FILM BASED CARBON DIOXIDE SENSOR

BACKGROUND OF THE INVENTION

[0001] The embodiments herein generally relate to gas content sensors and more particularly to film based carbon dioxide sensors.

[0002] The detection of concentrations of gases in ambient air can provide various information regarding products or other items in an environment. Further, it may be desirable to maintain specific concentrations of gases in the ambient air of an environment in order to achieve beneficial, or non-detrimental, environmental impacts on products within the environment.

[0003] For example, increased carbon dioxide atmospheres are often used to help maintain the freshness of fruits, vegetables, ornamentals, and meat. If the CO_2 concentration is too low, the desired benefit may not be attained. Likewise, if the CO_2 concentration is too high, the product may be damaged. Thus, monitoring the levels of CO_2 in an environment is desirable. The concentration of CO_2 may be increased or decreased intentionally, and, in some cases, no increase in CO_2 over that of normal atmosphere may be desired or intended, i.e., maintaining the CO_2 levels at normal atmospheric levels. However, in the case of products that produce CO_2 from respiration, the CO_2 level may unintentionally increase, i.e., the concentration may accumulate to levels that may damage the products, such as fruits, vegetables, ornamentals, and meat, merely because of the natural CO_2 generation by the products.

[0004] Thus, detecting the concentrations of carbon dioxide may be beneficial to monitoring the status and quality of produce, fruits, vegetables, ornamentals, meats, and other perishable products ("products) in transport containers or in storage. As noted, the emission of CO_2 from these products can impact the state of the product. For example, during ripening conditions of products, such as bananas, emission of CO_2 from the product may increase the CO_2 concentration in the environment to undesirable levels. Similarly, microbial action in products during fermentation or spoilage may also generate CO_2 and may raise ambient concentrations in the environment to undesirable levels. Thus, measuring the CO_2 concentration present in an environment is desirable and allows the processes to be monitored non-invasively and in real-time, such that undesirable levels may be avoided.

[0005] Gas concentration sensors can be used to effectively measure the CO_2 content in the environment around the products in cold chain applications. Cold chain applications refer to refrigeration of foods, perishable items, and other products during transportation and

storage. For example, cold chain applications may include storage and/or transportation of products in refrigerated storage facilities, refrigerated transport vehicles (especially refrigerated marine containers), sealed pallets, sealed boxes, and sealed packages.

[0006] Current sensing devices on the market use sophisticated and expensive CO_2 sensors that are typically based on non-dispersive infrared technology. This technology is electro-mechanically sophisticated and expensive. The devices have long device life and provide very accurate readings and detections of the concentrations of gases. However, the precision and device life duration of these sensing devices is not required in cold chain applications, particularly in view of the high cost of the sensing devices.

BRIEF DESCRIPTION OF THE INVENTION

[0007] According to one embodiment, a gas concentration monitoring system is provided. The system includes a radiation source having one or more emitting elements configured to emit radiation and a radiation sensor having one or more sensing elements configured to detect radiation received at the radiation sensor from the radiation source. A reactive material is located between the radiation source and the radiation sensor and is configured to react to the presence of a gas, wherein the reaction of the reactive material impacts an amount of radiation detected at the radiation sensor.

[0008] In addition to one or more of the features described above, or as an alternative, further embodiments of the monitoring system may include an enclosure having one or more vents configured to permit ambient air to enter the enclosure, the enclosure configured to house the radiation source, the radiation sensor, and the reactive material.

[0009] In addition to one or more of the features described above, or as an alternative, further embodiments of the monitoring system may include that the reactive material is a carbon dioxide color-sensitive film.

[0010] In addition to one or more of the features described above, or as an alternative, further embodiments of the monitoring system may include that the radiation source comprises one or more LEDs.

[0011] In addition to one or more of the features described above, or as an alternative, further embodiments of the monitoring system may include that the impact on the amount of radiation detected at the radiation sensor is one of (i) decreasing the amount of radiation that is received at the radiation sensor and (ii) increasing the amount of radiation that is received at the radiation sensor.

[0012] In addition to one or more of the features described above, or as an alternative, further embodiments of the monitoring system may include a control circuit configured to at least one of (i) control the radiation source and (ii) receive information from the radiation sensor.

[0013] In addition to one or more of the features described above, or as an alternative, further embodiments of the monitoring system may include a data logger configured to at least one of (i) record data associated with the amount of radiation received at the radiation sensor and (ii) determine if an amount of radiation received at the radiation sensor is either above or below a threshold.

