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(54) **Sensor, gas analyzer and method for measuring concentration of at least one respiratory gas component**

Sensor, Gasanalysegerät und Verfahren zum Messen der Konzentration von mindestens einer Atemgaskomponente

Capteur, analyseur de gaz et procédé pour mesurer la concentration d'au moins un composant de gaz respiratoire

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## Description

BACKGROUND OF THE INVENTION

**[0001]** This disclosure relates generally to a sensor, gas analyzer and method for measuring a concentration of at least one respiratory gas component in a breathing gas, which concentration is varying during a breathing cycle having an inspiration phase, an expiration phase and a phase between the inspiration and expiration.

**[0002]** Patient's that are health monitored are usually connected to host, such as patient monitor, via for example electrical cables or plastic tubing that transmit measurement samples or data from sensors attached to patient. Data and samples are usually analyzed at the host and showed on the host's display for the care giver. Cables and tubes between the patient and the host generate different problems for the care givers as wired patient complicate care procedures and even risk for the patient as tearing cables and tubes may hurt and disturb the patient. Wireless sensors may decrease these problems and risks, but the size, weight and operating time cause other type of problems.

**[0003]** To ensure good usability and functionality of breathing gas analyzer, such as a mainstream type analyzer that is placed close to patient's airways into the end of endotracheal tube, mask or prongs, it is important that the device size is small, especially with smaller patients, to ensure that device would not prevent clinical procedures by covering critical areas of patient's face or body. The device should also be light weight to ensure that the device would not for example bend endotracheal tube that would clock the air flow between the lungs and the ventilator or that the device would not unfasten from patient's nasal or oral cavities if mask or prongs are used.

**[0004]** Short operating time is one of the challenges in transportable wireless gas analyzing due to the electrical power consumption of the gas analyzer. This is especially a problem with gas analyzing based on gas absorption at infrared radiation wavelengths, which is the most common and functioning real-time method in analyzing the concentration of most common gases. The most power consuming component in such analyzer is the radiation source that generates the infrared radiation wave lengths. Optical reflector and collimator designs may increase the emitted signal efficiency few times higher, but the electrical power consumed by the radiation source still varies between 1W-1.5W at its best. The energy density of rechargeable lithium-ion batteries are between 150-250 Wh/1, which is one of the best, commercially available, rechargeable battery technologies at the moment. With these given values a wireless analyzer comprising a huge rechargeable battery which size is for example 100cam$^3$ (1dl) would function continuously about 10-25 hours. Short operating time, like 10-25 hours, together with the huge analyzer size, only the size of a battery 100cm$^3$, and the weight would be useless even with adults, but especially with smaller patients.

**[0005]** Thus at the moment there does not exist a proper, wireless, breathing gas concentration analyzing technique.

**[0006]** EP 0733341 discloses a capnometer for measuring carbon dioxide of a respiratory gas. The capnometer comprises a light source emitting infrared radiation through the respiratory gas, a detector for sensing the transmission of the infrared radiation, and a switch device for turning the radiation source on and off in a predetermined period.

**[0007]** US 4914720 discloses a portable gas analyzer to measure a concentration of a gas component, such as carbon dioxide in the respiratory gas. The analyzer comprises a portable unit, a transducer head connected to the portable unit by an electrical cable and an airway adapter, which can be coupled to the transducer head.

**[0008]** EP 0512535 discloses a portable carbon dioxide monitor comprising a disposable airway sensor to measure a respiratory gas component. The airway sensor comprises a sensor body with a gas passageway between gas inlet and outlet, and means in the sensor body for an optical path with a first and second end across the gas passageway. The light source can be mounted at the first end of the optical path. The airway adapter further comprises means for attaching a photodetector to the second end of the optical path, which photodetector can be removed from the sensor body without removing the light source.

**[0009]** US 2009/0227887 discloses a metabolic analyzer transducer comprising a housing which can be coupled to a facemask of a patient. Within the housing there is a sensor, a microcontroller receiving inputs from the sensor and computing carbon dioxide production, and a power source coupled to the microcontroller.

BRIEF DESCRIPTION OF THE INVENTION

**[0010]** The above-mentioned shortcomings, disadvantages and problems are addressed herein which will be understood by reading and understanding the following specification.

**[0011]** In an embodiment, not according to the invention, a sensor for measuring a concentration of at least one respiratory gas component in a breathing gas, which concentration is varying during a breathing cycle having an inspiration phase, an expiration phase and a phase between the inspiration and expiration, includes at least one radiation source for emitting radiation, and at least one radiation sensing detector for receiving radiation and for providing a signal indicative of the concentration of the at least one respiratory gas component. The sensor for measuring a concentration of at least one respiratory gas component in a breathing gas also includes an electronics board for receiving and processing the signal from the at least one radiation sensing detector to determine the concentration of the at least one respiratory gas component, and an energy storage device for supplying energy to the at least one radiation source. The electronics board is configured to choose from among at least two different modes energy supply to the at least one radiation source, one of the modes being an operation mode configured to allow sufficient energy supply during a first time period to the at least one radiation source needed for subsequent concentration determination within at least one phase of the breathing cycle, and another of the modes being a rest mode configured to allow reduced energy supply during a second time period to the at least one radiation source compared to the operation mode to limit radiation for saving energy of the energy storage device within the breathing cycle, and that the first time period is shorter than the second time period.

**[0012]** In another embodiment, not according to the invention, a method for measuring a concentration of at least one respiratory gas component in a breathing gas, which concentration is varying during a breathing cycle having an inspiration phase, an expiration phase and a phase between the inspiration and expiration, includes emitting radiation by means of at least one radiation source towards at least one optical component in direct or indirect contact with the respiratory gas inside a sampling cell, and receiving the radiation in at least one radiation sensing detector and providing from the at least one radiation sensing detector a signal indicative of the concentration of the at least one respiratory gas component. The method for measuring a concentration of at least one respiratory gas component also includes receiving the signal from the at least one radiation sensing detector and processing the signal in an electronics board to determine the concentration of the at least one respiratory gas component, and supplying energy from an energy storage device to the at least one radiation source. The method for measuring a concentration of at least one respiratory gas component also includes choosing in the electronics board from among at least two different modes energy supply to the at least one radiation source, one of the modes being an operation mode configured to allow sufficient energy supply during a first time period to the at least one radiation source needed for subsequent concentration determination within at least one phase of the breathing cycle, and another of the modes being a rest mode configured to allow reduced energy supply during a second time period to the at least one radiation source compared to the operation mode to limit radiation for saving energy of the energy storage device within the breathing cycle, and that the first time period is shorter than the second time period.

**[0013]** The invention is defined by the appended claims. Various other features, objects, and advantages of the invention will be made apparent to those skilled in art from the accompanying drawings and detailed description thereof.

## BRIEF DESCRIPTION OF THE DRAWINGS

**[0014]**

Figure 1 shows a schematic view of a gas analyzer and a sensor in a communication with a host device in accordance with an embodiment;

Figure 2 shows a carbon dioxide concentration curve measured in an operation mode, a derivative of the carbon dioxide concentration and a carbon dioxide concentration measured in a rest mode, when the measurements were made with the gas analyzer and sensor in Figure 1 as a function of time in accordance with an embodiment;

Figure 3 shows a carbon dioxide concentration curve measured in an operation mode, a carbon dioxide concentration curve measured in a rest mode, a pressure curve and a derivative of the pressure, when the measurements were made with the gas analyzer and sensor in Figure 1 as a function of time in accordance with an embodiment;

Figure 4 shows a carbon dioxide concentration curve measured in an operation mode, a carbon dioxide concentration measured in a rest mode, and a flow curve , when the measurements were made with the gas analyzer and sensor in Figure 1 as a function of time in accordance with an embodiment; and

Figure 5 shows a carbon dioxide concentration curve measured in an operation mode, a carbon dioxide concentration curve measured in a rest mode, an oxygen concentration curve and a derivative of oxygen concentration, when the measurements were made with the gas analyzer and sensor in Figure 1 as a function of time in accordance with an embodiment.

## DETAILED DESCRIPTION OF THE INVENTION

**[0015]** Specific embodiments are explained in the following detailed description making a reference to accompanying drawings. These detailed embodiments can naturally be modified and should not limit the scope of the invention as set forth in the claims.

**[0016]** Figure 1 shows a portable breathing gas analyzer 1 that comprises a sensor 2 and airway adapter 3 which is connectable to the sensor 2. The sensor 2 may also comprise a display 5 that can show the measured breathing gas values for the user as numbers, but in waveforms as well. The sensor 2 may also comprise a user interface 4, such as buttons 6, but as well a touch screen can replace the buttons 6, for the user to operate the sensor. Electrical power to operate the sensor can be delivered from an energy storage device 22, such as a battery, preferably a rechargeable battery. The gas analyzer can communicate wirelessly with other devices or host devices 23 such as a patient monitor through radio frequency transceivers 24 placed inside the sensor 2 and the host device 23. Host devices such as the patient monitor can show measured values and waveforms from its display 25 in similarly as the gas analyzer 1 shows values on its display 5. When the wireless operation is not necessary and when the energy level of the rechargeable energy storage device 22 is low and needs to be recharged the analyzer 1 or the sensor 2 can be connected to the host device 23 through an electrical cable to transmit electrical power, but measured values as well if needed. Naturally it is also possible to replace the rechargeable energy storage devices such as batteries with new or recharged batteries to enable continuous use of the gas analyzer when any of the host devices are present.

