents signaux de capteur à différents moments pendant la décomposition du gaz à mesurer, et
- déduire une concentration absolue de gaz à partir d'une fonction de concentration de gaz (R(t)) qui est une fonction du temps en évaluant la fonction de concentration de gaz (R(t)) au moins pour le point de données initial et la série de points de données de décomposition; dans lequel:

    - la décomposition du gaz est surveillée en utilisant le capteur de gaz (1) et en déterminant la série de points de données de décomposition à partir des signaux de capteur acquis et
    - la fonction de concentration de gaz (R(t)) est évaluée en ajustant une fonction de décomposition à une série de points de données comprenant la série de points de données de décomposition et le point de données initial.

2. Le procédé selon la revendication 1, dans lequel

- les moyens (11, 12) de décomposition d'un gaz à mesurer comprennent une source de lumière (12), en particulier une source de lumière ultraviolette, et
- le gaz est décomposé au moyen de la lumière émise par la source de lumière (12).

3. Le procédé selon la revendication 1 ou 2, dans lequel

- les moyens (11, 12) de décomposition d'un gaz à mesurer comprennent une source de chaleur (11) et
- le gaz est décomposé au moyen de la chaleur à émettre par la source de chaleur (11).

4. Le procédé selon l'une des revendications 1 à 3, dans lequel la fonction de concentration du gaz (R(t)) est évaluée en prenant une différence entre l'au moins un point de données initial et les points de données de décomposition.

5. Le procédé selon l'une des revendications 1 à 4, dans lequel l'arrangement de capteurs de gaz comprend un capteur de gaz (1), et dans lequel:

- acquérir le premier signal de capteur et déterminer à partir du premier signal de capteur l'au moins un point de données initial sont exécutées pendant une première phase avec les moyens (11, 12) de décomposition du gaz à mesurer désactivés ou fonctionnant à un état initial,
- la décomposition du gaz à mesurer, l'acquisition du deuxième signal de capteur et la détermination à partir du deuxième signal de capteur de la série de points de données de décomposition sont exécutées pendant une deuxième phase avec les moyens (11, 12) de décomposition du gaz à mesurer activés et fonctionnant dans une condition de décomposition, et
- la deuxième phase est terminée après une période de temps et le gaz est échangé à partir de l'arrangement de capteur de gaz au moyen de la diffusion et/ou du mouvement d'air actif dans une troisième phase.

6. Le procédé selon l'une des revendications 1 à 4, dans lequel l'arrangement de capteurs de gaz comprend un premier capteur de gaz (1) et un deuxième capteur de gaz (2), et dans lequel

- le au moins un point de données initial est déterminé au moyen du premier capteur de gaz (1),
- le gaz à mesurer est décomposé au niveau du deuxième capteur de gaz (2) à l'aide des moyens (11, 12) de décomposition du gaz de l'arrangement de capteurs de gaz,
- la série de points de données de décomposition est déterminée au moyen du deuxième capteur de gaz (2), et
- la concentration absolue de gaz est dérivée de la fonction de concentration de gaz (R(t)) en évaluant la fonction de concentration de gaz (R(t)) au moins pour le point de données initial du premier capteur de gaz (1) et pour la série de points de données de décomposition du deuxième capteur de gaz (2).

7. Le procédé selon la revendication 6, dans lequel les moyens (12) de décomposition du gaz à mesurer sont prévus au niveau du deuxième capteur de gaz (2), et dans lequel:

- l'acquisition du premier signal de capteur et la détermination à partir du premier signal de capteur d'au moins un point de données initial du premier capteur de gaz (1) sont exécutées pen-

dant une première phase avec les moyens (11, 12) de décomposition du gaz à mesurer désactivés ou fonctionnant dans un état initial,
- la décomposition du gaz à mesurer, l'acquisition du second signal de capteur provenant du second capteur de gaz (2) et la détermination à partir du second signal de capteur de la série de points de données de décomposition sont exécutées pendant une seconde phase avec les moyens (11, 12) de décomposition du gaz à mesurer activés et fonctionnant dans une condition de décomposition, et
- la deuxième phase est terminée après une période de temps et le gaz est échangé à partir de l'arrangement de capteur de gaz au moyen de la diffusion et/ou du mouvement d'air actif dans une troisième phase.