[0014] In addition to one or more of the features described above, or as an alternative, further embodiments of the monitoring system may include that the gas is carbon dioxide.

[0015] According to another embodiment, a gas concentration monitoring system is provided. The system includes a data logger, a radiation source having one or more emitting elements configured to emit radiation and a radiation sensor having one or more sensing elements configured to detect radiation received at the radiation sensor from the radiation source. A reactive material is located between the radiation source and the radiation sensor and is configured to react to the presence of a gas, wherein the reaction of the reactive material impacts an amount of radiation detected at the radiation sensor from the radiation source. In the system, the radiation sensor is in communication with the data logger, and the data logger is configured to at least one of (i) record data associated with the amount of radiation received at the radiation sensor and (ii) determine if an amount of radiation received at the radiation sensor is either above or below a threshold.

[0016] In addition to one or more of the features described above, or as an alternative, further embodiments of the monitoring system may include an enclosure having one or more vents configured to permit ambient air to enter the enclosure, the enclosure configured to house the radiation source, the radiation sensor, and the reactive material.

[0017] In addition to one or more of the features described above, or as an alternative, further embodiments of the monitoring system may include that the reactive material is a carbon dioxide color-sensitive film.

[0018] In addition to one or more of the features described above, or as an alternative, further embodiments of the monitoring system may include that the radiation source comprises one or more LEDs.

[0019] In addition to one or more of the features described above, or as an alternative, further embodiments of the monitoring system may include that the impact on the amount of

radiation detected at the radiation sensor is one of (i) decreasing the amount of radiation that is received at the radiation sensor and (ii) increasing the amount of radiation that is received at the radiation sensor.

[0020] In addition to one or more of the features described above, or as an alternative, further embodiments of the monitoring system may include a control circuit configured to at least one of (i) control the radiation source and (ii) receive information from the radiation sensor.

[0021] In addition to one or more of the features described above, or as an alternative, further embodiments of the monitoring system may include that the gas is carbon dioxide.

[0022] According to another embodiment, a method of monitoring a concentration of gas within an enclosure is provided. The method includes passing radiation through a reactive material, detecting the amount of radiation that passes through the reactive material, and determining a concentration of a gas based on the amount of radiation detected. The reactive material that the radiation passes through is configured to react to the presence of the gas, wherein the reaction of the reactive material impacts the amount of radiation that passes through the reactive material.

[0023] In addition to one or more of the features described above, or as an alternative, further embodiments of the method may include passing ambient air over the reactive material.

[0024] In addition to one or more of the features described above, or as an alternative, further embodiments of the method may include that wherein the gas is carbon dioxide.

[0025] In addition to one or more of the features described above, or as an alternative, further embodiments of the method may include that the radiation is at least one of visible light, ultraviolet radiation, and infrared radiation.

[0026] In addition to one or more of the features described above, or as an alternative, further embodiments of the method may include logging the determined concentration of gas with a data logger.

[0027] Technical effects of embodiments of the invention include providing a low cost, simple system and sensor to detect the presence and content levels of carbon dioxide in an environment.

BRIEF DESCRIPTION OF THE DRAWINGS

[0028] The subject matter which is regarded as the invention is particularly pointed out and distinctly claimed in the claims at the conclusion of the specification. The foregoing

and other features and advantages of the invention are apparent from the following detailed description taken in conjunction with the accompanying drawings in which:

[0029] FIG. 1 is a schematic illustration of a carbon dioxide sensor system in accordance with an exemplary embodiment of the invention; and

[0030] FIG. 2 is a flow chart of a process in accordance with an exemplary embodiment of the invention.

DETAILED DESCRIPTION OF THE INVENTION

[0031] As noted above, the monitoring and detection of carbon dioxide concentrations in cold chain applications assists in the monitoring of the quality of a product within cold chain applications. Cold chain applications include the transportation and storage of refrigerated, perishable products, such as produce and meats. With respect to fruits and vegetables, appropriate environmental concentrations of CO_2, e.g., within a shipping container, may range between 1% and 30%, depending on the specific product. Thus, it is important to monitor the levels of CO_2 to ensure that these appropriate levels are not exceeded, which may indicate that the food is approaching expiration or has expired.