**[0017]** The sensor 2 also comprises at least one radiation source 13, such as an infrared radiation source, to emit radiation, and at least one radiation sensing detector 14 to receive the radiation emitted by the at least one radiation source. An electronics board 26 is part of the sensor, too, receiving and processing the signal from the at least one radiation sensing detector 14 to determine the concentration of the at least one respiratory gas component of the breathing gas, Further the sensor 2 may comprise a flow detector 27 providing a signal indicative of the flow of the breathing gas to the electronics board 26, and a pressure detector 28 providing a signal indicative of the pressure of the breathing gas to the electronics board 26. The electronics board may comprise a CPU to control the different functions of the sensor and to process measurement data from different signal sources into the form of numbers and waveforms to be shown for the care giver on the display at the sensor or at the host where the data can be transmitted wirelessly.

**[0018]** Moreover the sensor 2 may comprise an oxygen detector 18 providing a signal indicative of the oxygen in the breathing gas. The oxygen detector 18 can be for example fuel cell or polarographic type technology, but can be implemented with other technologies as well. Alternatively the sensor 2 may comprise a radiation source 19 and a radiation sensing detector 20 based on for example fluorescence quenching providing a signal indicative of the oxygen in the breathing gas.

**[0019]** The airway adapter 3 has a first port 7 with a first opening 8 to deliver the respiratory gas to the sampling cell, which first port can be connected to an endotracheal tube, nasal mask, facial mask or similar that is further connected to the patient and a second port 9 with a second opening 10 to remove the respiratory gas from the sampling cell, which second port can be connected to for example a ventilator circuit, resuscitator or similar when the patient is intubated or it can be left non-connected if the sensor 2 is connected to nasal or facial mask or similar. The first opening 8 and the second opening 10 allow the fresh breathing gas to flow through the airway adapter into the patient's lungs and the used breathing gas to flow out from the patient's lungs through the airway adapter.

**[0020]** The airway adapter also comprises a sampling cell 11 allowing the breathing gas flow. The sampling cell 11 is also for measuring gas concentration(s) of breathing gases. Sampling cell comprises at least one optical component 12 for guiding the radiation, which guiding in some cases means conveying or passing the radiation or even reflecting the radiation. The optical component may be in direct or indirect contact with the respiratory gas inside the sampling cell. The optical component 12 may be at least one optical window 16 to convey or pass a radiation such as an infrared radiation through the sampling cell perpendicularly against through the breathing gas flowing in the airway adapter. In case there are two optical windows, they may locate on both sides of the sampling cell. The measurement is enabled when the airway adapter 3 is connected to a connecting point 17 of the sensor 2, when the at least one radiation source 13, the at least one optical window 16 and the at least one radiation sensing detector 14 are aligned so that the radiation from the at least one radiation source 13 can pass through the at least one optical window 12, and through the breathing gas, into the at least one radiation sensing detector 14.

**[0021]** The airway adapter 3 may also comprise a flow measuring component 15, such as a flow barrier 29 with pressure ports 30, 31, for measuring the breathing gas flow between the first port 7 and the second port 9 and a pressure measuring component 32, such as a port for measuring the pressure of the breathing gas between the first port 7 and the second port 9. As shown in Figure 1 the pressure measuring component 32 can be one of the pressure ports 30, 31 or it can be a separate port if such is reasonable for some specific reason.

**[0022]** The flow detector 27 for measuring the flow can be for example one of the known technologies such as a differential pressure measurement through the pressure ports 30, 31 over the flow barrier 29. Also the flow measurement can be based on hot wire or ultrasonic transducer technology. The pressure detector 28 for measuring the pressure can be made by comparing the breathing gas pressure through one of the pressure ports 30, 31 with the outside pressure. As explained hereinbefore Figure 1 shows the flow measurement over the flow barrier 29 located in airway adapter 3 that comprises the pressure ports 30 and 31 with pressure openings 33 and 34 to allow pressure and pressure differences proportional to flow of breathing gas to be measured over the flow barrier 29 inside the airway adapter 3 through the pressure openings 33 and 34. The measurement is enabled when the airway adapter 3 is connected to the connecting point 17 of the sensor 2 and when the pressure openings 33 and 34 connect with the flow detector 27 and the pressure detector 28 located inside the sensor 2. The pressure openings 33 and 34 may comprise filters (not shown in figures) to prevent bacteria and viruses to enter through the ports into the flow detector 27 and the pressure detector 28.

**[0023]** The oxygen detector 18, for example fuel cell type or polarographic type detector used for measuring the concentration of oxygen in the breathing gas, may be located inside the sensor 2. To enable the oxygen measurement from the breathing gas, the oxygen detector is in fluid connection with the breathing gas through the opening such as the pressure opening 34 in pressure port 31 in airway adapter 3. When the airway adapter 3 is connected to sensor 2 the fluid connection through the opening 34 between the breathing gas and the oxygen detector 18 is established.

**[0024]** Furthermore the airway adapter 3 may also comprise additional optical components for gas concentration measurement to measure gases that are insensitive to infrared radiation such as oxygen. The optical component 12 may have a luminophore coated surface, which component may be transparent to radiation and thus being able to guide and possibly to convey radiation, too. When the radiation emitted by the radiation source towards the optical component meets the luminescable material in contact with the respiratory gas, such as oxygen, luminescent radiation is generated indicative of oxygen concentration of the respiratory gas and received by the detector. In this specific embodiment the optical component may be in indirect contact with the respiratory gas. The luminescent radiation may be guided through the optical component or away from the surface of the optical component.

**[0025]** As an example in Figure 1 the concentration of oxygen in the breathing gas can be measured based on the fluorescence quenching, where the radiation source 19 directs the radiation towards the optical component 12, such as a fluorescence quenching element 21, which is in contact with the breathing gases, enabling the fluorescence quenching based oxygen measurement indicative of the oxygen in the breathing gas, which emits radiation proportional to the oxygen content in the gas directing it towards the optical component 12 and radiation sensing detector 20.

**[0026]** Some hospitals and users prefer disposable airway adapters, but also other breathing circuit accessories are made disposable to reduce contamination risk. Patient's lungs generate mucus and other secretions and injured lungs bleed blood, which easily enter the breathing circuit accessory forming a good environment for bacteria and viruses to survive and reproduce. To minimize the contamination risk a disposable accessory need to be changed and reusable accessory to be cleaned frequently enough. Thus sensible and costly flow and pressure detectors are better to locate inside the sensor 2 to avoid cleaning and to make them reusable.

**[0027]** When the patient is in stable condition it is usually sufficient enough to show only the end tidal (ET) values of gas concentrations such as carbon dioxide ($CO_2$) and oxygen ($O_2$). There may be need for showing fraction of inspired values (FI) in addition to ET-values or the accurate real time waveforms or capnogram if the condition of the patient changes rapidly or for some other clinical reason. ET-value of certain breathing gas is the maximal value of the concentration of that gas. FI-value is the concentration of a gas participating in gas exchange in the alveoli. The I:E ratio defines the ratio of the duration of inspiration to the duration of expiration. A range of 1:1.5 to 1:2 for an adult is considered acceptable for mechanical ventilation. Ratios of 1:1 or higher may cause hemodynamic complications, whereas ratios lower than 1:2 indicate lower mean airway pressure and fewer associated hazards.

**[0028]** The radiation source 13 used in detecting gases at radiation wavelengths, such as infrared radiation wavelengths, is one of the most power consuming electrical components in the gas analyzer 1 or the sensor 2 that has a big impact on the operation time of the gas analyzer 1. The operation time can be increased into some extent by increasing the size or the energy density of the energy storage device, but the gas analyzer with small size and weight is preferred as the analyzer is placed close to the patient's mouth and it should disturb the patient as little as possible.

**[0029]** Figure 2 shows a curve 40, which is a real-time gas concentration value or capnogram of carbon dioxide ($CO_2$) measured with a mainstream type gas analyzer 1 as described hereinbefore. The duration of inspiration is approximately 2 seconds and the duration of expiration approximately 3 seconds. The I:E ratio is thus 1:1.5 and the respiration rate (RR) approximately 12 breaths/minute, which is fairly normal breathing for an adult. The capnogram is generated from electrical signals from the at least one radiation sensing detector 14 that measure the infrared radiation traversing through breathing gases in the sampling cell 11 of the airway adapter 3, in this case carbon dioxide, which absorbs radiation proportional to its concentration. The infrared radiation is generated with the at least one radiation source 13, which electrical power consumption is approximately 1 watt, if it is kept constant to get uniform capnogram like a curve 40 in Figure 2. To keep the analyzer size even somewhat reasonable for usability and functional reasons the size of the energy storage device 22 should be as small as possible, for example less than 2 $cm^3$. The amount of energy stored into such device, using for example lithium-ion technology, would be around 0.4 Wh. The operating time for the gas analyzer would then be around half an hour, which is not enough even for instantaneous transport use usually.

