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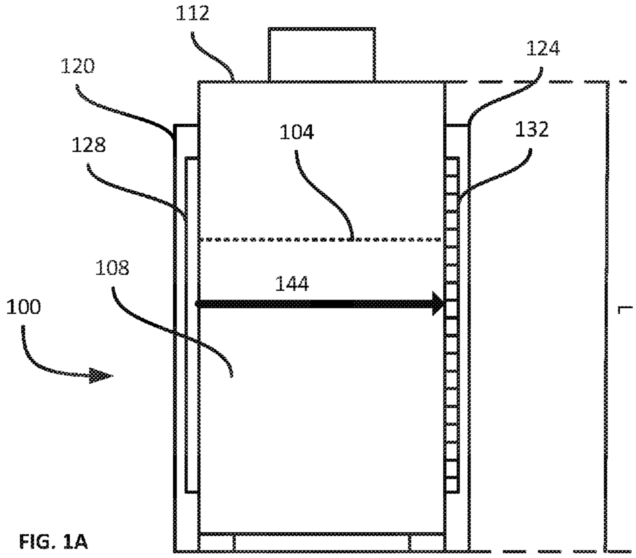

FIG. 1A

(57) Abstract: A label for determining a level of a substance in a container, the label comprising: a substrate configured to conform to the container, the substrate having: a first section supporting a light emitter configured to emit light into the container; and a second section supporting a light detector configured to detect the emitted light; and a processor connected to the detector, the processor configured to determine the level of the substance based on the detected light.

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LABEL FOR DETERMINING A LEVEL OF A SUBSTANCE IN A CONTAINER

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] This application claims priority from US application no. 63/545002, filed on October 20, 2023, entitled LABEL FOR DETERMINING A LEVEL OF A SUBSTANCE IN A CONTAINER, the contents of which are incorporated herein by reference.

FIELD

[0002] The specification relates generally to devices for determining a substance level, and specifically to devices for determining a substance level through optical means.

BACKGROUND

[0003] Detection of liquid level in a container is used for a variety of applications. In the medication adherence field, existing commercial technologies for medication administration and dosage detection rely on monitoring cap opening, and do not detect and report liquid level in medicine containers.

SUMMARY

[0004] An aspect of the specification provides a label for determining a level of a substance in a container, the label comprising: a substrate configured to conform to the container, the substrate having: a first section supporting a light emitter configured to emit light into the container; and a second section supporting a light detector configured to detect the emitted light; and a processor connected to the detector, the processor configured to determine the level of the substance based on the detected light.

[0005] Another aspect of the specification provides a method of determining a level of a substance in a container, the method comprising: emitting light through the container; detecting the emitted light by a photodetector array, the photodetector array extending along a length of the container; determining the level of the substance by identifying a position along the photodetector array with a maximum change in the detected light; and outputting the level of the substance.

[0006] Yet, another aspect of the specification provides a system comprising: a container; a light emitter configured to emit light through the container; a conformable substrate affixed to the container, the substrate supporting a photodetector array extending along a length of the container, the photodetector array configured to detect the emitted light; and a processor connected to the photodetector array, the processor configured to determine a level of a substance in the container based on the detected light.

BRIEF DESCRIPTIONS OF THE DRAWINGS

[0007] Embodiments are described with reference to the following figures:

[0008] FIG. 1A. depicts a cross-section view of an example container with an example label for determining a level of a substance in a container conformed and affixed to an example container.

[0009] FIG. 1B depicts a top view of the example label of FIG. 1A extended and laid flat.

[0010] FIG. 2 depicts a flowchart of an example method of determining a level of a substance in a container.

[0011] FIG. 3 depicts a flowchart of an example method of calibrating an example label to a substance in a container.

[0012] FIG. 4 depicts a flowchart of an example method for synchronizing a light detection signal of the to a light emission signal.

[0013] FIG. 5A depicts a cross-section view of the example label of FIGS. 1A and 1B affixed to the example container of FIG. 1A with an emitter emitting light through the container towards a detector.

[0014] FIG. 5B depicts a diagram showing an example graph of light measurements made by the detector of FIG. 4A.

[0015] FIGS. 6A, 6B and 6C depict cross-section views of an example container with a suspension stable substance, a sedimented substance, and a creamed substance, respectively.

[0016] FIGS. 6D, 6E, and 6F depict diagrams showing example graphs of light measurements of the substance of FIGS. 6A, 6B, and 6C, respectively.

[0017] FIG. 7A depicts a top view of an example label extended and laid flat with a light blocking section.

[0018] FIG. 7B depicts a cross-section view of an example container with the example label of FIG. 7A conformed and affixed to the example container.

[0019] FIG. 8A depicts a top view of an example label extended and laid flat with detachable sections.

[0020] FIGS. 8B and 8C depict the example label of FIG. 8A being adjusted to an example container.

[0021] FIG. 9A depicts a top view of an example label extended and laid flat with a light emitter and a light detector at opposite ends of a rectangular conformable substrate.

[0022] FIG. 9B depicts a cross-section view of an example container with the example label of FIG. 9A conformed and affixed to the example container.

DETAILED DESCRIPTION

[0023] A commercially viable system to automatically measure and report levels of substances in containers would be highly beneficial in a variety of applications, for example, in medication adherence programs. The example embodiments hereinafter explained in detail with reference to the drawings describe conformable labels comprising optical sensors that may be used to determine the level of a substance in containers.

[0024] FIG. 1A depicts an example label 100 for determining a level 104 of a substance 108 in a container 112. For example, the container 112 may be a medicine vial containing a liquid medication, and the label 100 may be applied to the container 112 to determine the amount of the liquid medication remaining in the container. In other examples, the label 100 may be applied to other suitable containers containing other types of substances.

[0025] The label 100 may employ optical sensors to determine the level 104 of the substance 108 in the container 112. The material forming the container 112 may therefore be transparent, translucent, or partially translucent.

[0026] Different containers 112 may be of varying shapes and sizes, including substantially cylindrical shapes, having a substantially elliptical cross section, varying axial lengths and radii, and the like. Accordingly, the label 100 may be configured to conform to the container 112 to enable the label 100 to be used with a variety of different types of containers 112. In particular, the label 100 comprises a conformable substrate 116 to allow the label 100 to conform to the shape of the container 112. In some examples, the entirety of the substrate 116 may be conformable, while in other examples, select portions of the substrate 116 may be conformable, for example to allow the label 100 to wrap from a base of the container 112 and along the length of the container 112. The conformable substrate 116 may be formed of any flexible material such as a polymer, cellulose, a metal sheet, paper-based materials, combinations thereof, and the like. The conformable substrate 116 may also be formed as a laminate material of more than one layer.

[0027] In particular, the conformable substrate 116 has a first section 120 and a second section 124 configured to extend along an axial length L of at the exterior of the wall of the container 112. The first section 120 and the second section 124 may be formed as wings extending from a central section of the conformable substrate 116, and hence are referred to herein as the first wing section 120 and the second wing section 124. In other examples, the first and second sections 120 and 124 may be otherwise configured to conform to the container 112. In addition to wrapping from the base of the container 112 to the wall, the wing sections 120 and 124 may be flexed or bent to conform to the curvature or other contours of the wall of the container 112.

[0028] The conformable substrate 116 may further include an adhesive layer to adhere the label 100 to the exterior of the container 112.

[0029] The first wing section 120 supports a light emitter 128 configured to emit light 144 into the container 112 and the second wing section supports a light detector 132 configured to detect the emitted light 144. The light detected by the light detector 132 may be analyzed to determine the level 104 of the substance 108 in the container 112. In the example shown in FIG. 1A the emitter 128 and the detector 132 are oriented towards each other and the emitted light 144 travels directly from the emitter 128 to the detector 132 through the container 112. In other examples, the detector 132 may detect emitted light 144 emitted into the container and reflected off an interior of the container 112, a reflective surface, or the like.

[0030] FIG. 1B depicts a top view of the label 100 extended and laid flat.

[0031] In the present example, the substrate 116 further includes a base section 126 from which each of the wing sections 120 and 124 extend. In particular, the wing sections 120 and 124 extend opposite one another to allow the emitter 128 and the detector 132 to be oriented towards one another when the label 100 is applied to the container 112. The base section 126 may be shaped and sized to correspond to the base of the container 112. In other examples, the base section 126 may have a predefined size and shape to be applied to a variety of different containers 112, and the wing sections 120 and 124 may be extend from the base section 126 to conform to each individual container 112.