8. Procédé selon la revendication 7, dans lequel les moyens de décomposition du gaz à mesurer sont prévus à la fois au niveau du premier et du deuxième capteur de gaz (1, 2), et dans lequel les première, deuxième et troisième phases sont complétées par une quatrième, une cinquième et une sixième phase, dans lequel:

- dans la quatrième phase, le deuxième capteur de gaz (2) est utilisé pour acquérir le premier signal de capteur et déterminer un autre point de données initial à partir du premier signal de capteur, les moyens (11, 12) de décomposition du gaz à mesurer étant désactivés ou fonctionnant dans un état initial,
- dans la cinquième phase, le premier capteur de gaz (1) est utilisé pour décomposer le gaz à mesurer, acquérir le deuxième signal de capteur et déterminer à partir du deuxième signal de capteur la série de points de données de décomposition avec les moyens de décomposition du gaz à mesurer activés et fonctionnant dans un état de décomposition, et
- dans la sixième phase, la cinquième phase est terminée après une autre période de temps et le gaz est échangé à partir de l'arrangement de capteur de gaz au moyen d'une diffusion et/ou d'un mouvement d'air actif.

9. Le procédé selon l'une des revendications 1 à 8, dans lequel le gaz à mesurer est l'ozone et le capteur de gaz (1, 2) comprend un capteur de gaz d'ozone.

10. Arrangement de capteur de gaz pour déterminer une concentration absolue de gaz, comprenant:

- au moins un capteur de gaz (1, 2) arrangé pour générer un signal de capteur indicatif d'un gaz à mesurer, en particulier, indicatif d'une concentration d'ozone,
- un ou plusieurs moyens (11, 12, 21, 22) pour décomposer le gaz à mesurer en composants chimiques, et
- une unité de commande arrangée pour faire fonctionner le capteur de gaz (1) et les moyens (11, 12, 21, 22) pour décomposer le gaz de telle sorte que:
- un premier signal de capteur est acquis à partir du capteur de gaz (1, 2) et au moins un point de données initial est déterminé à partir du premier signal de capteur,
- le gaz à mesurer est décomposé à l'aide des moyens (11, 12, 21, 22) de décomposition du gaz,
- un second signal de capteur est acquis à partir du capteur de gaz (1, 2) et une série de points de données de décomposition est déterminée à partir du second signal de capteur, dans lequel le point de données initial et la série de points de données de décomposition correspondent à différents signaux de capteur à différents moments pendant la décomposition du gaz à mesurer; et l'arrangement de capteur de gaz comprend en outre:
- une unité de traitement qui est agencée pour déterminer une concentration absolue de gaz à partir d'une fonction de concentration de gaz (R(t)) qui est une fonction du temps en évaluant la fonction de concentration de gaz au moins pour le point de données initial et la série de points de données de décomposition, et dans lequel l'unité de traitement est agencée pour:

- surveiller la décomposition du gaz en utilisant le capteur de gaz (1) et en déterminant la série de points de données de décomposition à partir des signaux de capteur acquis et
- évaluer la fonction de concentration de gaz (R(t)) en ajustant une fonction de décomposition à une série de points de données comprenant la série de points de données de décomposition et le point de données initial.

11. L'arrangement de capteur de gaz selon la revendication 10, dans lequel le moyen (11, 12, 21, 22) pour décomposer le gaz à mesurer comprend au moins l'un des éléments suivants:

- une source de chaleur (11, 21), un appareil de chauffage, une plaque chauffante du capteur de gaz, une source de lumière (12, 22), une source de lumière ultraviolette, une source infrarouge; et/ou
- dans lequel le capteur de gaz comprend au moins un des éléments suivants:

- un capteur de gaz à semi-conducteur, un capteur de gaz à oxyde métallique, MOX, un capteur de gaz WO3 MOX, un capteur de gaz résistif ou un capteur de gaz chimio-résistif.