**[0030]** One way to decrease electrical power consumption of the gas analyzer 1, to lengthen the operation time and to minimize the size of the energy storage device, is to choose from among at least two different modes an energy supply to said at least one radiation source. One of the modes is an operation mode, such as a normal operating power mode, allowing sufficient energy supply to the at least one radiation source needed for subsequent concentration determination within at least one phase of the breathing cycle. The breathing cycle includes an inspiration phase, an expiration phase and a phase between the inspiration and the expiration. Another of the modes is a rest mode, such as a lower power mode, allowing reduced energy supply to the at least one radiation source compared to the operation mode to limit radiation for saving energy of the energy storage device within the breathing cycle when reduced accuracy in concentration determination is acceptable, which means that for example concentration determination can be avoided or the accuracy can be decreased.

**[0031]** The reduced energy supply during the rest mode may be at least 50 % less than during the operation mode, more specifically at least 70 % less than during the operation mode, or even more specifically at least 90 % less than during the operation mode. This means that the radiation source can even be turned off or if desired to adjust it into a lower power consumption mode within at least one phase of the breathing cycle. The electronics board 26 may choose the operation mode, when the phase of the breathing cycle includes at least part of the expiration or at least an end tidal volume of the expiration. Instead the electronics board may choose the rest mode within the inspiration phase and within the phase between the inspiration and expiration, but, if desired, to choose the rest mode also within the expiration phase excluding a plateau period when an end tidal volume of the expiration exists in which case the electronics board may choose the operation mode. So according to one embodiment the electronics board may choose the operation mode to measure end-tidal values of gas concentrations and to measure also only a fraction of inspired values. This may mean that the rest mode can be chosen during the rest of time required by the breathing cycle. Typically the first time period, when the operation mode is valid, is shorter than a second time period, when the rest mode is valid. The decision when the operation mode and the rest mode is chosen can be based on different available and measureable breathing gas signals such as carbon dioxide, oxygen, flow, pressure etc.

**[0032]** If the gas concentration, such as carbon dioxide, or any other radiation source dependent signal, is the only measurable and available signal the radiation source cannot be turned off by choosing the rest mode since otherwise the triggering signal for making the decision to turn the source back on would be lost. The gas concentration of carbon dioxide measured with constant power in the operation mode is the curve 40 in Figure 2. Thus energy supply to the radiation source is allowed in the rest mode, but which energy supply is below the energy supply during the operation mode, rather than turning it off to get a continuous signal for decision making. A curve 41 shows the gas concentration measured in the rest mode during the inspiration, the period between the inspiration and expiration, and the expiration excluding the end tidal volume of the expiration when the operation mode is valid and when the gas concentration curve 41 goes suddenly up and after a short period goes suddenly down.

**[0033]** The decision of when the radiation source is turned on and when it is turned into a lower power consumption mode can be based on the derivative of the real-time carbon dioxide concentration curve 42 as shown in Figure 2. The derivative of the gas concentration gives a value relative to how fast the gas concentration is changing. When the derivative of the concentration is zero the concentration stays constant, when the derivative is less than zero the concentration decreases and when the derivative is more than zero the concentration increases. The higher or lower the value of derivative, the faster is the change of concentration. The derivative is zero or close to zero at the plateau 43 of expiration, where the maximal gas concentration value or ET-value should be measured as shown in Figure 2. On the other hand the derivative would be zero or close to zero also when the gas concentration reaches its minimum during inspiration. Thus the plateau 43 at the end of expiration, where the gas concentration should be measured, can be found always when the derivative returns back to zero or close to zero after a positive peak of derivative caused by exhale of gases, transition from inspiration to expiration when the gas concentration changes. When the derivative reaches zero or value close to zero the radiation source is turned on by choosing the operation mode to enable adequate signal levels for gas concentration analyzes to get ET-value. However, the measured gas concentration signal rise to a new level proportional to added radiation power and at the same time the concentration signal rises due to exhaled gas. For that reason there would be another positive peak in derivative proportional to concentration signal change describing that it cannot be used for analyzing purposes yet. After the peak, when the derivative returns back to zero or value close to zero, the maximal concentration or ET-value can be measured.

**[0034]** Later on when the derivative starts decrease and go below zero, as the gas concentration starts to decrease at the end of expiration, the radiation source can be turned into the rest mode again to save electrical energy. The gas concentration signal decreases proportional to decreased radiation and the amplitude of its derivative decreases as well. The lowest radiation power that can be used depends on the lowest signal to noise ratio that can be used reliably to detect the start of normal operating mode to turn on the radiation source again to its normal operating power to get end tidal gas concentration values. When the source is turned into the rest mode the amplitude of derivative will decrease proportionally. It is also possible to scale and filter the derivative with a value inversely proportional to radiation decrease to get more reliable signal for decision making purposes, but this will limit the highest possible respiration rates (RR). When the radiation source is turned on only for the time of plateau, for $1/10^{th}$ of the time and otherwise it is turned into the rest mode, such as $1/5^{th}$ of the electrical power in normal operation mode, as shown in Figure 2, the electrical power consumption of the radiation source can be decreased easily by 75%, for example from 1 W to 0.25 W.

**[0035]** In infrared radiation based gas absorption measurement the gas concentration measurement resolution and the signal to noise ratio are better at lower gas concentration values and decrease towards higher concentrations. With appropriate radiation source supply energy during the rest mode, which occurs mainly during the inspiration and when the gas concentration values should be close to zero, it is also possible to measure the fraction of inspired (FI) gas concentration values to get understanding and to ensure that the patient is really breathing the fresh gas into the lungs. Obviously, if the radiation source supply energy is turned off, the fraction of inspired gas concentration measurement during the rest mode is also turned off.

**[0036]** It is also possible to switch into the normal operating mode during the inspiration phase to get the fraction of inspired (FI) gas concentration values if desired, but this will increase the supply power consumption of course depending on how long the period of normal operating mode is. The decision when the normal operating mode is switched on during the rest mode during inspiration can be based on the signal sources similar to those as described earlier for the carbon dioxide. For example if the breathing circuit pressure is used as a signal source, as shown in Figure 3, the normal operating mode can be switched on when the derivative of the pressure is close to zero after a positive derivative peak, which describes the start of inspiration. Similarly the normal operating mode can be turned back to rest mode to save supply energy when the derivative of pressure starts to decrease from the value close to zero. Thus the time of normal operating mode during the inspiration locates to the end of inspiration when the gas concentration value should be the lowest and the most reliable and the period of time would be similar to that of during expiration depending on the switching window, the lower and upper limit of derivative close to zero.

**[0037]** The radiation source can also be turned on by choosing the operation mode to get ET-values and turned off by choosing the rest mode during the rest of the time to save electrical energy when the decision is based on the pressure measurement of the breathing gases as is the case in Figure 3. If the breathing gas pressure is measured the continuous pressure curve 44 in Figure 3 looks similar to gas concentration capnogram curve 40 in the operation mode also shown in Figure 3, but is shifted 180° decrees in phase. The decision of when the radiation source is turned on and off by means of the electronics board 26 can be based on the real-time gas pressure curve 44 as shown in Figure 3. At the end of exhalation the gas pressure reaches its minimum values, when the radiation source is turned on by means of the electronics board 26 and as the pressure starts to increase again as inspiration starts the radiation source 13 is turned off again. The disadvantage is the pressure offset needed inside the breathing circuit that keeps the patient's lungs open during all times and prevents the alveoli to collapse, which means that the pressure will not reach zero values at any point, but rather it drifts along time causing inaccuracy into radiation source control.

**[0038]** Also the derivative of the real-time gas pressure curve 45 as shown in Figure 3 can be used by the electronics board 26 to turn on and off the radiation source 13. In Figure 3 there is shown the carbon dioxide gas concentration curve 41 measured in the rest mode during the inspiration, the period between the inspiration and expiration, and the expiration excluding the end tidal volume of the expiration when the operation mode is valid and when the gas concentration curve 41 goes suddenly up and after a short period goes suddenly down. The energy supply to the radiation source 13 is zero in this embodiment. The carbon dioxide gas concentration curve 40 is measured in the operation mode. The derivative of the gas pressure gives a value relative to how fast the pressure is changing. When the derivative of the pressure is zero the pressure stays constant, when the derivative is less than zero the pressure decreases and when the derivative is more than zero the pressure increases. The higher or lower the value of derivative, the faster is the change of pressure. The derivative of the gas pressure is zero or close to zero when the gas pressure is at its minimum at the end of expiration, when the maximal gas concentration value or ET-value should be measured at the plateau 43 of expiration as shown in Figure 3. On the other hand the derivative is zero or close to zero also when the gas pressure reaches its maximum during inspiration. Thus the plateau 43 at the end of expiration, where the gas concentration should be measured, can be found always when the derivative returns back to zero or close to zero after a negative peak of derivative caused by a pressure drop during exhale of gases. When the derivative reaches zero or value close to zero the radiation source 13 is turned on to its normal operating power to enable adequate signal levels for gas concentration analyzes to get ET-value. Later on when the derivative starts to increase and go above zero, as the gas pressure starts to increase when inspiration starts, the radiation source can be turned off again to save electrical energy. When the radiation source is turned on only for the time of plateau 43, approximately for 1/10$^{th}$ of the time and otherwise it is turned off, as shown in Figure 3, the electrical power consumption of the radiation source can be decreased more than 90%, for example from 1W to 0.1 W.

**[0039]** The pressure curve 44 measured by the pressure detector 28 and its derivative curve 45 can also be combined to turn on and off the radiation source by means of the electronics board 26. The time when the radiation source 13 is turned on may be due to combination when the pressure is close to its minimum value and its derivative is close to zero within some predetermined limits. The radiation source is turned off again when the pressure and its derivative start to rise again.