[0032] The emitter 128 may be any type of flexible light emitter such as a flexible photoluminescent (e.g., fluorescent, phosphorescent, etc.) light emitter strip, a flexible electroluminescent light emitter strip, a flexible array of light emitting diodes (LEDs), a flexible array or organic light emitting diodes (OLEDs), a flexible array of polymer light emitting diodes (POLEDs) a single flexible LED, a single flexible OLED, a single flexible POLED, etc. The emitter 128 may optionally comprise a flexible light guide to distribute the emitted light 144. The emitter 128 may have an elongated strip form. In a different example, the emitter 128 may have a different form, such as a square form, a dot form, etc. The emitter 128 may be selected based on an average wavelength range that the container 112 may be translucent to (i.e. a default emitter 128 to be used with most containers). Alternatively, the emitter 128 may be selected based on a specific wavelength range that a particular container 112 is translucent to; for example, a programmable emitter 128 that allows for a selection of the working wavelength range may be selected and programmed to emit light 144 at the specific wavelength range; alternatively, a non-programmable emitter 128 emitting light 144 at a suitable wavelength range overlapping the specific wavelength range may be selected. As a further alternative, the container 112 may be selected based on the working wavelength range of the emitter 128. The emitter 128 may be printed on the first wing section 120 or affixed to the first wing section 120 by any known means.

[0033] The detector 132 in the present example is a photodetector array. A number of photodetectors in the array and a spacing of the photodetectors along an axial direction of the wing section 124 may be selected based on a size of the photodetectors, a volume of the container 112 and the length L of the container 112 such that, along the length L of the container 112, the distance between adjacent photodetectors corresponds to a predefined target measurement volume. The predefined target measurement volume may be, for example, about 2.5 mL to about 5 mL according to standard liquid medication doses. In other applications, the predefined target measurement volume may be more or less. In the present example, the photodetectors in the detector 132 are aligned with one another, while in other examples, the photodetectors may be offset, for example to allow the wing section 124 to have different shapes to conform to different containers 112, or the like. The photodetectors may further be selected to allow for minor variances (e.g., less than about 10°) of application of the wing section 124 along the axial length L. The detector 132 may be printed on the second wing section 124 or affixed to the second wing section 124 by any known means.

[0034] The label 100 further includes a processor 136. The processor 136 may comprise a memory communicatively connected to the processor. The memory may comprise a non-transitory machine-readable storage medium that may be any electronic, magnetic, optical, or other physical storage device. The non-transitory machine-readable storage medium of the memory may include, for example, Random Access Memory (RAM), Electrically Erasable Programmable Read-Only Memory (EEPROM), flash memory, a storage drive, an optical disc, or the like. The processor 136 may include one or more of a Central Processing Unit (CPU), a microcontroller, a microprocessor, a processing core, a Field-Programmable Gate Array (FPGA) or the like, and combinations thereof. The processor 136 and the memory may cooperate to execute various instructions to interact with the detector 132 and optionally with the emitter 128 to determine the level 104 of the substance 108 in the container 112 as explained further below.

[0035] In the present example, the processor 136 is supported by the base section 126. Accordingly, the base section 126 may be formed of a less flexible material than the wing sections 120 and 124 to provide suitable support to the processor 136. In addition to the processor 136, other circuitry in communication with the processor 136 such as an energy source, a wireless transmitter, additional sensors such as accelerometers, temperature sensors, load cells, etc., input buttons, a speaker, a display, etc., may also be supported by the base section 126.

[0036] FIG. 2 depicts a flow chart of an example level determination method 200 to determine a level of a substance in a container. The method 200 will be discussed in conjunction with its performance by the label 100 with reference to the components of FIGS. 1A and 1B. In other example, some or all of the method 200 may be performed by other suitable devices or systems.

[0037] Starting at block 205, the processor 136 may optionally calibrate the label 100 to the substance 108 and to the container 112.

[0038] For example, FIG. 3 depicts a flow chart of an example calibration method 300 to calibrate the label 100. At block 305, the processor 136 may set the label 100 in a calibration mode for example, in response to a signal from a calibration button on the label 100, from a computing device in wireless communication with the processor 136, or the like. In some examples, the calibration mode may be initiated when the label 100 is initially placed on the container 112.

[0039] If the container 112 is empty, at block 310, the emitter 128 may emit light 144 and the processor 136 may obtain and store light intensities detected by the detector 132 for calibration when the container 112 is empty. For example, the processor 136 may determine an empty container average light intensity by averaging the empty container detected light intensities of each photodetector in the photodetector array. The processor 136 may also determine an empty container light intensity range spanning from a lowest detected empty container light intensity to a highest detected empty container light intensity of the photodetectors in the photodetector array. Optionally, without the emitter

128 emitting light 144, the processor 136 may obtain and store baseline light intensities detected by the detector 132 for increasing the signal-to-noise ratio of the empty container light intensities. For example, the processor 136 may determine a baseline empty container average light intensity and a baseline empty container light intensity range. The processor 136 may then subtract the baseline empty container light intensities from the empty container light intensities, removing a contribution of baseline light from the empty container light intensities. The light intensities detected by the detector 132 may also be analyzed for predefined patterns to identify positions and/or particular photodetectors along the photodetector array corresponding to a bottom of the container 112 and to a top of the container 112. In other examples, the light intensities detected when the container 112 is empty may be analyzed and/or stored for other calibration parameters.

[0040] Upon completion of the calibration for the empty container 112, the processor 136 may generate a notification to prompt a user or machine to fill the container 112 with the substance 108 to a base level where the level 104 of the substance 108 covers at least one photodetector placed on the wall of the container 112. In some examples, the base level may be a predefined volume of the substance 108.

[0041] At block 315, when the container 112 has been filled with the substance 108 to the base level, the emitter 128 may emit light 144 and the processor 136 may obtain and store light intensities detected by the detector 132. The light intensities detected by the detector 132 may be analyzed to determine a position and/or photodetector in the array corresponding to the base level. Further, the determined position may be mapped to the predefined volume of the substance 108, and hence the processor 136 may correlate each position or photodetector on the array with a volume based on this mapping. In other examples, the light intensities detected when the container 112 is filled to the base level may be analyzed for other calibration parameters.

[0042] Upon completion of the calibration for the container 112 as filled to the base level, the processor 136 may generate a notification to prompt the user or machine to fill the container 112 with the substance 108 to a top level. In some examples, the top level may correspond to the level 104 of the substance 108 covering all of the photodetectors in the photodetector array. In other examples, the top level may be a predefined volume of the substance 108 to be dispensed in the container 112.

[0043] When the container 112 is at the top level, at block 320, the emitter 128 may emit light 144 and the processor 136 may obtain and store light intensities detected by the detector 132. For example, the processor 136 may determine a full container average light intensity by averaging the full container detected light intensities of each photodetector in the photodetector array. The processor 136 may also determine a full container light intensity range spanning from a lowest detected full container light intensity to a highest detected full container light intensity of the photodetectors in the photodetector array. Optionally, without the emitter 128 emitting light 144, the processor 136 may obtain and store baseline light intensities detected by the detector 132 for increasing the signal-to-noise ratio of the full container light intensities. For example, the processor 136 may determine a baseline full container average light intensity and a baseline full container light intensity range. The processor 136 may then subtract the baseline full container light intensities from the full container light intensities, removing a contribution of baseline light from the full container light intensities. Alternatively or additionally to analyzing the empty container light intensities, the light intensities detected by the detector 132 at block 320 may also be analyzed for predefined patterns to identify positions and/or particular photodetectors along the photodetector array corresponding to a bottom of the container 112 and to a top of the container 112. The top and bottom photodetectors may optionally be validated against those detected with the empty container 112. In other examples, the light intensities detected when the container 112 is at the top level may be analyzed and/or stored for other calibration parameters.

[0044] At block 325, processor 136 may receive various predefined thresholds, or other parameters, such as a container volume, container dimensions, a low level threshold, a time to dispense interval, and the like via an input device directly connected to the processor 136 or from a remote input device communicating with the processor 136 wirelessly.

[0045] In a different example, any, or all parts of the example calibration method 300 performed by the processor 136 may alternatively be performed remotely by a calibrating device in communication with the processor 136. Further, some of the blocks may be skipped or omitted, or performed in different orders.

[0046] Returning to FIG. 2, at block 210, the processor 136 may determine whether a level detection is requested. For example, the processor 136 may determine whether a regular predefined interval of time has elapsed (i.e. every 30 minutes, every day, etc.), whether a level detection request has been generated, for example, at a remote input or monitoring device (e.g., by a caregiver or medical professional), at the label 100 itself (e.g., via a button or the like), . whether another initiation condition has been detected (e.g., based on detection of removal of a cap of the container 112, detection of any movement of the container 112 via an accelerometer, or the like), or the like.

[0047] If the determination at block 210 is negative, the processor 136 remains at block 210 to wait for an affirmative determination. The processor 136 may remain in an energy saving mode while awaiting for the affirmative determination.