12. L'arrangement de capteur de gaz selon les revendications 10 ou 11, dans lequel

- le capteur de gaz est situé dans un boîtier de capteur (13, 23) qui est conçu pour permettre une diffusion passive du gaz à détecter dans et/ou hors du boîtier de capteur, et/ou
- des moyens pour fournir un flux d'air actif pour échanger le gaz à détecter à l'écart du capteur de gaz et sous le contrôle de l'unité de commande, et/ou
- un piège à charbon (26) comme source de chaleur (11, 21) .

FIG 1

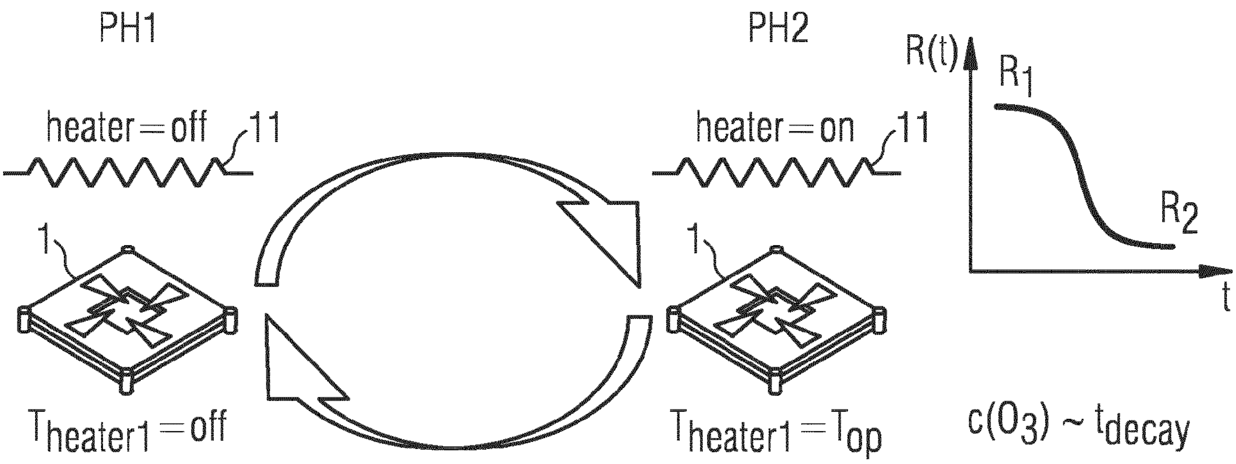

PH1
PH2
heater=off
11
heater=on
11
1
1
R(t)
R_1
R_2
t
$T_{heater1}$ =off
$T_{heater1}$ = T_{op}
$c(O_3) \sim t_{decay}$