[0032] Referring to FIG. 1, a gas concentration monitoring system 100 in accordance with an exemplary embodiment of the invention is shown. The monitoring system 100 may be located within a container that is used for the transportation or storage of perishable products. For example, the container may be a refrigerated shipping container, a storage room, or a transportation vehicle. Further, in some embodiments, the monitoring system 100 may be located within the packaging of products or within a pallet that is used for transporting products.

[0033] The monitoring system 100 includes a sensor enclosure 102 that is configured to house various component parts of the monitoring system 100 and is exposed to ambient air (air external to the enclosure 102) through air vents 103. The air vents 103 allow for ambient air to flow and pass into and through the enclosure 102 such that the flowing ambient air interacts with sensing components of the monitoring system 100.

[0034] The sensing components of the monitoring system 100 include a radiation source 104, a radiation sensor 106, and a reactive material 108 located between the radiation source 104 and the radiation sensor 106. The radiation source 104 and the radiation sensor 106 are electrically connected to control circuity 110. The control circuitry 110 is configured to control and send commands to the radiation source 104 and receive and/or process information received from the radiation sensor 106.

[0035] The radiation source 104, for example, is configured as a pulse modulated single or multi-color LED that emits radiation in one or more spectra. The radiation source 104 is configured to emit radiation toward the radiation sensor 106. Those skilled in the art will appreciate that various electromagnetic radiation sources may be used without departing from the scope of the invention. For example, radiation sources may include sources of visible light radiation, ultraviolet radiation, infrared radiation, and/or combinations of these or other radiation spectra. As such, the radiation source 104 may be any type of radiation source known or will become known without departing from the scope of the invention.

[0036] Based on the type of radiation source 104 (and associated emitted radiation), the radiation sensor 106 is configured to detect radiation of the type generated by the radiation source 104. For example, the radiation sensor 106 may be a single radiation sensor element or an array of radiation sensors configured in parallel to detect the wavelength(s) and energy of the radiation emitted by the radiation source 104. In this embodiment, the radiation sensor 106 is configured to detect or measure the amount of radiation that is received at the elements of the radiation sensor 106 based on the energy received at the sensor elements. The sensor 106 will then output an analog or digital signal that is sent to the control circuitry 110 for further processing. In some embodiments, the radiation sensor 106 consists of multiple sensing elements configured in parallel that are individually sensitive to specific, different wavelengths or, in other embodiments, the radiation sensor 106 may consist of multiple elements that are sensitive to the same wavelength. Further, in some embodiments, the radiation sensor 106 may include only one sensing element. Thus, those skilled in the art will appreciate that the number of sensing elements is variable.

[0037] The reactive material 108 located between the radiation source 104 and the radiation sensor 106 is configured to affect the amount of radiation (and energy) that passes therethrough and reaches the sensor 106. For example, the reactive material 108 is configured to react to the presence of a gas in the ambient air, such as CO_2, and change or alter such that the amount of radiation that passes through the reactive material 108 is changed (either increased or decreased) relative to when no CO_2 or a baseline concentration of CO_2 is present. The change in received radiation at the radiation sensor 106 may be directly proportional to the change in the amount or concentration of CO_2 present in the enclosure 102. Thus, the concentration of a gas, such as CO_2, may be effectively and efficiently monitored and is indicative of the CO_2 concentration within the environment within which the monitoring system 100 is located.

[0038] The reactive material 108 may be a plastic, composite, glass, or other material that is inherently reactive to the presence of certain gas(es), such as CO_2, or may be formed of material that is combined with dyes, inks, pigments, or other compounds and/or materials to make a resultant material that is reactive to the presence of certain gas(es), such as CO_2. In some embodiments, the reactive material 108 may be configured to be transparent when there is no CO_2 present, when in the presence of atmospheric concentrations of CO_2, or when some predetermined concentration, threshold concentration, known concentration, or baseline concentration of CO_2 is present. Then, as the CO_2 concentration increases in the ambient air, the reactive material 108 will become opaque or change color, for example, and further transition to higher levels of opacity as the CO_2 concentration increases in the ambient air. Thus, the amount of radiation that passes through the reactive material 108 will lessen due to the absorption of the radiation by the opaque reactive material 108. As a result, the amount of radiation that reaches and is detected at the radiation sensor 106 will decrease and can be used to indicate changes in CO_2 concentrations.