[0048] If the determination at block 210 is affirmative the processor 136 proceeds to block 215. At block 215 the processor 136 may determine whether a level detection condition is met. That is, after determining that a level detection operation is to be performed, the processor 136 determines whether environmental and other contextual conditions are suitable for obtaining an accurate level detection. For example, the processor 136 may determine whether ambient light is adequate for level detection by comparing detected ambient light by the detector 132 (when the emitter 128 is not emitting light 144) to one or more predetermined reference value. For example, the reference values may eliminate lighting conditions which are too dark (e.g., in an unlit room) or too bright (e.g., in sunlight) which may result in poor accuracy of the level detection operation. Optionally, the processor 136 may also determine whether the container is in an upright position by analyzing a measurement taken by an additional sensor, such as an accelerometer, in communication with the processor 136.

[0049] If the determination at block 215 is negative (i.e., the detected ambient light is not adequate for level detection and/or the container is not in an upright position), then the processor 136 proceeds to block 220. At block 220 the processor 136 may generate a notification to inform the user that the container 112 may be exposed to inadequate ambient light for level detection and/or that the container 112 is not in an upright position. The notification may be a visual indication from the emitter 128. Alternatively, the notification may be a visual or audio indication from another component on the label 100 such as a display, a speaker, etc. Still further, the notification may be from a computing device optionally wirelessly connected to the processor 136. The notification may be generated for a predetermined amount of time, for example, for 5 seconds. The processor 136 may optionally additionally output the notification to a remote database.

[0050] In some examples, after generating the notification at block 220, the processor 136 may wait for a response and/or rectification of the level detection condition. For example, the response may be to proceed to attempt the level detection, irrespective of an inadequate level detection condition. The processor 136 may wait for a predetermined amount of time (e.g., 5 seconds, 1 minute, etc.) for the response and/or rectification of the level detection condition. If the condition is not rectified and/or no response is received, the processor 136 may skip the level detection operation and return to block 210 to wait for a subsequent level detection operation to be requested.

[0051] In other examples, after the notification at block 220 is generated, the processor 136 may skip the level detection operation and return to block 210 for further determination of the level detection.

[0052] If the determination at block 215 is affirmative, then the processor 136 proceeds to block 225. At block 225 the emitter 128 emits light 144 into the container 112. The emitter 128 may emit light 144 continuously or at regular time intervals. The emitter 128 may emit light 144 of a constant or alternating intensity. Optionally, the processor 136 may control the emitter 128 to emit light 144.

[0053] At block 230, detector 132 detects the emitted light 144 in the container 112. Optionally, the processor 136 may additionally determine a baseline ambient light (without the emitter 128 emitting light 144) and subtract the baseline ambient light from the detected emitted light 144 to remove possible contributions of the baseline ambient light to the detected emitted light 144 that may negatively affect the level detection, for example, when the container 112 is placed near an additional source of artificial light, such as a lamp, at a time of level detection. The detector 132 may detect the emitted light 144 continuously. Optionally, when the emitted light 144 is alternating at a specific frequency, the processor 136 may perform a light detection signal synchronization method that may be based on a homodyne detection technique similar to techniques used in lock-in amplification, as further explained with reference to FIG. 4. That is, the processor 136 may generally isolate the signal received at the same frequency at which the emitted light 144 is emitted by the emitter 128.

[0054] FIG. 4 depicts a flowchart of an example synchronization method 400 to synchronize a light detection signal to a light emission signal to facilitate a detection of the emitted light 144 at consistent light intensity ranges. Starting at block 405, the processor 136 determines a light emission frequency f_e of the emitter 128. For example, when the processor 136 controls the alternating light intensities emitted by the emitter 128, the light emission frequency f_e may simply be a frequency driving the emitter 128 at a peak light intensity.

[0055] In other examples, when the alternating light intensities is a property of the emitter 128 itself, such as for electroluminescent light emitters, the processor 136 may analyze the light intensities detected by the detector 132 to determine the light emission frequency f_e. For example, the processor 136 may identify peaks in the detected light intensities of similar intensity and consistent period. In some examples, to facilitate distinguishing the peaks corresponding to light emitted by the emitter 128 from other light noise detected by the detector 132, the processor 136 may also drive the emitter 128 in a predefined, distinguishable pattern. Other manners of determining the light emission frequency f_e based on the detected light are also contemplated.

[0056] At block 410, the processor 136 may optionally determine whether a lag or phase shift exists between emission of the light 144 from the emitter 128 and detection of the same light 144 by the detector 132. For example, the processor 136 may similarly drive the emitter 128 in a predefined distinguishable pattern and determine a lag or phase shift between the corresponding pattern detected by the detector 132.

[0057] At block 415, the processor 136 may synchronize the light detection frequency f_d of the detected light to the light emission frequency f_e of the emitted light by processing light measurements of the detector 132 at the light detection frequency f_d and offset from the time of light emission by any lag or phase shift determined at block 410.

[0058] In a different embodiment, any, or all parts of the example synchronization method 400 performed by the processor 136 may alternatively be performed remotely by a synchronizing device in communication with the processor 136.

[0059] Returning again to FIG. 2, at block 235, the processor 136 may determine the level 104 in the container 112 based on the detected light. For example, FIG. 5A shows a cross-section view of the label 100 applied to the container 112 further depicting arrows representing detected light 504 which is above the level 104, detected light 508 which is at the level 104, and detected light 512 which is below the level 104. The detected light 504 may have different light intensity ranges from the detected light 512. The detected light 508 may have a light intensity outside the light intensity ranges of the detected light 504 and. FIG. 5B depicts an example graph of light measurements 516 (in mV) from each photodetector in the photodetector array that the processor 136 may use to identify the level 104 along the photodetector array (mm). One example way by which the processor 136 may identify the level 104 is by differentiating the detected light with respect to the direction X and identifying a position in the direction X where a maximum or minimum change in the detected light (ΔmV) per change in the direction X (Δmm) occurs. That is, the position may correspond to the inflection point of the detected light. Another example way by which the processor 136 may identify the position is by, for example, comparing changes between light measurements 516 of neighboring photodetectors to a threshold change value or by comparing the light measurements 516 to the empty container light average value and/or the full container light average value obtained in the calibration method 300. The level 104 defines a point with respect to the direction X along the length of the container where a meniscus of the substance 108 is located

[0060] Going back to FIG. 2, after determining the level 104, at block 240, the processor 136 may output an indication of the level 104 to the user through any indication means such as a visual or audio indication by a component on the label 100 directly connected to the processor 136 such as a display, a speaker, etc. or by a computing device wirelessly connected to the processor 136 through a transmitter. The processor 136 may alternatively, or in addition to outputting the indication of the level 104 at the label 100, output the indication of level 104 to a remote database so that, for example, a caregiver or medical professional may monitor the level 104 against expected reference levels determined based on a medication schedule. The indication of the level 104 may comprise an absolute value of the level 104 (for example, a fill percentage of the container 112, a volume of the substance 108, a number of doses remaining, etc.), a relative value of the level 104 indicating an amount of change with respect to a previously determined value, a flag indicating whether the level 104 has changed, etc.

[0061] At block 245, the processor 136 may optionally further determine a property of the substance 108 such as, for example, dispersion stability, and output an indication of the property. In some examples, block 245 may be performed at each determination of the level in the container 112, while in other examples, block 245 may be performed independently of the level detection operation. For example, block 245 may be performed at regular predefined intervals, or in response to other suitable conditions.

[0062] FIGS. 6A, 6B and 6C depict cross-section views of the example container 112 and label 100 with a substance 600 containing particles 604 in a suspension stable state, a sedimented state and a creamed state, respectively. FIGS. 6D, 6E and 6F depict example graphs of light measurements 608 (mV) of each photodetector in the photodetector array of detector 132 for the substance 600 in the suspension stable state, the sedimented state and the creamed state depicted in FIGS. 6A, 6B and 6C, respectively. The light measurements 608 below the level 612 of the substance 600 may fall within the full container light intensity range determined by the calibration process; however, as depicted in FIG. 6E and FIG. 6F, when the substance 600 is in a sedimented or creamed state, a detectable change in level between light measurements 608 below the level 612 at a boundary level 616 between a zone of the substance 600 with a high concentration of particles 604 and a zone of the substance 600 with a low concentration of particles 604 may be detected by the processor 136. The processor 136 may, for example, determine an average change of detected light between neighboring light measurements 608 below the level 612 and output the average change of detected light as an indication of dispersion stability in visual or audio form by a component on the label

100 directly connected to the processor 136 such as a display, a speaker, etc. or by a computing device wirelessly connected to the processor 136. Additionally or alternatively, the processor 136 may determine a state of the substance 600 such as a stable, a sedimented or a creamed state, by, for example, comparing a dispersion stability threshold to the average change of detected light between neighboring light measurements 608 below the level 612 and output an indication of the state in visual or audio form.