FIG 2

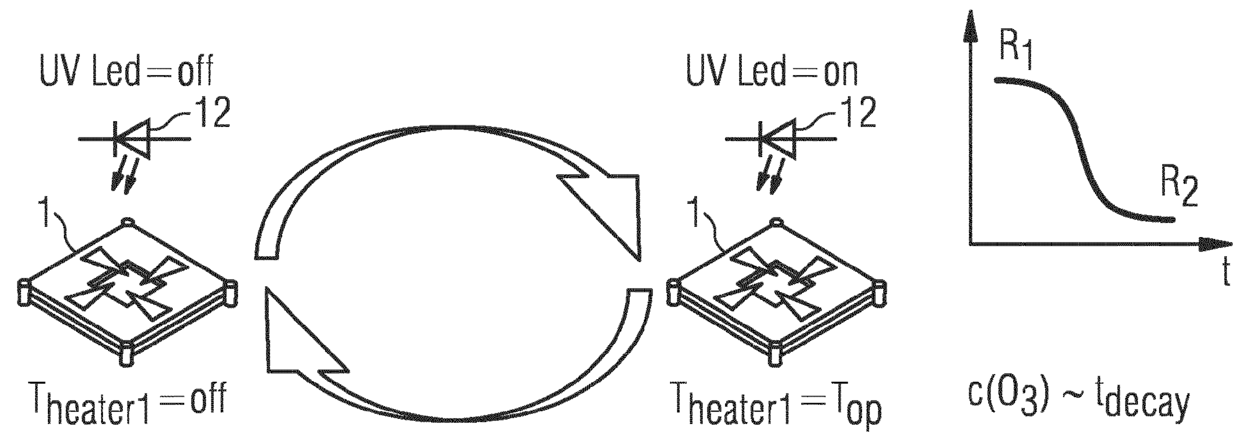