**[0040]** If the decision of when the radiation source 13 is turned on and off is based on the breathing gas flow curve 36 measured by the flow detector 27 as shown in Figure 4, the radiation source should be turned on during expiration, when the expiration flow closes the zero (no flow) after the maximum flow and turned off again when the flow turns to negative. It is also possible to combine the derivative of flow signal (not shown in Figure 4) with the actual flow signal similarly as described with pressure signals, but the flow signal should already be fairly accurate for making a decision whether to turn on or off the radiation source and can be useful alone. In Figure 4 there is also shown the carbon dioxide concentration curve 41 measured partly in the rest mode and partly in the operation mode just as explained when referring to Figure 3, the carbon dioxide concentration curve 40 measured in the operation mode and the plateau 43, too.

**[0041]** Also other signal sources can be used for decision making in the electronics board 26 whether to turn on and off the radiation source 13. If for example oxygen measuring device or similar is available oxygen concentration curve 47, as shown in Figure 5, is in 180° degree phase shift compared to the carbon dioxide gas concentration curve 40 measured in the operation mode as shown in Figure 5, too. This means that $CO_2$ will be at its maximum during expiration, but oxygen will be at its minimum. As oxygen is measured with another measurement technology than gases based on absorption of infrared radiation wave lengths, its signal can be used to turn on and off the radiation source to save electrical energy similarly as described previously with gas pressure and its derivative. This is the fact especially in case another oxygen measurement technology is using less energy than typical radiation source. Chemical oxygen sensors need less energy or can function without energy than sensors with the radiation source. Also the derivative of oxygen concentration curve 48 can be used by the electronics board to turn on and off the radiation source 13. The carbon dioxide concentration curve 41 in Figure 5 was measured partly in the rest mode and partly in the operation mode just as explained when referring to Figure 3 and 4.

**[0042]** The breathing gas measurements, such as pressure, flow or oxygen based on for example fuel cell or polarography technologies are less power consuming and thus they can be operated continuously without consuming too much supply energy from the energy storage device. It is also advantageous to use these measurements as signal sources to switch the more power consuming measurements between the normal operating mode and the rest mode, such as gas concentration measurement based on infrared radiation wavelengths or similarly the oxygen measurement based on fluorescence quenching that may be more power consuming measurement as well. The switching logic to operate for example the fluorescence quenching based oxygen measurement between the normal operating mode and the rest mode would be similar to that of gas concentration measurement at infrared radiation wavelengths, but with the phase shift of 180° compared to for example carbon dioxide. Thus the oxygen measurement indicative of the oxygen in the breathing gas can be switched between the operating mode and the rest mode based on the derivative of the oxygen concentration signal where in the rest mode the radiation source is not turned off, but it is adjusted to lower supply power to ensure continuous derivative of oxygen concentration for decision making of the mode. Similarly for example the breathing gas pressure and the flow, as described previously for the carbon dioxide, can be used to switch power supply modes, just noticing the 180° phase shift in regard to carbon dioxide.

**[0043]** The written description uses examples to disclose the invention, including the best mode, and also to enable any person skilled in the art to make and use the invention.

## Claims

**1.** A sensor for measuring a concentration of at least one respiratory gas component in a breathing gas, which concentration is varying during a breathing cycle having an inspiration phase, an expiration phase and a phase between the inspiration and expiration, said sensor comprising:

at least one radiation source (13, 19) for emitting radiation;
at least one radiation sensing detector (14, 20) for receiving radiation and for providing a signal indicative of the concentration of the at least one respiratory gas component;
an electronics board (26) for receiving and processing the signal from said at least one radiation sensing detector to determine the concentration of the at least one respiratory gas component; and
an energy storage device (22) for supplying energy to said at least one radiation source,
**characterized in that** said electronics board is configured to choose from among at least two different modes of energy supply to said at least one radiation source, one of the modes being an operation mode configured to allow sufficient energy supply to said at least one radiation source needed for subsequent concentration determination within at least one phase of the breathing cycle, and another of the modes being a rest mode configured to allow reduced energy supply to said at least one radiation source compared to said operation mode to limit radiation for saving energy of said energy storage device within the breathing cycle, wherein the electronics board is configured to turn on the radiation source by choosing the operation mode when a derivative of a concentration of the at least one respiratory gas component returns back to zero or close to zero after a positive peak, and the electronics board is configured to turn the radiation source into the rest mode when the derivative is less than zero.

**2.** The sensor according to claim 1, **characterized in that** said electronics board is configured to choose the operation mode when the phase of the breathing cycle includes one of at least part of the expiration and at least an end tidal volume of the expiration, and that said electronics board is configured to choose the rest mode within one of the inspiration phase and the phase between the inspiration and expiration.

**3.** The sensor according to claim 1, **characterized in that** said electronics board is configured to choose the rest mode within the expiration phase excluding a plateau period when an end tidal volume of the expiration exists in which case said electronics board is configured to choose the operation mode.

**4.** The sensor according to claim 1, **characterized in that** said electronics board is configured to choose the operation mode to measure end-tidal values of gas concentrations and also only a fraction of inspired values and to choose the rest mode during the rest of the time required by the breathing cycle, when reduced accuracy in concentration determination is acceptable, and that a time period, when the operation mode is valid, is shorter than a time period, when the rest mode is valid.

**5.** The sensor according to claim 1, further comprising at least one of a display (5) for showing breathing gas values measured, a user interface (6) to operate the sensor, radio frequency transceiver (24) to communicate with a host device (23), and another radiation source for emitting radiation with another radiation sensing detector for receiving radiation and for providing a signal indicative of the concentration of another respiratory gas component.

**6.** The sensor according to claim 1, **characterized in that** at least one respiratory gas component is one of carbon dioxide and oxygen and said at least one radiation source is emitting radiation towards the breathing gas to measure the concentration of one of carbon dioxide and oxygen.

**7.** The sensor according to claim 1, **characterized in that** in the rest mode when reduced energy is configured to be supplied to said at least one radiation source, the at least one radiation source is configured to be either turned off, in which case said electronics board is configured to pause energy supply to said at least one radiation source, or said at least one radiation source is configured to receive less energy than in said operation mode, but more than pausing energy supply, in which case said electronics board is configured to adjust energy supply to said at least one radiation source to a lower operating power.

**8.** The sensor according to claim 1, further comprising one of a pressure detector (28) configured to provide a signal indicative of the pressure of the breathing gas to said electronics board and a flow detector (27) configured to provide a signal indicative of the flow of the breathing gas to said electronics board, wherein choosing from among at least two different modes is based on a signal from one of said pressure detector and said flow detector.

**9.** The sensor according to claim 1, **characterized in that** choosing from among at least two different modes is based on a signal indicative of a concentration of another respiratory gas component than the one for which concentration is due to be determined.

**10.** The sensor according to claim 1, **characterized in that** said sensor is configured to be connectable to an airway adapter (3) having a sampling cell (11) configured to allow the breathing gas flow, at least one optical component (12) for guiding radiation, which optical component is in direct or indirect contact with the respiratory gas inside said sampling cell, a first port (7) configured to deliver respiratory gas to said sampling cell, and a second port (9) configured to remove respiratory gas from said sampling cell.

**11.** The sensor according to claim 1, **characterized by** comprising at least one of a pressure detector (28) and a flow detector (27), and the airway adapter also comprising at least one of a pressure measuring component (32) communicating with said pressure detector configured to provide a signal indicative of the pressure inside said airway adapter to said electronics board, and a flow measuring component (15) communicating with said flow detector configured to provide a signal indicative of the flow through said airway adapter to said electronics board.

**12.** A method for measuring a concentration of at least one respiratory gas component in a breathing gas, which concentration is varying during a breathing cycle having an inspiration phase, an expiration phase and a phase between the inspiration and expiration, said method comprising:

emitting radiation by means of at least one radiation source (13, 19) towards at least one optical component (12) in direct or indirect contact with the respiratory gas inside a sampling cell (11),
receiving the radiation by means of at least one radiation sensing detector (14, 20) and providing from said at least one radiation sensing detector a signal indicative of the concentration of the at least one respiratory gas component;

receiving the signal from said at least one radiation sensing detector and processing the signal in an electronics board (26) to determine the concentration of the at least one respiratory gas component; and

supplying energy from an energy storage device (22) to said at least one radiation source,

**characterized in that** the method also comprising choosing in said electronics board from among at least two different modes of energy supply to said at least one radiation source, one of the modes being an operation mode configured to allow sufficient energy supply to said at least one radiation source needed for subsequent concentration determination within at least one phase of the breathing cycle, and another of the modes being a rest mode configured to allow reduced energy supply to said at least one radiation source compared to said operation mode to limit radiation for saving energy of said energy storage device within the breathing cycle, wherein the electronics board is configured to turn on the radiation source by choosing the operation mode when a derivative of a concentration of the at least one respiratory gas component returns back to zero or close to zero after a positive peak, and the electronics board is configured to turn the radiation source into the rest mode when the derivative is less than zero.

**13.** The method according to claim 12, **characterized in that** choosing the rest mode within the expiration phase is configured to exclude a plateau period when an end tidal volume of the expiration exists, and that choosing the operation mode for the plateau period.

**14.** The method according to claim 12, **characterized in that** choosing the operation mode for measuring end-tidal values of gas concentrations and only a fraction of inspired values and choosing the rest mode for the rest of time required by the breathing cycle, and that a time period, when the operation mode is valid, is shorter than a time period, when the rest mode is valid.