[0063] Going back to FIG. 2, at block 245, the property of the substance 108 that the processor 136 may determine and output an indication of may further comprise a temperature of the substance 108 detected by an additional sensor, such as a temperature sensor, in communication with the processor 136. The property may further comprise a storage state of the substance 108, indicating whether the substance 108 is being stored in direct sunlight by, for example, comparing the detected ambient light by the detector 132 (when the emitter 128 is not emitting light 144) to a predetermined direct sunlight reference value.

[0064] At block 250, the processor 136 determines whether a trigger condition has been met. The trigger condition may be detected when a dispersion stability trigger condition is met, for example, when the sedimented or the creamed state are determined, when a low level 104 threshold is met, when a time to dispense the substance 108, 600 expires, when a high temperature threshold is met determined by comparing the temperature of the substance 108 to a high temperature reference value, when the substance has been stored in direct sunlight for a determined time period, etc.

[0065] If the determination at block 250 is negative, then the processor 136 may return to block 210 for a subsequent determination of the level detection and iteration through the method 200.

[0066] If the determination at block 250 is affirmative, then the processor 136 proceeds to block 255. At block 255 the processor 136 may generate a trigger condition notification. The notification of the trigger condition may be a visual indication generated by the emitter 128. Alternatively, the notification of the trigger condition may be a visual or audio indication by a component on the label 100 directly connected to the processor 136 such as a display, a speaker, etc. or by a computing device optionally wirelessly connected to the processor 136. The trigger condition may additionally be output to a remote database.

[0067] After generating the trigger condition notification at block 255, the processor may return to block 210 for a subsequent determination of the level detection and iteration through the method 200.

[0068] In a different embodiment, any, or all parts of the example level determination method 200 performed by the processor 136 may alternatively be performed remotely by a determination device in communication with the processor 136.

[0069] The label 100 may have different form factors, such as the form factor depicted in the example of FIGS. 7A and 7B, which depict an example label 700 where a wing section 704 of a flexible substrate 702 has a wing width Wof similar proportions to a perimeter of the container 112 so that when the wing section 704 conforms to the container 112, as shown in FIG. 7B, the wing section 704 may block ambient light 708 from the detector 132. In this example, the wing section 704 is a light blocking section. The light blocking section 704 may, in one example, block from the detector 132 an ambient light range 712 around an emitted light range by the emitter 128 so that the detected light within the range of the emitted light 144 is not altered by the ambient light.

[0070] FIG. 8A depicts an example label 800 that may be adaptable to containers 112 of different dimensions. The label 800 comprises a conformable substrate 802 with a first wing section 804 with emitter tear lines 808 along an emitter 812, and a second wing section 816 with detector tear lines 820 along a detector 824. The emitter 812 may be a resizable emitter 812 by having multiple redundant circuits, by not requiring a closed loop circuit to emit light, etc., so that the emitter 812 may continue emitting after a portion of the emitter 812 is cut from the substrate 802. The detector 824 is similarly configured to continue detecting after a portion of the detector 824 is cut from the substrate 802. In the example of FIG. 8A, the detector 824 is formed by a photodetector array where each photodetector in the array may be independently connected to a processor 828 so that a first subset of photodetectors may be detached from the substrate 802 while a second subset of photodetectors remaining in the substrate 802 may continue detecting after the first subset has been detached. The emitter tear lines 808 align to the detector tear lines

820 so that the emitter 812 and the detector 824 may match after portions of the emitter 812 and the detector 824 are cut from the substrate 802. Alternatively, in another example, the tear lines 808 and/or 820 may be omitted.

[0071] FIGS. 8B and 8C depict a cross-section view of the container 112 before, and after the first and second wing sections 804 and 816 have been adjusted to the length L of the container 112, respectively.

[0072] FIGS. 9A and 9B depict another example label 900. The label 900 comprises a base section 902 and a conformable substrate 904. The conformable substrate 904 is of a rectangular shape and of a substrate width W_S roughly equivalent to half a perimeter πR of the container 112. In this example, the light emitter 128 and the light detector are supported on opposite sides of a surface of the conformable substrate 904 so that when the label 900 is conformed to the container 112, as shown in FIG. 9B, the emitter 128 and the detector 132 may be roughly directly facing each other through the wall of the container 112.

[0073] In the foregoing specification, specific embodiments of labels for determining a level of a substance in a container have been described. The described embodiments may be implemented in commercially viable systems to automatically measure and report levels of substances in containers, for example, to facilitate medication adherence programs. The prescribed embodiments may be implemented, for example, in label systems of a standard size that may determine levels of a variety of substances in a variety of containers of different sizes. The prescribed embodiments may additionally be implemented in label systems that may determine a physical property of a substance in a container in addition to determining the level of the substance. However, one of ordinary skill in the art appreciates that various modifications and changes can be made without departing from the scope of the invention as set forth in the claims below. Accordingly, the specification and figures are to be regarded in an illustrative rather than a restrictive sense, and all such modifications are intended to be included within the scope of present teachings.

[0074] The benefits, advantages, solutions to problems, and any element(s) that may cause any benefit, advantage, or solution to occur or become more pronounced are not to be construed as a critical, required, or essential features or elements of any or all the claims. The invention is defined solely by the appended claims including any amendments made during the pendency of this application and all equivalents of those claims as issued.

[0075] Moreover in this document, relational terms such as first and second, top and bottom, and the like may be used solely to distinguish one entity or action from another entity or action without necessarily requiring or implying any actual such relationship or order between such entities or actions. The terms “comprises,” “comprising,” “has”, “having,” “includes”, “including,” “contains”, “containing” or any other variation thereof, are intended to cover a non-exclusive inclusion, such that a process, method, article, or apparatus that comprises, has, includes, contains a list of elements does not include only those elements but may include other elements not expressly listed or inherent to such process, method, article, or apparatus. An element proceeded by “comprises …a”, “has …a”, “includes …a”, “contains …a” does not, without more constraints, preclude the existence of additional identical elements in the process, method, article, or apparatus that comprises, has, includes, contains the element. The terms “a” and “an” are defined as one or more unless explicitly stated otherwise herein. The terms “substantially”, “essentially”, “approximately”, “about” or any other version thereof, are defined as being close to as understood by one of ordinary skill in the art, and in one non-limiting embodiment the term is defined to be within 10%, in another embodiment within 7%, in another embodiment within 1% and in another embodiment within 0.5%. The term “coupled” as used herein is defined as connected, although not necessarily directly and not necessarily mechanically. A device or structure that is “configured” in a certain way is configured in at least that way, but may also be configured in ways that are not listed.

[0076] Certain expressions may be employed herein to list combinations of elements. Examples of such expressions include: “at least one of A, B, and C”; “one or more of A, B, and C”; “at least one of A, B, or C”; “one or more of A, B, or C”. Unless expressly indicated otherwise, the above expressions encompass any combination of A and/or B and/or C.

[0077] It will be appreciated that some embodiments may be comprised of one or more specialized processors (or “processing devices”) such as microprocessors, digital signal processors, customized processors and field programmable gate arrays (FPGAs) and unique stored program instructions (including both software and firmware) that control the one or more processors to implement, in conjunction with certain non-processor circuits, some, most, or all of the functions of the method and/or apparatus described herein. Alternatively, some or all functions could be implemented by a state machine that has no stored program instructions, or in one or more application specific integrated circuits (ASICs), in which each function or some combinations of certain of the functions are implemented as custom logic. Of course, a combination of the two approaches could be used.

[0078] Moreover, an embodiment can be implemented as a computer-readable storage medium having computer readable code stored thereon for programming a computer (e.g., comprising a processor) to perform a method as described and claimed herein. Examples of such computer-readable storage mediums include, but are not limited to, a hard disk, a CD-ROM, an optical storage device, a magnetic storage device, a ROM (Read Only Memory), a PROM (Programmable Read Only Memory), an EPROM (Erasable Programmable Read Only Memory), an EEPROM (Electrically Erasable Programmable Read Only Memory) and a Flash memory. Further, it is expected that one of ordinary skill, notwithstanding possibly significant effort and many design choices motivated by, for example, available time, current technology, and economic considerations, when guided by the concepts and principles disclosed herein will be readily capable of generating such software instructions and programs and Ics with minimal experimentation.

[0079] The Abstract of the Disclosure is provided to allow the reader to quickly ascertain the nature of the technical disclosure. It is submitted with the understanding that it will not be used to interpret or limit the scope or meaning of the claims. In addition, in the foregoing Detailed Description, it can be seen that various features are grouped together in various embodiments for the purpose of streamlining the disclosure. This method of disclosure is not to be interpreted as reflecting an intention that the claimed embodiments require more features than are expressly recited in each claim. Rather, as the following claims reflect, inventive subject matter lies in less than all features of a single disclosed embodiment. Thus the following claims are hereby incorporated into the Detailed Description, with each claim standing on its own as a separately claimed subject matter.