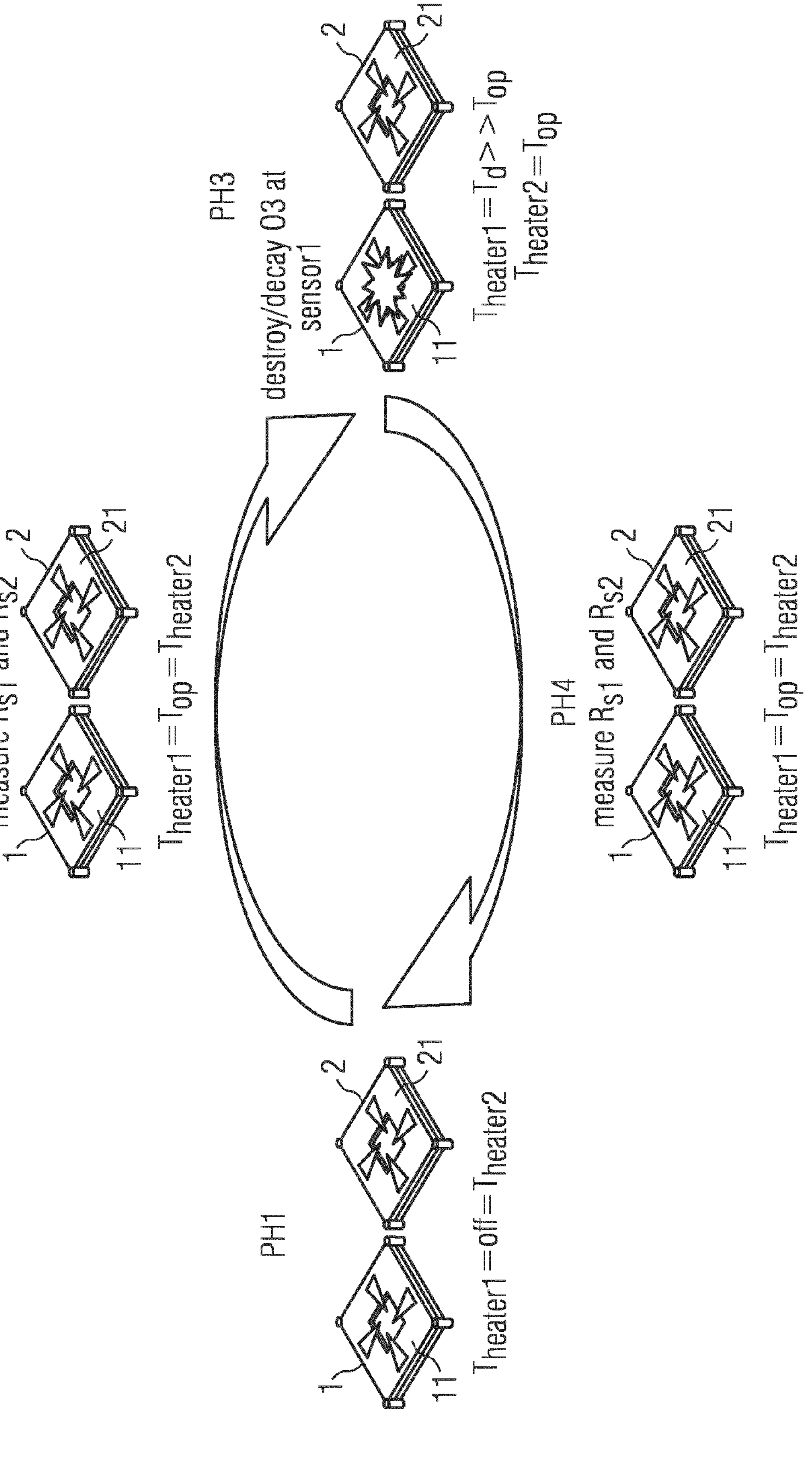
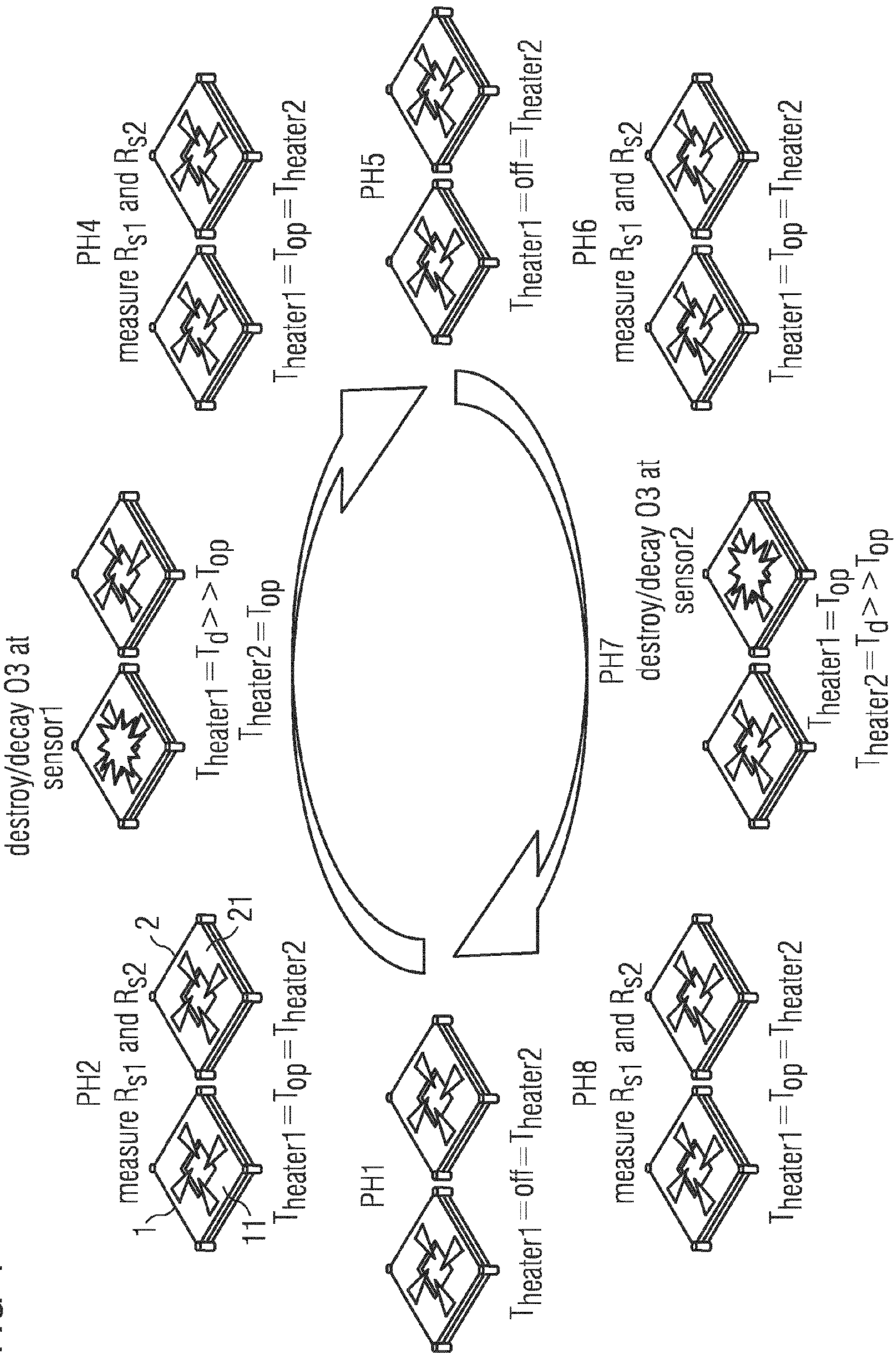