[0039] As the color or opacity of the reactive material 108 changes, the reactive material 108 will absorb more of the radiation transmitted by the radiation source 104, thus decreasing the amount of radiation or energy received and detected by the radiation sensor 106. In other exemplary embodiments, the reactive material 108, as it reacts to the presence of CO_2, may instead reflect a greater portion of the radiation that is incident to the reactive material 108, or may disperse, or provide other impacts on the radiation that is transmitted from the radiation source 104, thus reducing the amount of energy received or detected by the radiation sensor 106. In these exemplary configurations, an increase in the presence of CO_2 will reduce the amount of energy received by the radiation sensor 106.

[0040] In some such embodiments, the reactive material 108 may be configured as a color changing film. In this embodiment, in the presence of CO_2, the color changing film (reactive material 108) will change color or change the opacity of a color. The color or opacity changing of the reactive material 108 may be a result of direct contact or interaction with CO_2 or may be due to an indirect interaction, such as pH levels of the moisture content in the ambient air that flows through the enclosure 102. The color of the color changing film is configured to match the radiation source 104 so that changes in the color changing film affect the amount of radiation that reaches radiation sensor 106.

[0041] In alternative embodiments, the reactive material 108 may operate in the opposite manner. For example, the reactive material 108 may be an opaque color when the concentration of CO_2 is low, and may become more transparent as the CO_2 concentration

increases. In this configuration, the amount of energy or radiation detected by radiation sensor 106 will increase as the CO_2 concentration increases.

[0042] In accordance with embodiments of the invention, the change in detected radiation or energy by the radiation sensor 106 is indicative of the concentration of CO_2, or indicative of a change (a delta) in the concentration of CO_2, that is present within the sensor enclosure 102 and thus representative of the CO_2 content in the environment in which monitoring system 100 is located. As an example, the sensitivity of detecting the concentration of CO_2 may be to an accuracy of ±0.5% concentration within the range of 1% to 30% concentration of CO_2 in the ambient air. Thus, the monitoring system 100 can monitor the concentrations and/or changes in the concentrations of CO_2 to an adequate degree. Such accuracy is sufficient for the purpose of cold chain applications.

[0043] In the monitoring system 100, the detected radiation or energy at the sensor 106 may be converted from an analog signal to a digital signal. Or, in the case of an array or plurality of sensors, the detected signals may be summed and then converted to a digital signal. In either case, an analog-to-digital converter is provided within the system and may be part of the radiation sensor 106, part of the control circuitry 110, or part of some other connected and/or associated system or device. The digital signal may then be processed, recorded, and/or analyzed.

[0044] The control circuitry 110, as noted above, is in electrical communication with the radiation source 104 and the radiation sensor 106. The control circuitry 110 is configured to control the radiation source 104 to emit radiation upon command, which in some embodiments may allow for ON and OFF states of the radiation source 104. The ON/OFF states may be used to conserve power and/or enable data collection only when desired, without a continuous source of radiation. Further, as noted above, the control circuitry 110 may include the A/D converter to convert an analog signal received from the radiation sensor 106 to a digital signal for processing. As shown, the control circuitry 110 is located and/or housed within the enclosure 102. However, this is merely presented for exemplary purposes and those skilled in the art will appreciate that the control circuitry may be configured outside of the enclosure 102 and/or may be configured as part of a larger or more comprehensive computing device (e.g., a data logger 116 discussed below). Further, in some embodiments the digital signal may be a digital timing signal with frequency, voltage changes, pulse width output, or other outputs known or that will become known.

[0045] The control circuitry 110, as shown in FIG. 1, is further connected to a data interface 112 and a power source 114. The power source 114 may be a battery or other

electrical power source known in the art, and may be configured to provide power to the monitoring system 100 and may also provide power to the data logger 116 and/or other electrical equipment.

[0046] The data interface 112 is configured to enable communication between the control circuitry 110 and other components, such as a data logger 116. The data logger 116 may include a central processing unit and volatile and non-volatile memory for data processing, data logging, control of alert and notification systems, input/output functions, etc. In some embodiments, the data logger 116 is configured as a data logging system which incorporates the monitoring system 100 along with other types of sensors and monitoring devices, such as humidity sensors, temperature sensors, etc.