CLAIMS

1. A label for determining a level of a substance in a container, the label comprising:

a substrate configured to conform to the container, the substrate having:

a first section supporting a light emitter configured to emit light into the container; and

a second section supporting a light detector configured to detect the emitted light; and

a processor connected to the detector, the processor configured to determine the level of the substance based on the detected light.

2. The label of claim 1 wherein the processor is further configured to determine a physical property of the substance based on the detected light.

3. The label of claim 1 wherein the emitter is one of a photoluminescent strip, an electroluminescent strip, an organic light emitting diode, and a polymer organic light emitting diode.

4. The label of claim 1 wherein the detector is a photodetector array.

5. The label of claim 4 wherein a first subset of the photodetector array is configured to be detachable from the substrate and wherein a second subset of the photodetector array is configured to continue detecting after the first subset is detached.

6. The label of claim 1 wherein the detector is further configured to continue detecting after a portion of the detector is cut from the substrate.

7. The label of claim 1 wherein the emitter is further configured to continue emitting after a portion of the emitter is cut from the substrate.

8. The label of claim 1 further comprising a light blocking section configured to block ambient light from the detector when the substrate is conformed to the container.

9. The label of claim 8 wherein the light blocking section is configured to block from the detector ambient light within an ambient light range around an emitted light range when the substrate is conformed to the container.

10. The label of claim 1 wherein the emitter is connected to the processor and wherein the processor is further configured to control the emitter.

11. The label of claim 10 wherein the processor is further configured to synchronize a light detection frequency of the detected light to a light emission frequency of the emitted light.

12. The label of claim 10 wherein the processor is further configured to detect a trigger condition and control the emitter to generate a visual indication in response to the trigger condition.

13. The label of claim 1 wherein prior to conformance, the label is flat.

14. A method of determining a level of a substance in a container, the method comprising:

emitting light into the container;

detecting the emitted light by a photodetector array, the photodetector array being supported by a conformable substrate and extending along a length of the container;

determining the level of the substance by identifying a position along the photodetector array with a maximum change in the detected light; and

outputting an indication of the level of the substance.

15. The method of claim 14 further comprising:

determining the level of the substance by differentiating the detected light with respect to a direction along the length of the container and identifying the position along the photodetector array with the maximum change in the detected light per change in the direction.

16. The method of claim 14 wherein the level defines a point with respect to a direction along the length of the container where a meniscus of the substance is located.

17. The method of claim 14 further comprising:

determining a physical property of the substance based on the detected light; and

outputting an indication of the physical property.

18. The method of claim 14 further comprising synchronizing a light detection frequency of the detected light to a light emission frequency of the emitted light.

19. The method of claim 14 further comprising detecting a trigger condition and generating a notification of the trigger condition.

20. A system comprising:

a container;

a light emitter configured to emit light through the container;

a conformable substrate affixed to the container, the substrate supporting a photodetector array extending along a length of the container, the photodetector array configured to detect the emitted light; and

a processor connected to the photodetector array, the processor configured to determine a level of a substance in the container based on the detected light.

21. The system of claim 20 further comprising:

a light blocking section affixed to the container, the light blocking section configured to block ambient light from the photodetector array.