## Patentansprüche

**1.** Sensor zum Messen einer Konzentration von mindestens einer Atemgaskomponente in einem Atemgas, wobei die Konzentration während des Atemzyklus variiert, der eine Einatmungsphase, eine Ausatmungsphase und eine Phase zwischen der Einatmung und der Ausatmung hat, wobei der Sensor umfasst:

mindestens eine Strahlungsquelle (13, 19) zum Emittieren von Strahlung;

mindestens einen Strahlungserfassungsdetektor (14, 20) zum Aufnehmen von Strahlung und zum Bereitstellen eines Signals, das auf die Konzentration der mindestens einen Atemgaskomponente schließen lässt;

eine Elektronikkarte (26) zum Aufnehmen und Verarbeiten des Signals von dem mindestens einen Strahlungserfassungsdetektor, um die Konzentration der mindestens eine Atemgaskomponente zu bestimmen; und

eine Energiespeichervorrichtung (22) zum Zuführen von Energie zu der mindestens einen Strahlungsquelle,

**dadurch gekennzeichnet, dass** die Elektronikkarte dafür ausgelegt ist, zwischen mindestens zwei verschiedenen Modi der Energieversorgung für die mindestens eine Strahlungsquelle zu wählen, wobei einer der Modi ein Betriebsmodus ist, der dafür ausgelegt ist, eine ausreichende Energieversorgung für die mindestens eine Strahlungsquelle zu ermöglichen, die für die nachfolgende Konzentrationsbestimmung innerhalb von mindestens einer Phase des Atemzyklus benötigt wird, und wobei ein weiterer der Modi ein Ruhemodus ist, der dafür ausgelegt ist, die reduzierte Energieversorgung für die mindestens eine Strahlungsquelle im Vergleich zum Betriebsmodus zu ermöglichen, um die Strahlung zum Sparen von Energie der Energiespeichervorrichtung innerhalb des Atemzyklus zu beschränken, wobei die Elektronikkarte dafür ausgelegt ist, die Strahlungsquelle durch Wählen des Betriebsmodus einzuschalten, wenn eine Ableitung einer Konzentration der mindestens einen Atemgaskomponente auf null oder auf nahe null nach einem positiven Peak zurückkehrt, und die Elektronikkarte ist dafür ausgelegt, die Strahlungsquelle in den Ruhemodus zu versetzen, wenn die Ableitung kleiner als null ist.

**2.** Sensor nach Anspruch 1, **dadurch gekennzeichnet, dass** die Elektronikkarte dafür ausgelegt ist, den Betriebsmodus zu wählen, wenn die Phase des Atemzyklus ein Element aus mindestens einem Teil der Ausatmung und mindestens ein Endatemzugsvolumen der Ausatmung enthält, und dass die Elektronikkarte dafür ausgelegt ist, den Ruhemodus in einer Phase aus der Einatmungsphase und der Phase zwischen der Einatmung und Ausatmung zu wählen.

**3.** Sensor nach Anspruch 1, **dadurch gekennzeichnet, dass** die Elektronikkarte dafür ausgelegt ist, den Ruhemodus innerhalb der Ausatmungsphase, unter Ausschluss einer Plateauphase, zu wählen, wenn ein Endatemzugsvolumen der Ausatmung existiert, in welchem Fall die Elektronikkarte dafür ausgelegt ist, den Betriebsmodus zu wählen.

4. Sensor nach Anspruch 1, **dadurch gekennzeichnet, dass** die Elektronikkarte dafür ausgelegt ist, den Betriebsmodus zum Messen von Werten von Gaskonzentrationen am Ende des Atemzugs und auch nur einen Bruchteil von eingeatmeten Werten zu wählen und den Ruhemodus während des Restes der Zeit zu wählen, der vom Atemzyklus benötigt wird, wenn eine reduzierte Genauigkeit in der Konzentrationsbestimmung akzeptabel ist, und dass ein Zeitabschnitt, wenn der Betriebsmodus valide ist, kürzer als ein Zeitabschnitt ist, wenn der Ruhemodus valide ist.

5. Sensor nach Anspruch 1, der ferner mindestens ein Element aus einem Display (5) zum Zeigen der Atemgaswerte, die gemessen wurden, einer Benutzerschnittstelle (6) zum Betreiben des Sensors, einen Hochfrequenz-Transceiver (24) zum Kommunizieren mit einer Host-Vorrichtung (23) und einer weiteren Strahlungsquelle zum Emittieren von Strahlung mit einem weiteren Strahlungserfassungsdetektor zum Aufnehmen von Strahlung und zum Bereitstellen eines Signals, das bezeichnend für die Konzentration einer weiteren Atemgaskomponente ist, umfasst.

6. Sensor nach Anspruch 1, **dadurch gekennzeichnet, dass** mindestens eine Atemgaskomponente eine aus Kohlendioxid und Sauerstoff ist und die mindestens eine Strahlungsquelle Strahlung zum Atemgas hin emittiert, um die Konzentration von einem aus Kohlendioxid und Sauerstoff zu messen.

7. Sensor nach Anspruch 1, **dadurch gekennzeichnet, dass** im Ruhemodus, wenn reduzierte Energie für die Zufuhr zu mindestens einer Strahlungsquelle ausgelegt ist, wobei die mindestens eine Strahlungsquelle entweder zum Abschalten ausgelegt ist, in welchen Fall die Elektronikkarte für das Pausieren der Energieversorgung für die mindestens eine Strahlungsquelle ausgelegt ist, oder die mindestens eine Strahlungsquelle zum Aufnehmen von weniger Energie als im Betriebsmodus ausgelegt ist, aber mehr als beim Pausieren der Energiezufuhr, in welchem Fall die Elektronikkarte zum Einstellen der Energiezufuhr zu mindestens einer Strahlungsquelle auf eine niedrigere Betriebsleistung ausgelegt ist.

8. Sensor nach Anspruch 1, der ferner ein Element aus einem Druckdetektor (28), der zum Bereitstellen eines Signals, das auf den Druck des Atemgases schließen lässt, für die Elektronikkarte ausgelegt ist, und einem Strömungsdetektor (27) umfasst, der zum Bereitstellen eines Signals ausgelegt ist, das auf den Strom des Atemgases zur Elektronikkarte schließen lässt, wobei das Wählen aus mindestens zwei verschiedenen Modi auf einem Signal von einem Element aus dem Druckdetektor und dem Strömungsdetektor beruht.

9. Sensor nach Anspruch 1, **dadurch gekennzeichnet, dass** das Auswählen aus mindestens zwei verschiedenen Modi auf einem Signal beruht, das auf eine Konzentration einer anderen Atemgaskomponente schließen lässt als der, für die die Konzentration aussteht.

10. Sensor nach Anspruch 1, **dadurch gekennzeichnet, dass** der Sensor mit einem Luftwegeadapter (3) verbunden werden kann, der eine Probenzelle (11), die den Atemgasstrom, zumindest eine optische Komponente (12), zum Führen der Strahlung ermöglicht, wobei die optische Komponente in direktem oder indirektem Kontakt mit dem Atemgas im Inneren der Probenzelle ist, einen ersten Port (7), der zum Zuführen von Atemgas zur Probenzelle ausgelegt ist, und einen zweiten Port (9), der zum Entfernen des Atemgases aus der Probenzelle ausgelegt ist, hat.

11. Sensor nach Anspruch 1, **gekennzeichnet dadurch, dass** er mindestens ein Element aus einem Druckdetektor (28) und einem Strömungsdetektor (27) umfasst, und der Luftwegeadapter umfasst ebenfalls mindestens ein Element aus einer Druckmesskomponente (32), die mit dem Druckdetektor kommuniziert, welche dafür ausgelegt ist, ein Signal, das auf diesen Druck innerhalb des Luftwegeadapters hinweist, für die Elektronikkarte bereitzustellen, und einer Strommesskomponente (15), die mit dem Stromdetektor kommuniziert, welcher dafür ausgelegt ist, ein Signal, das auf den Strom durch den Luftwegeadapter hinweist, an die Elektronikkarte zu liefern.