[0047] The data logger 116 or other processing component can process and log the information collected at the radiation sensor 106 in order to monitor the CO_2 levels in the ambient air surrounding the monitoring system 100. The data logger 116 may be configured to monitor for specific percentage levels of CO_2 concentrations and/or monitor for a threshold level being surpassed in the ambient air. For example, if a threshold level is exceeded, it may indicate that the monitored products that are generating the CO_2 have reached a level that begins to indicate, for example, spoilage. In this case, the food may not have spoiled, but a particular threshold may indicate a level at which spoilage may become a concern. As such, the data logger 116 may monitor a time elapsed since the threshold has been exceeded. The monitored time may then be used to indicate if the product has reached or exceeded unacceptable levels or standards for the particular product.

[0048] Turning now to FIG. 2, a flow chart of an exemplary process 200 is shown. As a first step 202, radiation is provided in an environment from a radiation source, such as an LED. The radiation is configured to pass through a reactive material at step 204 and be received or detected at a radiation sensor in step 206. The reactive material employed at step 204 is a color changing material such as described above with respect to reactive material 108 and the sensor is configured to detect the type of radiation transmitted by the radiation source. The sensor will detect or receive an amount of energy based on the amount of radiation that passes through the reactive material. An analog signal representative of the amount of energy detected at the sensor will then be converted to a digital signal at step 208 which will then be processed at step 210. The processing of the digital signal at step 210 may include logging the digital signal as a form of data and/or determining if the level of energy detected exceeds or is below a predetermined threshold. If the threshold is passed, either above or below

depending on the configuration, a clock may start and/or an alarm or alert may be issued to indicate that the threshold has been passed.

[0049] Advantageously, embodiments of the invention provide a low cost CO_2 sensor that can affordably and effective be used in cold chain applications. A CO_2 sensor device or system, as disclosed herein, functions at adequate resolutions for cold chain applications, and thus provides a low cost alternative to overly accurate and expensive devices. Further, the sensor devices disclosed herein provide a single-use sensor that may be usable to monitor CO_2 levels over the course of weeks, and then be discarded. However, such configuration is advantageous because the cost is significantly low, particularly compared to high cost, precise, and long duration (order of years) sensors.

[0050] While the invention has been described in detail in connection with only a limited number of embodiments, it should be readily understood that the invention is not limited to such disclosed embodiments. Rather, the invention can be modified to incorporate any number of variations, alterations, substitutions, combination, sub-combination, or equivalent arrangements not heretofore described, but which are commensurate with the spirit and scope of the invention. Additionally, while various embodiments of the invention have been described, it is to be understood that aspects of the invention may include only some of the described embodiments.

[0051] For example, although described herein as a reactive material located between a radiation source and a radiation sensor and thus transparent, in alternative embodiments, the same concepts may be applied to reflective materials, wherein the reflective properties of the reactive material changes based on the concentration of CO_2. In such embodiments, the sensor may be appropriately located and/or configured within the enclosure of the system. Moreover, in some embodiments, the reactive material may be directly coated onto the surface of the radiation sensor, such that, with reference to FIG. 1, elements 106 and 108 comprise a single element. Alternatively, the reactive material may be coated onto the surface or exterior of the radiation source, such that elements 104 and 108 are combined to form a single element. Thus, the configuration of FIG. 1 is merely presented for exemplary and explanatory purposes and does not limit the scope of the invention.

[0052] Further, although described with respect to the detection and monitoring of carbon dioxide, those skilled in the art will appreciate that the reactive material described herein may be configured to detect and/or react to the presence of other gases, compounds, and/or fluids, and thus the invention is not merely limited to detecting and monitoring carbon dioxide. Furthermore, in line with this, although described with respect to application within

cold chain applications, those skilled in the art will appreciate that the claimed monitoring systems and methods may be used in other applications for the detection and monitoring of gases, or other fluids, in an environment.

[0053] Further, for example, the control circuitry and/or data logger disclosed above has been described as physically connected with the sensor components. However, those of skill in the art will appreciate that wireless communication may be used to provide the communication between the various components of the devices. Moreover, although described as separate elements, the sensor, the control circuitry, and the data logger may all, or some sub-combination thereof, be formed as a single unit.

[0054] Accordingly, the invention is not to be seen as limited by the foregoing description, but is only limited by the scope of the appended claims.