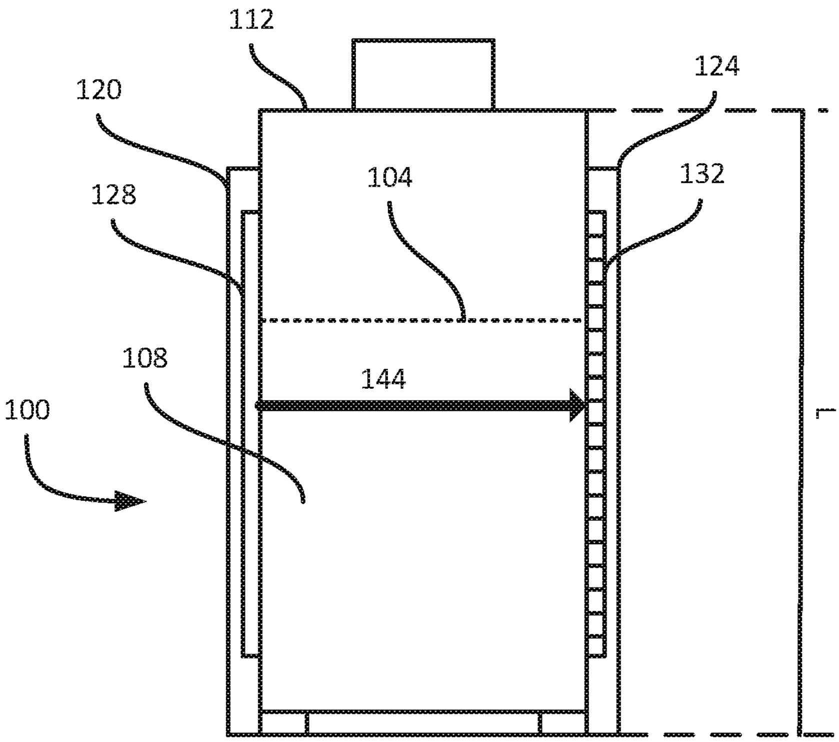
112
124
120
104
132
128
108
144
100
L

FIG. 1A

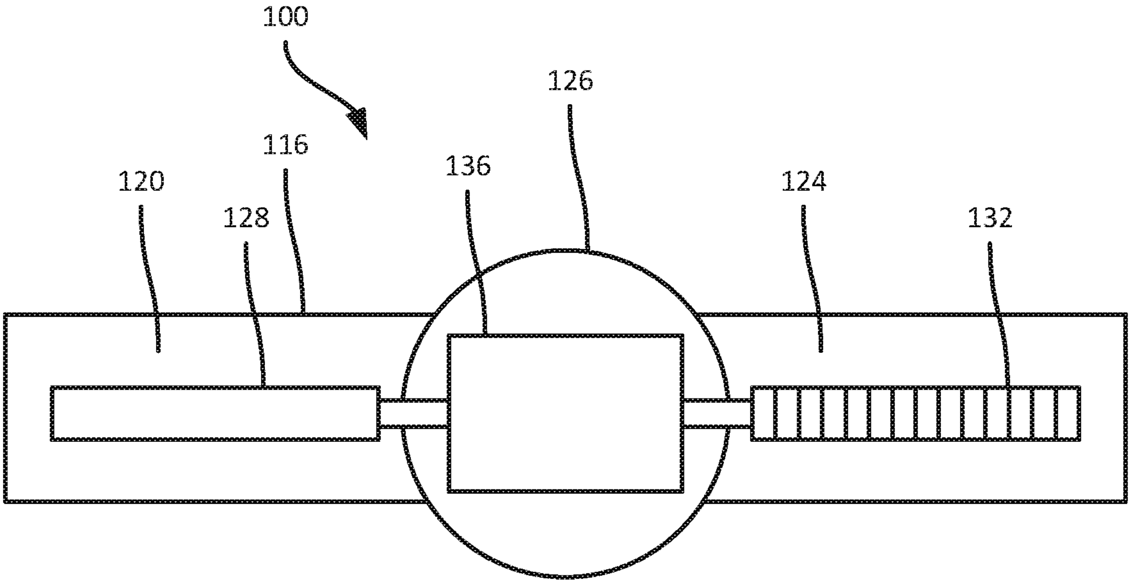
100
126
116
136
120
124
128
132

FIG. 1B

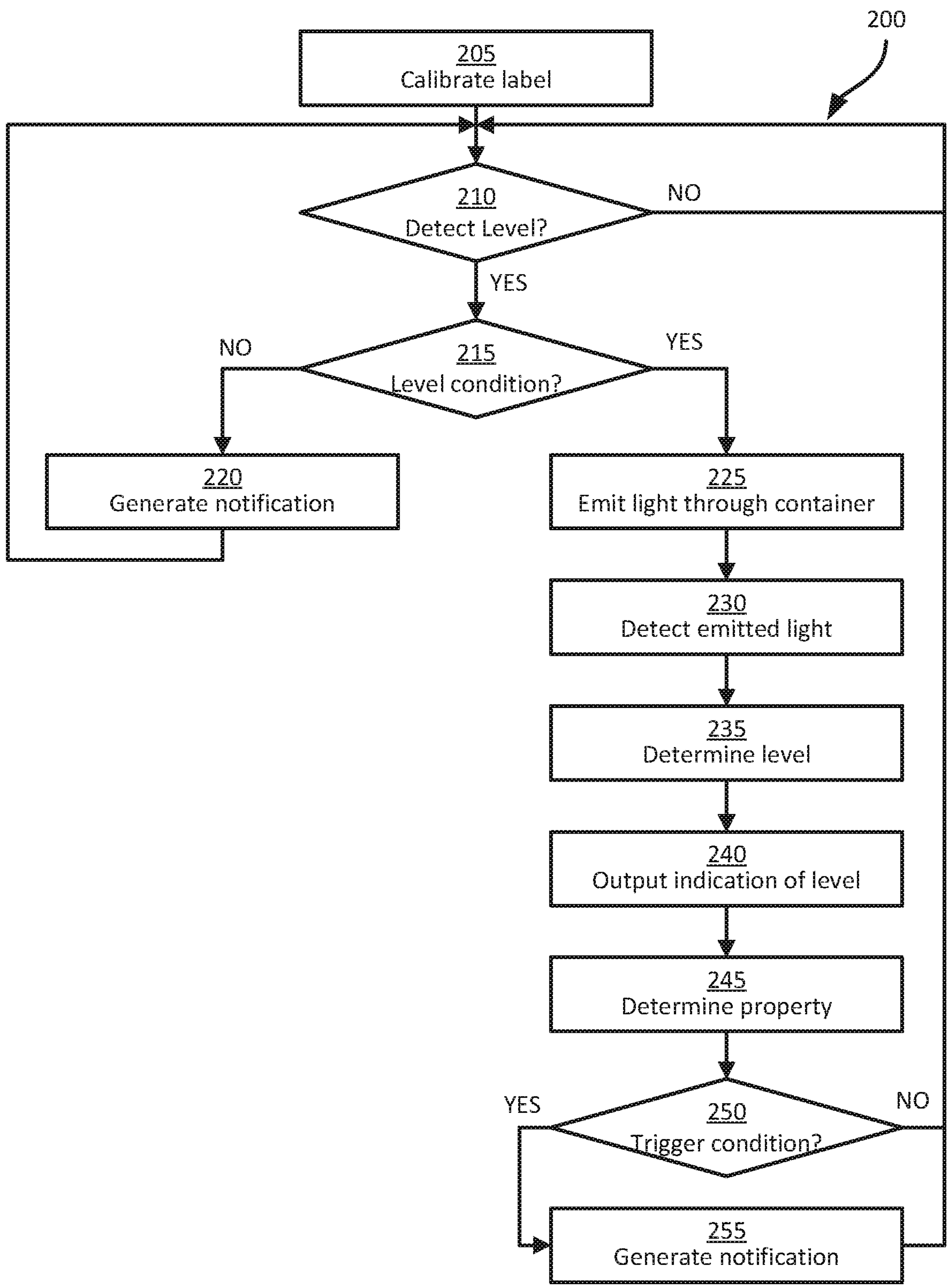
200
205
Calibrate label
210
Detect Level?
NO
YES
215
Level condition?
NO
YES
220
Generate notification
225
Emit light through container
230
Detect emitted light
235
Determine level
240
Output indication of level
245
Determine property
250
Trigger condition?
YES
NO
255
Generate notification

FIG. 2

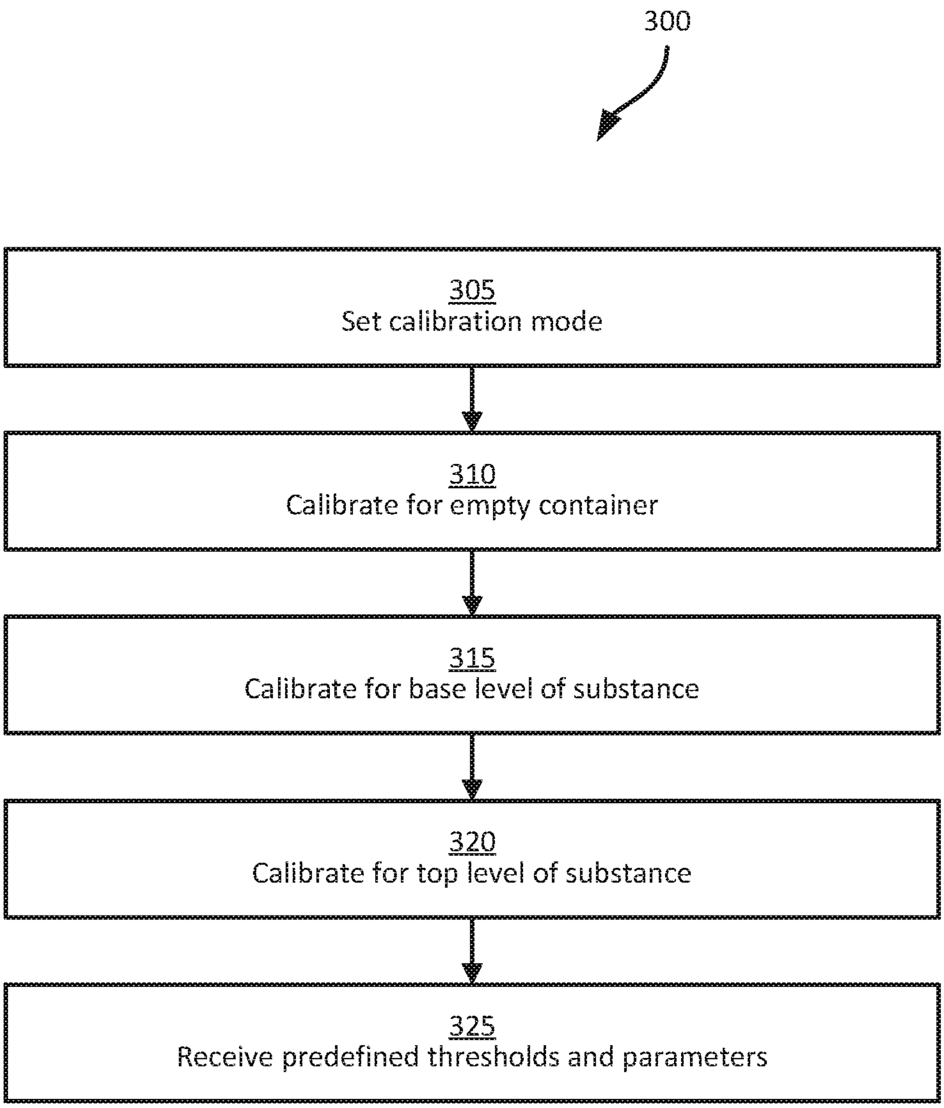
300
305
Set calibration mode
310
Calibrate for empty container
315
Calibrate for base level of substance
320
Calibrate for top level of substance
325
Receive predefined thresholds and parameters

FIG. 3

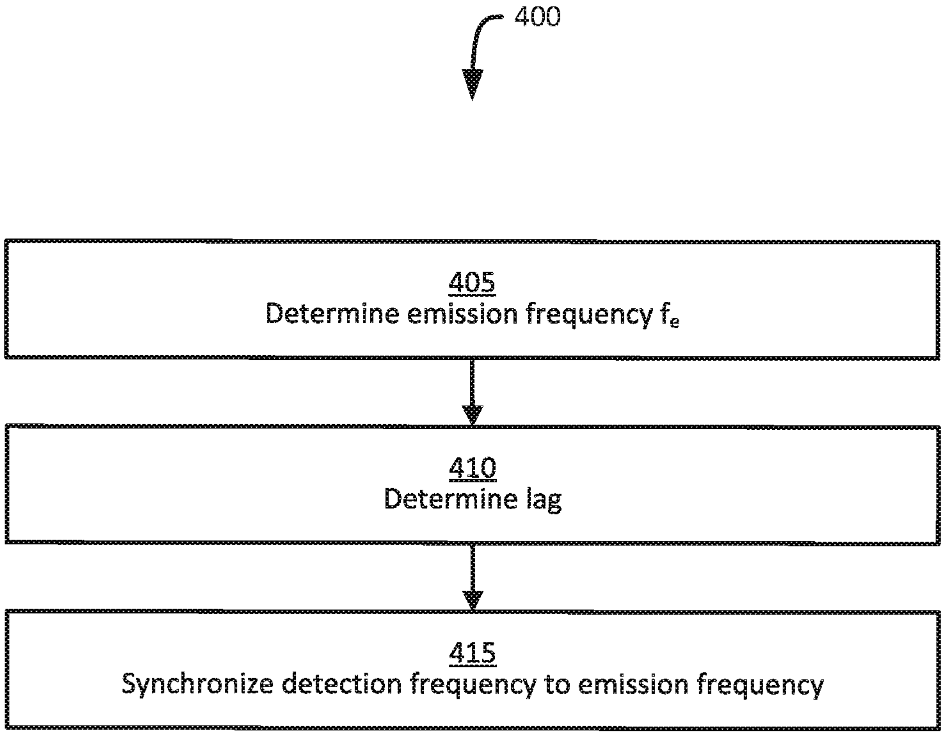
400
405
Determine emission frequency f_e
410
Determine lag
415
Synchronize detection frequency to emission frequency