12. Verfahren zum Messen einer Konzentration von mindestens einer Atemgaskomponente in einem Atemgas, wobei die Konzentration während eines Atemzyklus variiert, der eine Einatmungsphase, eine Ausatmungsphase und eine Phase zwischen der Einatmung und der Ausatmung hat, wobei das Verfahren umfasst:

Emittieren von Strahlung mithilfe von mindestens einer Strahlungsquelle (13, 19) zu mindestens einer optischen Komponente (12) in direktem oder indirektem Kontakt mit dem Atemgas im Inneren einer Probenzelle (11),
Aufnehmen der Strahlung mithilfe von mindestens einem Strahlungserfassungsdetektor (14, 20) und, durch mindestens einen Strahlungserfassungsdetektor, Bereitstellen eines Signals, das auf die Konzentration der mindestens einen Atemgaskomponente schließen lässt;

Empfangen des Signals von dem mindestens einen Strahlungserfassungsdetektor und Verarbeiten des Signals in einer Elektronikkarte (26), um die Konzentration der mindestens einen Atemgaskomponente zu bestimmen; und Liefern von Energie von einer Energiespeichervorrichtung (22) an die mindestens eine Strahlungsquelle,
**dadurch gekennzeichnet, dass** das Verfahren auch das Wählen in der Elektronikkarte zwischen mindestens zwei verschiedenen Modi der Energieversorgung für die mindestens eine Strahlungsquelle umfasst, wobei einer der Modi ein Betriebsmodus ist, der dafür ausgelegt ist, eine ausreichende Energieversorgung für die mindestens eine Strahlungsquelle zu ermöglichen, die für die nachfolgende Konzentrationsbestimmung innerhalb von mindestens einer Phase des Atemzyklus benötigt wird, und wobei ein weiterer der Modi ein Ruhemodus ist, der dafür ausgelegt ist, die reduzierte Energieversorgung für die mindestens eine Strahlungsquelle im Vergleich zum Betriebsmodus zu ermöglichen, um die Strahlung zum Sparen von Energie der Energiespeichervorrichtung innerhalb des Atemzyklus zu beschränken, wobei die Elektronikkarte dafür ausgelegt ist, die Strahlungsquelle durch Wählen des Betriebsmodus einzuschalten, wenn eine Ableitung einer Konzentration der mindestens einen Atemgaskomponente auf null oder auf nahe null nach einem positiven Peak zurückkehrt, und die Elektronikkarte ist dafür ausgelegt, die Strahlungsquelle in den Ruhemodus zu versetzen, wenn die Ableitung kleiner als null ist.

**13.** Verfahren nach Anspruch 12,
**gekennzeichnet durch** das Wählen des Ruhemodus innerhalb der Ausatemphase, der dafür ausgelegt ist, eine Plateauperiode auszuschließen, wenn ein Endatemzugsvolumen vorhanden ist, und das Wählen des Betriebsmodus für die Plateauperiode.

**14.** Verfahren nach Anspruch 12,
**gekennzeichnet durch** das Wählen des Betriebsmodus zum Messen von Endatemzugswerten von Gaskonzentrationen und nur einem Bruchteil von Einatmungswerten und Wählen des Ruhemodus für den Rest der Zeit, die durch den Atemzyklus benötigt wird, und das ein Zeitabschnitt, wenn der Betriebsmodus valide ist, kürzer ist, als ein Zeitabschnitt, wenn der Ruhemodus valide ist.

## Revendications

**1.** Capteur pour mesurer une concentration d'au moins un composant de gaz respiratoire dans un gaz de respiration, laquelle concentration varie au cours d'un cycle de respiration ayant une phase d'inspiration, une phase d'expiration et une phase entre l'inspiration et l'expiration, ledit capteur comprenant :

au moins une source de rayonnement (13, 19) pour émettre un rayonnement ;
au moins un détecteur de rayonnement (14, 20) pour recevoir un rayonnement et fournir un signal indicatif de la concentration du au moins un composant de gaz respiratoire ;
une carte électronique (26) pour recevoir et traiter le signal venant du au moins un détecteur de rayonnement pour déterminer la concentration du au moins un composant de gaz respiratoire ; et
un dispositif de stockage d'énergie (22) pour fournir de l'énergie à ladite au moins une source de rayonnement,
**caractérisé en ce que** ladite carte électronique est configurée pour choisir parmi au moins deux modes différents de fourniture d'énergie à ladite au moins une source de rayonnement, l'un des modes étant un mode de fonctionnement configuré pour permettre une fourniture suffisante d'énergie à ladite au moins une source de rayonnement nécessaire pour une détermination ultérieure de la concentration dans au moins une phase du cycle de respiration, et un autre des modes étant un mode de repos configuré pour permettre une fourniture d'énergie réduite à ladite au moins une source de rayonnement en comparaison dudit mode de fonctionnement pour limiter le rayonnement afin d'économiser de l'énergie dudit dispositif de stockage d'énergie dans le cycle de respiration, dans lequel la carte électronique est configurée pour activer la source de rayonnement en choisissant le mode de fonctionnement lorsqu'une dérivée d'une concentration du au moins un composant de gaz respiratoire revient à zéro ou près de zéro après un pic positif, et la carte électronique est configurée pour placer la source de rayonnement en mode de repos lorsque la dérivée est inférieure à zéro.

**2.** Capteur selon la revendication 1, **caractérisé en ce que** ladite carte électronique est configurée pour choisir le mode de fonctionnement lorsque la phase du cycle de respiration comprend un(e) d'au moins une partie de l'expiration et d'au moins un volume de fin de l'expiration, et ladite carte électronique est configurée pour choisir le mode de repos dans l'une de la phase d'inspiration et de la phase entre l'inspiration et l'expiration.

**3.** Capteur selon la revendication 1, **caractérisé en ce que** ladite carte électronique est configurée pour choisir le mode de repos dans la phase d'expiration à l'exclusion d'une période de plateau lorsqu'un volume de fin de l'expiration existe, auquel cas ladite carte électronique est configurée pour choisir le mode de fonctionnement.

**4.** Capteur selon la revendication 1, **caractérisé en ce que** ladite carte électronique est configurée pour choisir le mode de fonctionnement afin de mesurer des valeurs de fin d'expiration de concentrations de gaz et également seulement une fraction de valeurs inspirées et pour choisir le mode de repos au cours du reste du temps requis par le cycle de respiration, lorsqu'une précision réduite de la détermination de la concentration est acceptable, et une période de temps, lorsque le mode de fonctionnement est valable, est plus courte qu'une période de temps lorsque le mode de repos est valable.

**5.** Capteur selon la revendication 1, comprenant en outre au moins l'un(e) d'un affichage (5) pour montrer des valeurs de gaz respiratoire mesurées, d'une interface utilisateur (6) pour faire fonctionner le capteur, d'un émetteur-récepteur de fréquence radio (24) pour communiquer avec un dispositif hôte (23) et d'une autre source de rayonnement pour émettre un rayonnement avec un autre détecteur de rayonnement pour recevoir un rayonnement et fournir un signal indicatif de la concentration d'un autre composant de gaz respiratoire.

**6.** Capteur selon la revendication 1, **caractérisé en ce qu'**au moins un composant de gaz respiratoire est l'un parmi le dioxyde de carbone et l'oxygène et ladite au moins une source de rayonnement émet un rayonnement vers le gaz de respiration pour mesurer la concentration de l'un parmi le dioxyde de carbone et l'oxygène.

**7.** Capteur selon la revendication 1, **caractérisé en ce que**, dans le mode de repos lorsque de l'énergie réduite est configurée pour être fournie à ladite au moins une source de rayonnement, la au moins une source de rayonnement est configurée pour être mise hors circuit, auquel cas ladite carte électronique est configurée pour pauser l'alimentation en énergie à ladite au moins une source de rayonnement, ou ladite au moins une source de rayonnement est configurée pour recevoir moins d'énergie que dans ledit mode de fonctionnement, mais plus que la fourniture d'énergie de pause, auquel cas ladite carte électronique est configurée pour ajuster la fourniture d'énergie à ladite au moins une source de rayonnement à une puissance de fonctionnement plus basse.

**8.** Capteur selon la revendication 1, comprenant en outre l'un d'un capteur de pression (28) configuré pour fournir un signal indicatif de la pression du gaz de respiration à ladite carte électronique et d'un détecteur de débit (27) configuré pour fournir un signal indicatif du débit de gaz de respiration à ladite carte électronique, dans lequel la sélection parmi au moins deux modes différents est basée sur un signal provenant d'un dudit détecteur de pression et dudit détecteur de débit.

**9.** Capteur selon la revendication 1, **caractérisé en ce que** la sélection parmi au moins deux modes différents est basée sur un signal indicatif d'une concentration d'un autre composant de gaz respiratoire que celui pour lequel la concentration doit être déterminée.

**10.** Capteur selon la revendication 1, **caractérisé en ce que** ledit capteur est configuré pour pouvoir être connecté à :

un adaptateur des voies aériennes (3) ayant une cellule d'échantillonnage (11) configurée pour permettre l'écoulement de gaz de respiration, au moins un composant optique (12) pour guider le rayonnement, lequel composant optique est en contact direct ou indirect avec le gaz respiratoire à l'intérieur de ladite cellule d'échantillonnage, un premier orifice (7) configuré pour délivrer du gaz respiratoire à ladite cellule d'échantillonnage et un second orifice (9) configuré pour retirer le gaz respiratoire de ladite cellule d'échantillonnage.

**11.** Capteur selon la revendication 1, **caractérisé en ce qu'**il comprend au moins l'un d'un détecteur de pression (28) et d'un détecteur de débit (27) et l'adaptateur des voies aériennes comprenant également au moins l'un d'un composant de mesure de pression (32) communiquant avec ledit détecteur de pression configuré pour fournir un signal indicatif de la pression à l'intérieur de l'adaptateur de voies aériennes à ladite carte électronique, et un composant de mesure de débit (15) communiquant avec ledit détecteur de débit configuré pour fournir un signal indicatif du débit à travers ledit adaptateur de voies aériennes à ladite carte électronique.