CLAIMS:

1. A gas concentration monitoring system comprising:

a radiation source comprising one or more emitting elements configured to emit radiation at different wavelengths;

a radiation sensor comprising a plurality of sensing elements configured to detect radiation received at the radiation sensor from the radiation source;

a reactive material located between the radiation source and the radiation sensor and configured to react to the presence of a gas, wherein the reaction of the reactive material impacts an amount of radiation detected at the radiation sensor,

characterized in that the plurality of sensing elements are arranged as an array, wherein the sensing elements are arranged in parallel to detect the different wavelengths as emitted by the radiation source,

an analog-to-digital converter operably connected to the radiation sensor, the analog-to-digital converter configured to sum and convert a signal received at the radiation sensor; and

an enclosure having one or more vents configured to permit ambient air to enter the enclosure, the enclosure configured to house the radiation source, the radiation sensor, and the reactive material.

2. The monitoring system of any of the preceding claims, wherein the reactive material is a carbon dioxide color-sensitive film.

3. The monitoring system of any of the preceding claims, wherein the radiation source comprises one or more LEDs.

4. The monitoring system of any of the preceding claims, wherein the impact on the amount of radiation detected at the radiation sensor is one of (i) decreasing the amount of radiation that is received at the radiation sensor and (ii) increasing the amount of radiation that is received at the radiation sensor.

5. The monitoring system of any of the preceding claims, further comprising a control circuit configured to at least one of (i) control the radiation source and (ii) receive information from the radiation sensor.

6. The monitoring system of any of the preceding claims, further comprising a data logger configured to at least one of (i) record data associated with the amount of radiation received at the radiation sensor and (ii) determine if an amount of radiation received at the radiation sensor is either above or below a threshold.

7. The monitoring system of any of the preceding claims, wherein the gas is carbon dioxide.

8. A gas concentration monitoring system comprising:

a data logger;

a radiation source comprising one or more emitting elements configured to emit radiation at different wavelengths;

a radiation sensor comprising a plurality of sensing elements configured to detect radiation received at the radiation sensor from the radiation source, the plurality of sensing elements arranged as an array, wherein the sensing elements are arranged in parallel to detect the different wavelengths as emitted by the radiation source; and

a reactive material located between the radiation source and the radiation sensor and configured to react to the presence of a gas, wherein the reaction of the reactive material impacts an amount of radiation detected at the radiation sensor,

an analog-to-digital converter operably connected to the radiation sensor, the analog-to-digital converter configured to sum and convert a signal received at the radiation sensor; and

an enclosure having one or more vents configured to permit ambient air to enter the enclosure, the enclosure configured to house the radiation source, the radiation sensor, and the reactive material,

wherein the radiation sensor is in communication with the data logger, and the data logger is configured to at least one of (i) record data associated with the amount of radiation received at the radiation sensor and (ii) determine if an amount of radiation received at the radiation sensor is either above or below a threshold.

9. The monitoring system of claim 8, wherein the reactive material is a carbon dioxide color-sensitive film.

10. The monitoring system of any of claims 8-9, wherein the radiation source comprises one or more LEDs.

11. The monitoring system of any of claims 8-10, wherein the impact on the amount of radiation detected at the radiation sensor is one of (i) decreasing the amount of radiation that is received at the radiation sensor and (ii) increasing the amount of radiation that is received at the radiation sensor.

12. The monitoring system of any of claims 8-11, further comprising a control circuit configured to at least one of (i) control the radiation source and (ii) receive information from the radiation sensor.

13. The monitoring system of any of claims 9-12, wherein the gas is carbon dioxide.

14. A method of monitoring a concentration of gas within an enclosure, the method comprising:

controlling a radiation source to transmit radiation at different wavelengths;

passing the transmitted radiation through a reactive material;

detecting the amount of radiation that passes through the reactive material with a plurality of sensing elements that are arranged as an array, wherein the sensing elements are arranged in parallel to detect the different wavelengths as emitted by the radiation source;

summing and converting the detected amount of radiation received at the arrange of sensing elements, and

determining a concentration of a gas based on the amount of radiation detected at the different wavelengths,

wherein the reactive material is configured to react to the presence of the gas, wherein the reaction of the reactive material impacts the amount of radiation at different wavelengths that passes through the reactive material.

15. The method of claim 14, further comprising passing ambient air over the reactive material.

16. The method of any of claims 14-15, wherein the gas is carbon dioxide.

17. The method of any of claims 14-16, wherein the radiation is at least one of visible light, ultraviolet radiation, and infrared radiation.

18. The method of any of claims 14-17, further comprising logging the determined concentration of gas with a data logger.