FIG. 4

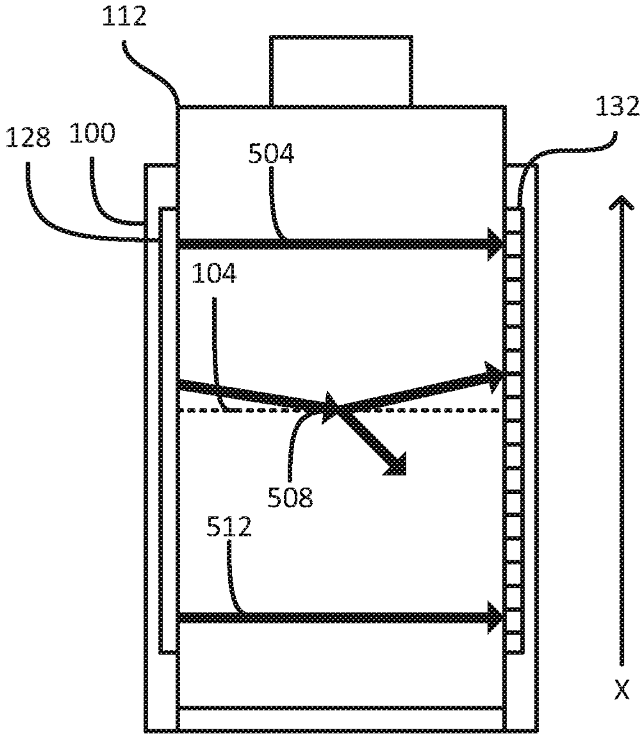
112
132
128
100
504
104
508
512
X

FIG. 5A

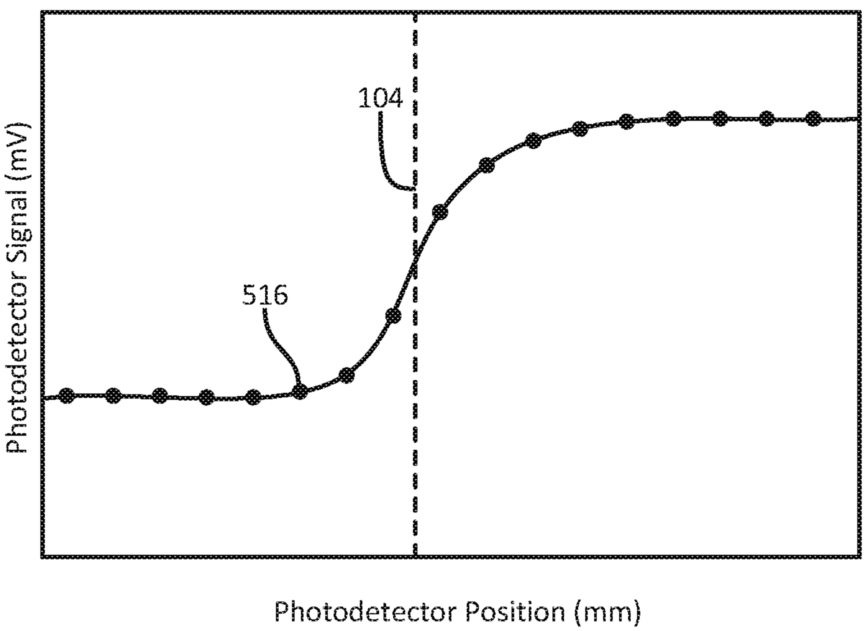
104
516
Photodetector Signal (mV)
Photodetector Position (mm)