UV Led=off
12
UV Led=on
12
1
1
R_1
R_2
t
$T_{heater1}$ =off
$T_{heater1}$ = T_{op}
$c(O_3) \sim t_{decay}$

FIG 3



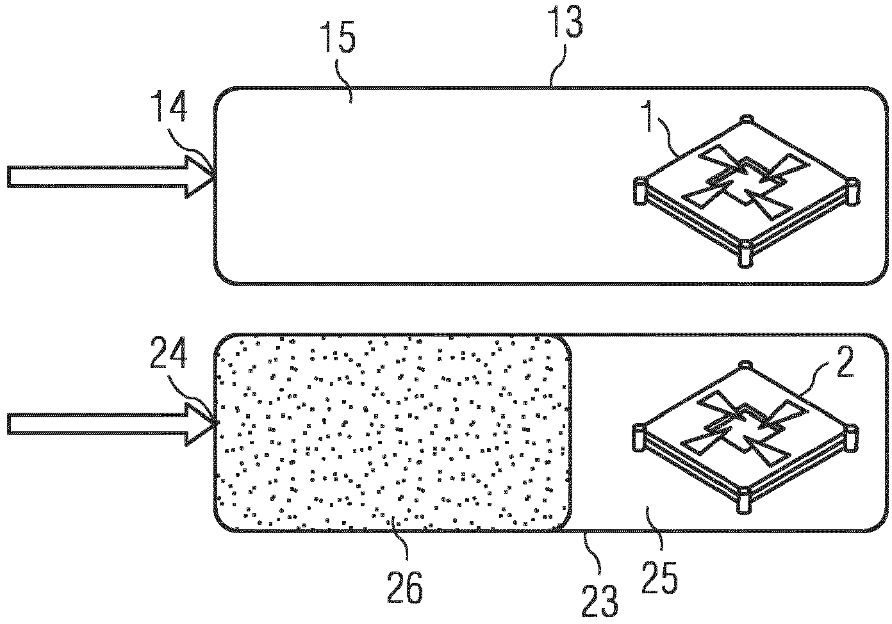
SUBSTITUTE SHEET (RULE 26)

FIG 4



SUBSTITUTE SHEET (RULE 26)

FIG 5



SUBSTITUTE SHEET (RULE 26)

REFERENCES CITED IN THE DESCRIPTION

This list of references cited by the applicant is for the reader's convenience only. It does not form part of the European patent document. Even though great care has been taken in compiling the references, errors or omissions cannot be excluded and the EPO disclaims all liability in this regard.

Patent documents cited in the description

- US 6054098 A **[0005]**

Non-patent literature cited in the description

- **BART et al.** High Density Ozone Monitoring Using Gas Sensitive Semi-Conductor Sensors in the LowerFraser Valley, British Columbia. *ENVIRONMENTAL SCIENCE & TECHNOLOGY,* 01 April 2014, vol. 48 (7), 3970-3977 **[0004]**
- **WILLIAMS et al.** Ozone sensors based on WO3: a model for sensor drift and a measurement correction method modelling the response of a tungsten oxide semiconductor validation of low-cost ozone measurement instruments suitable for use in an air-quality monitoring network A simple equivalent circuit model to represent. *Meas. Sci. Technol.,* 01 June 2001, 684-690 **[0004]**