**12.** Procédé de mesure d'une concentration d'au moins un composant de gaz respiratoire dans un gaz de respiration, laquelle concentration varie au cours d'un cycle respiratoire ayant une phase d'inspiration, une phase d'expiration et une phase entre l'inspiration et l'expiration, ledit procédé comprenant :

l'émission d'un rayonnement au moyen d'une source de rayonnement (13, 19) vers au moins un composant optique (12) en contact direct ou indirect avec le gaz respiratoire à l'intérieur d'une cellule d'échantillonnage (11),

la réception du rayonnement au moyen d'un détecteur de détection de rayonnement (14, 20) et la fourniture à partir dudit au moins un détecteur de détection de rayonnement d'un signal indicatif de la concentration du au moins un composant de gaz respiratoire ;
la réception du signal dudit au moins un détecteur de détection de rayonnement et le traitement du signal dans une carte électronique (26) pour déterminer la concentration du au moins un composant de gaz respiratoire ; et
la fourniture d'énergie venant d'un dispositif de stockage d'énergie (22) à ladite au moins une source de rayonnement,
**caractérisé en ce que** le procédé comprend également la sélection dans ladite carte électronique parmi au moins deux modes différents de fourniture d'énergie à ladite au moins une source de rayonnement, l'un des modes étant un mode de fonctionnement configuré pour permettre une fourniture d'énergie suffisante à ladite au moins une source de rayonnement nécessaire pour une détermination ultérieure de la concentration dans au moins une phase du cycle de respiration, et un autre des modes étant un mode de repos configuré pour permettre une fourniture d'énergie réduite à ladite au moins une source de rayonnement en comparaison dudit mode de fonctionnement afin de limiter le rayonnement pour économiser de l'énergie dudit dispositif de stockage d'énergie dans le cycle de respiration, dans lequel la carte électronique est configurée pour activer la source de rayonnement en sélectionnant le mode de fonctionnement lorsqu'une dérivée d'une concentration du au moins un composant de gaz respiratoire retourne à zéro ou près de zéro après un pic positif et que la carte électronique est configurée pour placer la source de rayonnement dans le mode de repos lorsque la dérivée est inférieure à zéro.

**13.** Procédé selon la revendication 12,
**caractérisé en ce que** la sélection du mode de repos dans la phase expiratoire est configurée pour exclure une période de plateau lorsqu'un volume de fin de l'expiration existe et la sélection du mode de fonctionnement pendant la période de plateau.

**14.** Procédé selon la revendication 12,
**caractérisé en ce que** la sélection du mode de fonctionnement pour mesurer des valeurs de fin d'expiration de concentrations de gaz et uniquement une fraction de valeurs inspirées et la sélection du mode de repos pendant le reste du temps requis par le cycle de respiration et une période de temps, lorsque le mode de fonctionnement est valable, est plus courte qu'une période de temps lorsque le mode de repos est valable.

Figure 1

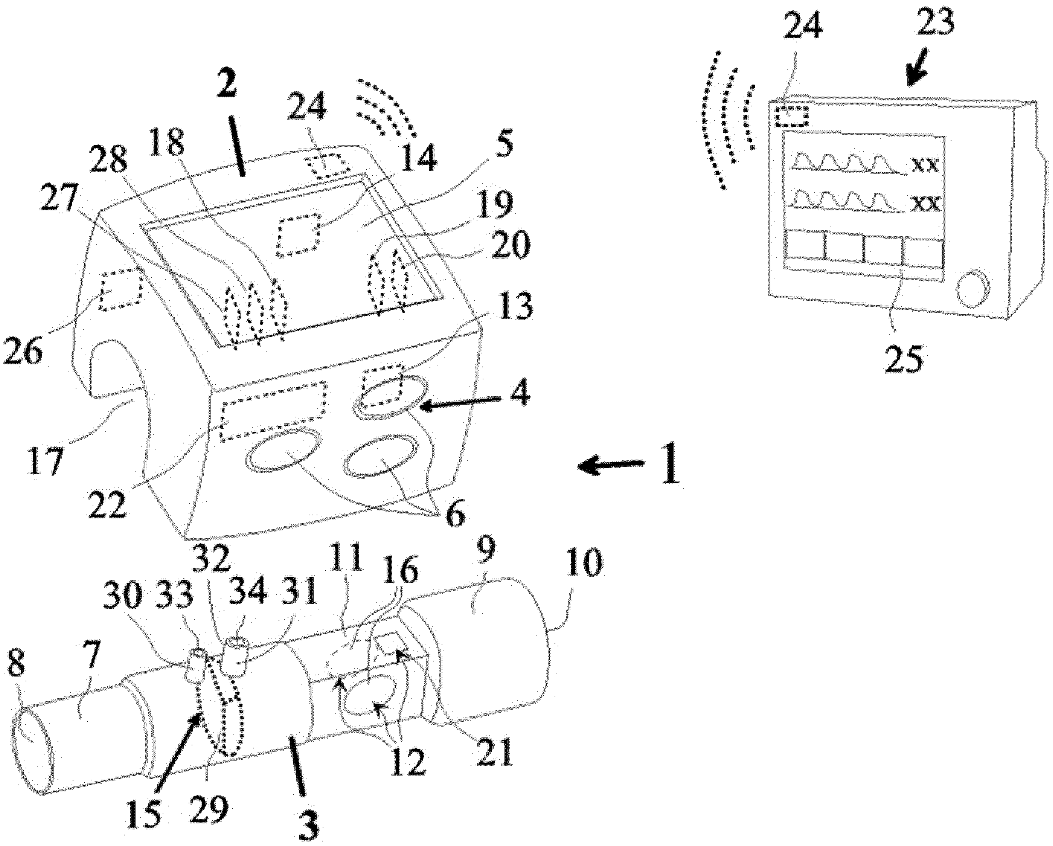



Figure 2

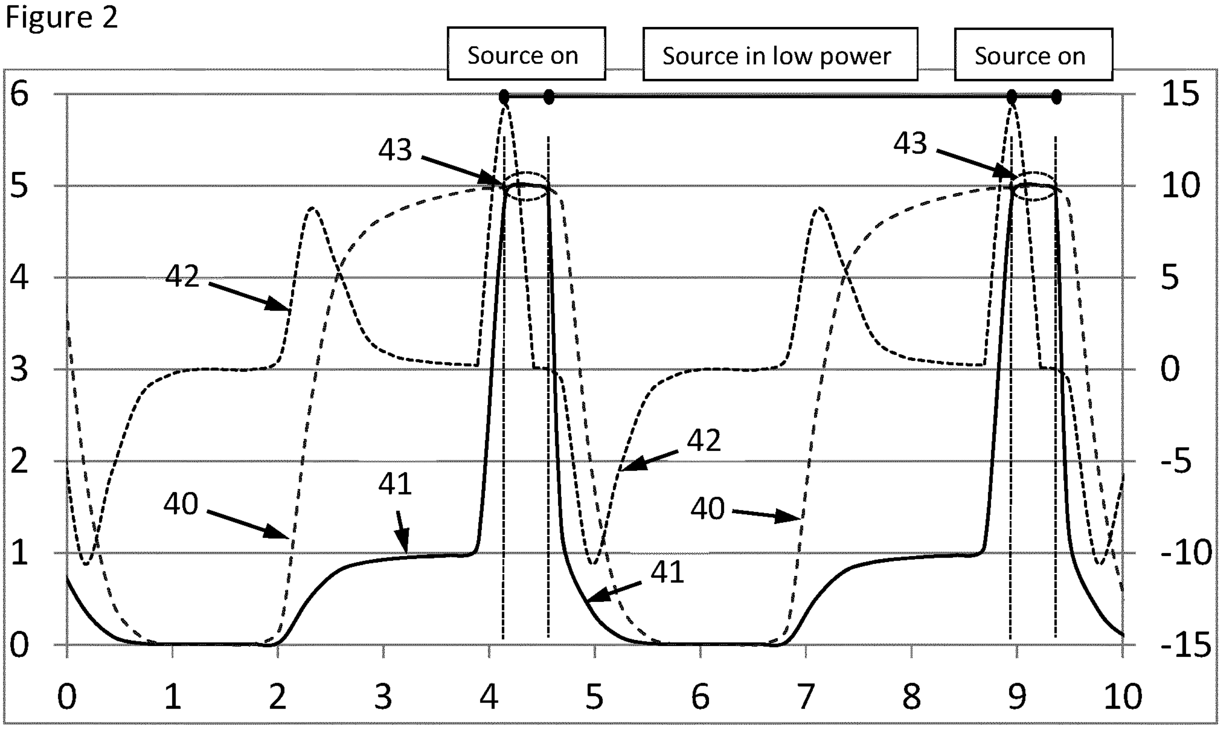


Figure 3

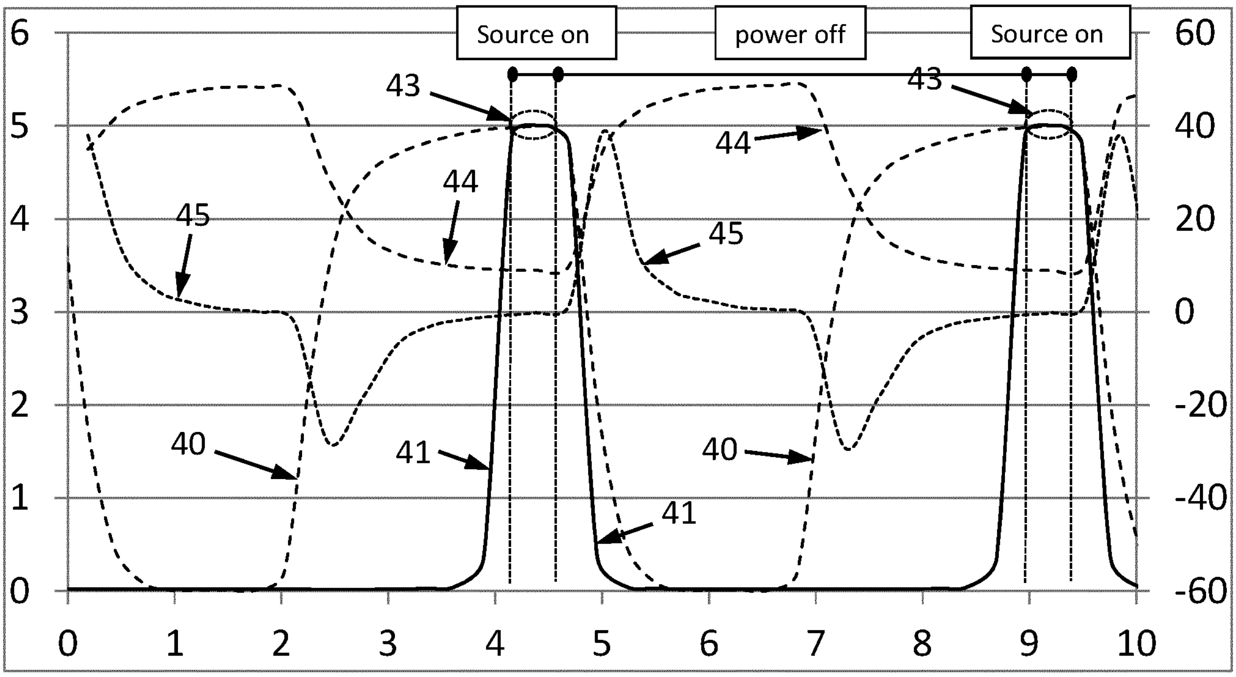



Figure 4

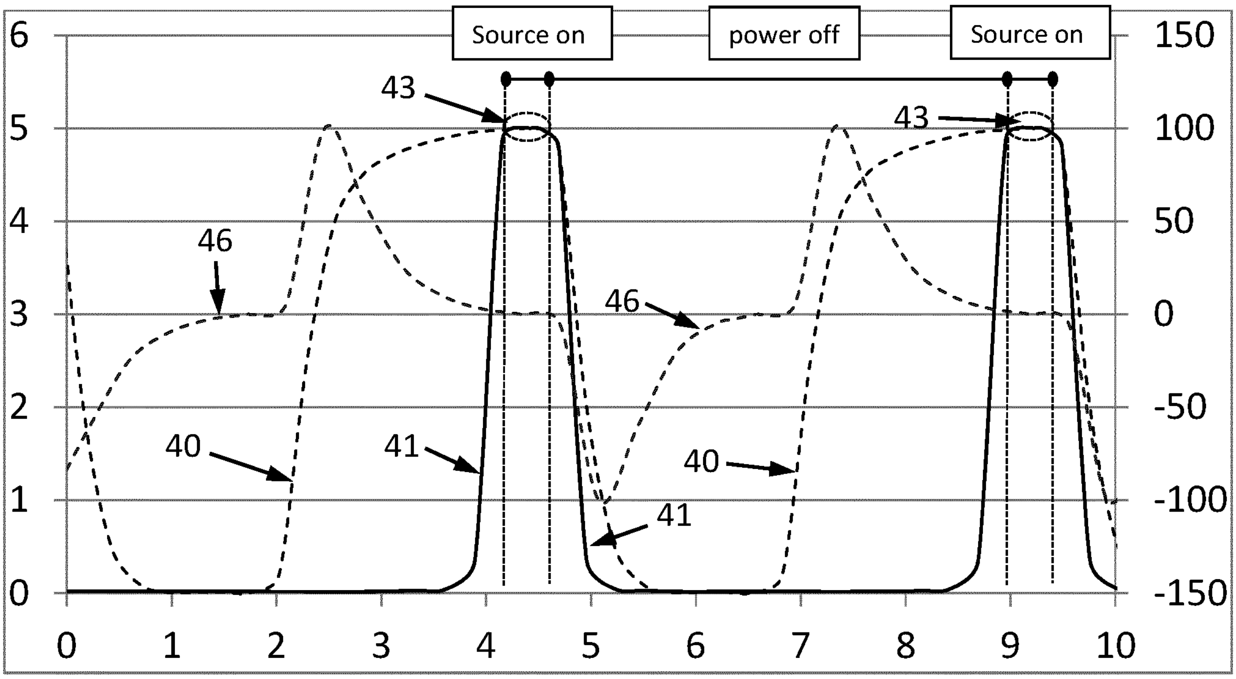
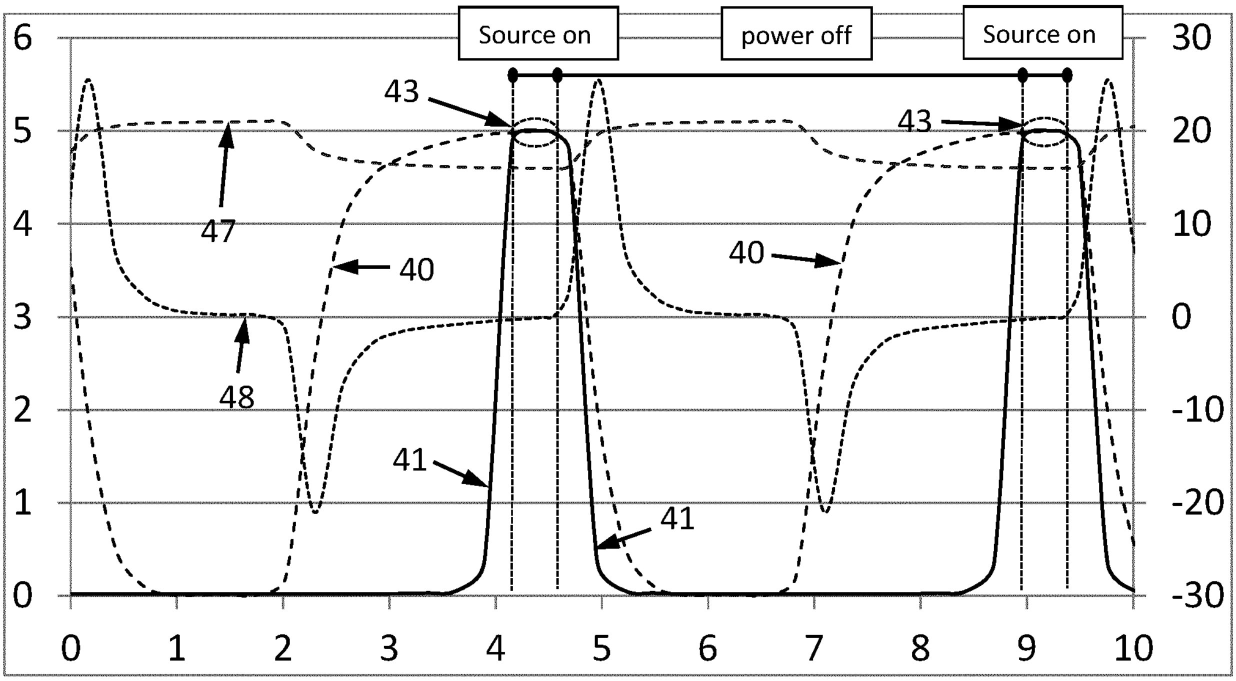


Figure 5


Source on
power off
Source on
43
43
47
40
40
48
41
41
6
5
4
3
2
1
0
30
20
10
0
-10
-20
-30
0
1
2
3
4
5
6
7
8
9
10

## REFERENCES CITED IN THE DESCRIPTION

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- EP 0733341 A **[0006]**
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- US 20090227887 A **[0009]**

| | |
|---|---|
| 专利名称(译) | 传感器，气体分析仪和测量至少一种呼吸气体组分浓度的方法 |
| 公开(公告)号 | EP2644094B1 |
| 公开(公告)日 | 2018-03-14 |
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| [标]申请(专利权)人(译) | 通用电气公司 |
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| 其他公开文献 | EP2644094A1 |
| 外部链接 | Espacenet |


摘要(译)

这里公开了一种用于测量呼吸气体成分浓度的传感器。该传感器包括用于发射辐射的至少一个辐射源（13,19）和用于接收辐射并且用于提供指示气体成分的浓度的信号的至少一个辐射感测检测器（14,20）。传感器还包括用于接收和处理信号以确定浓度的电子板（26）以及用于向辐射源供应能量的能量存储装置（22）。电子板可以从至少两种不同的模式中选择，一种是允许向辐射源提供足够的能量供应的操作模式，另一种是休眠模式，与操作模式相比，允许减少的能量供应，以限制辐射以节省能量呼吸循环。还提供了一种用于测量呼吸气体成分浓度的气体分析仪和方法。


Figure 1

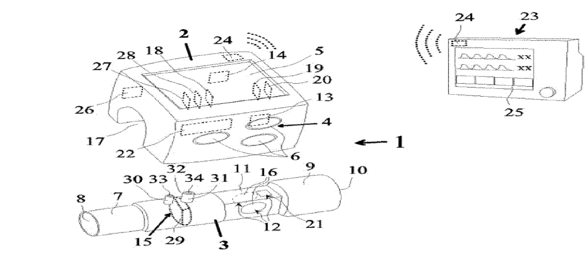

Figure 2