FIG. 5B

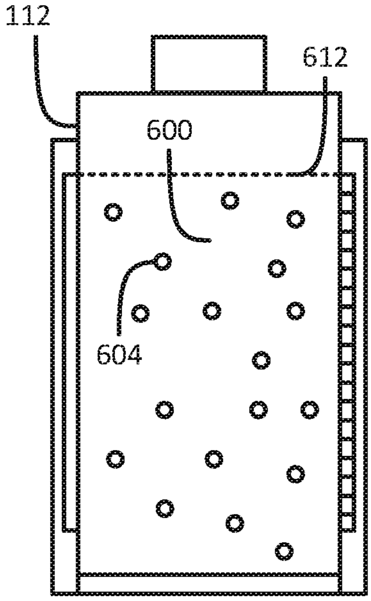

FIG. 6A

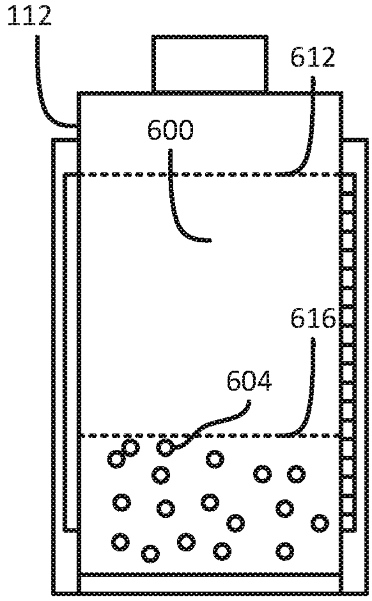

FIG. 6B

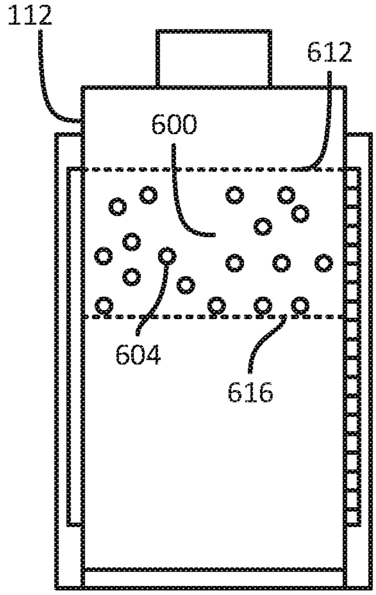

FIG. 6C

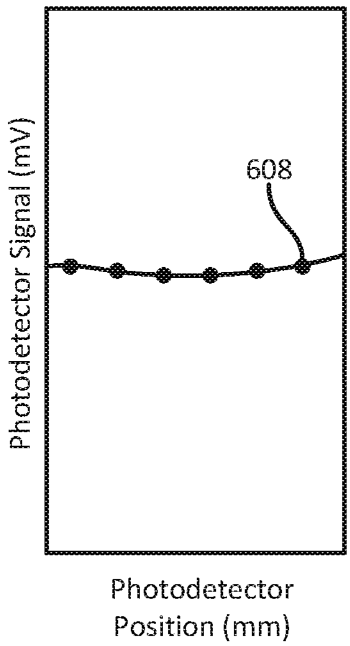

FIG. 6D

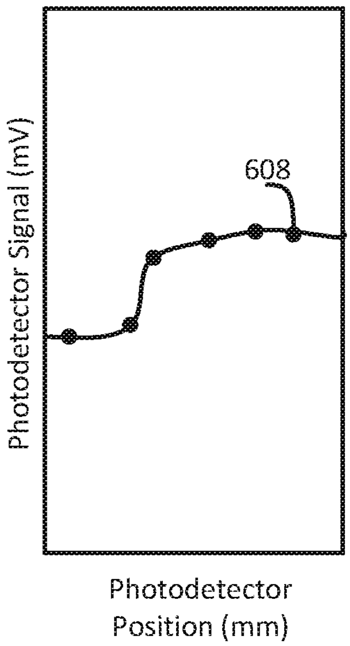

FIG. 6E

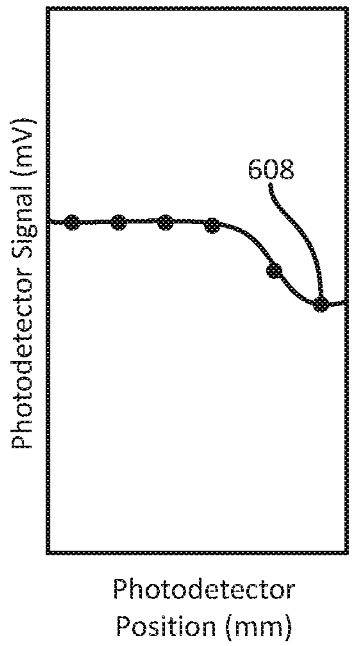

FIG. 6F

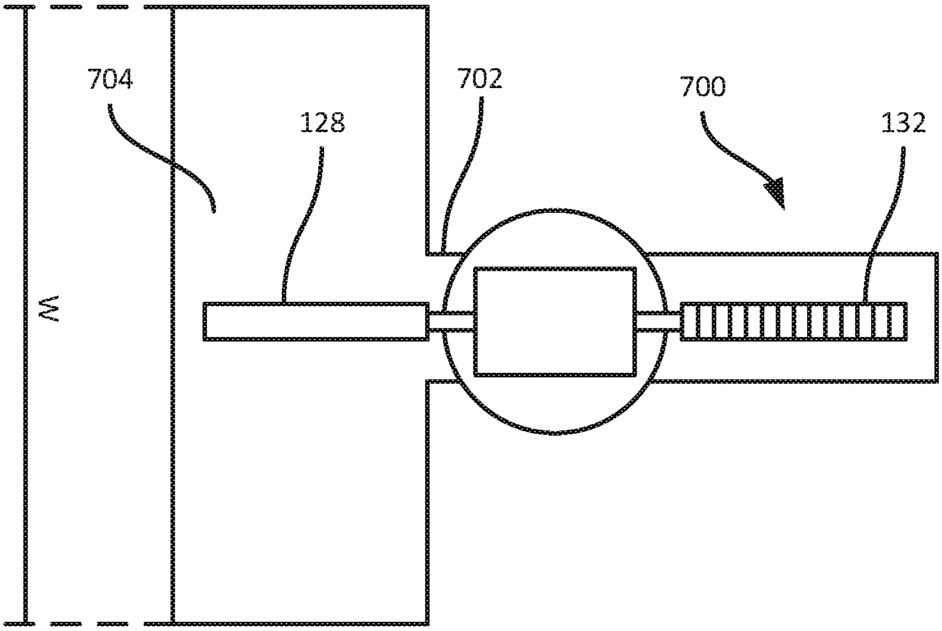

FIG. 7A

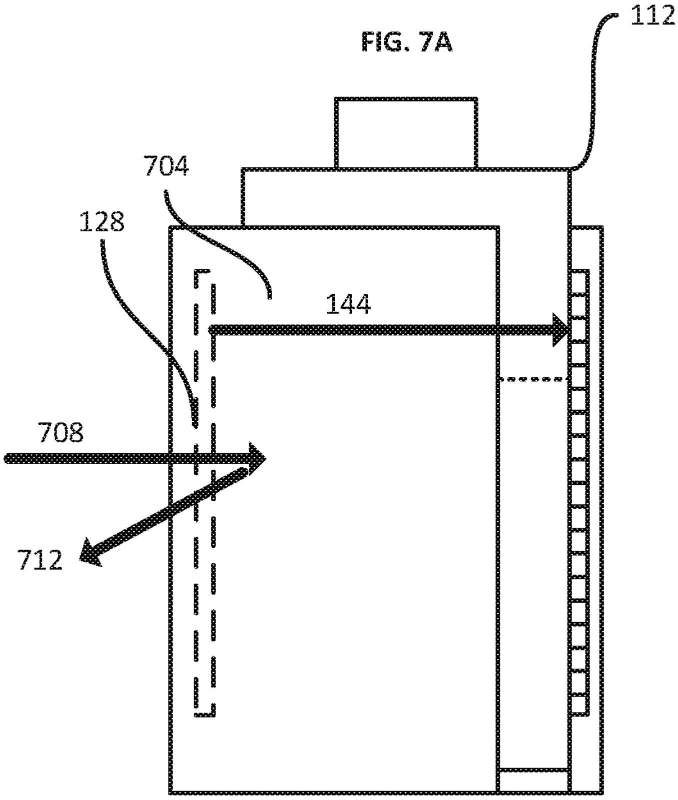

FIG. 7B

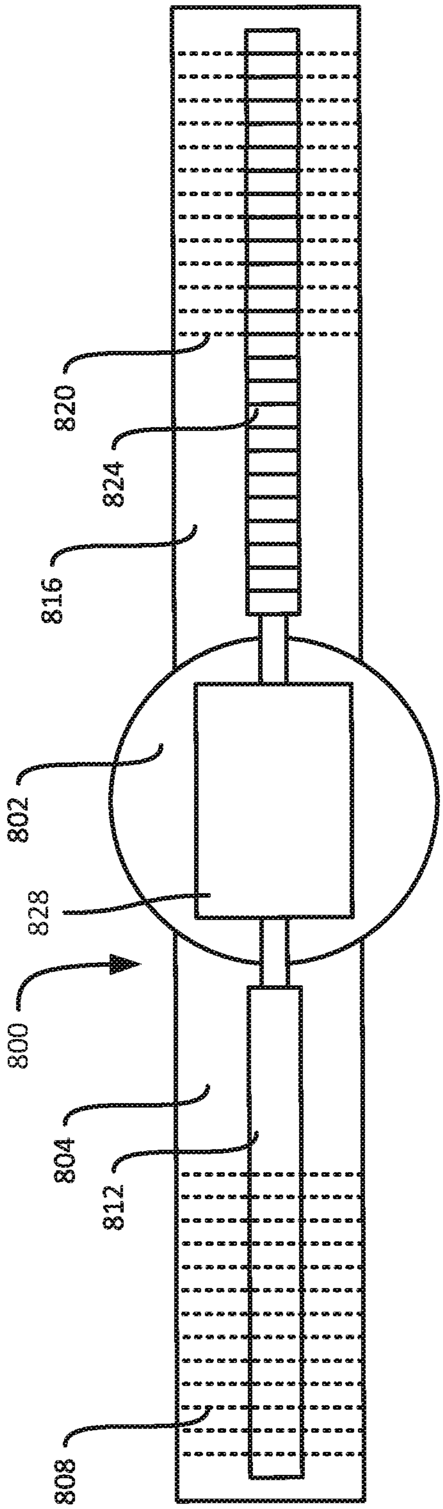

FIG. 8A

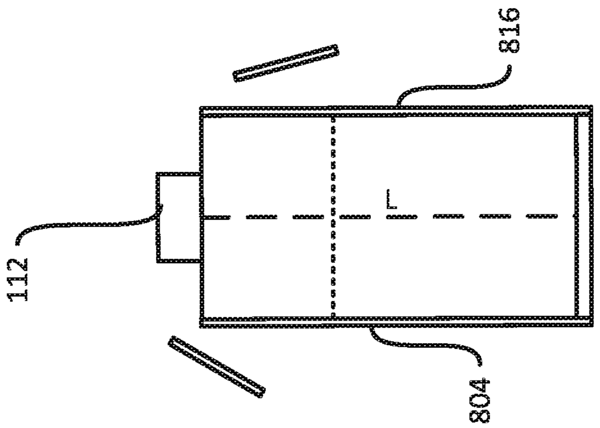

FIG. 8C

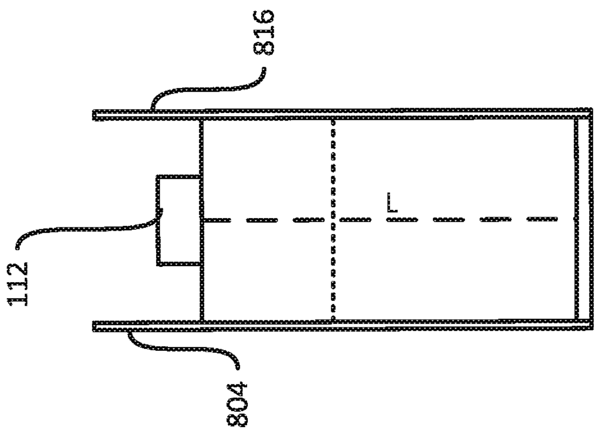

FIG. 8B

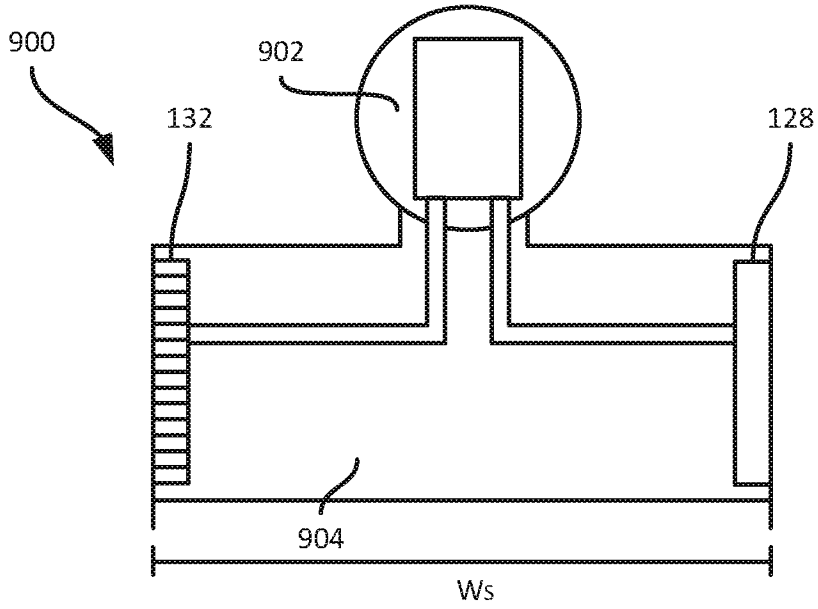

FIG. 9A

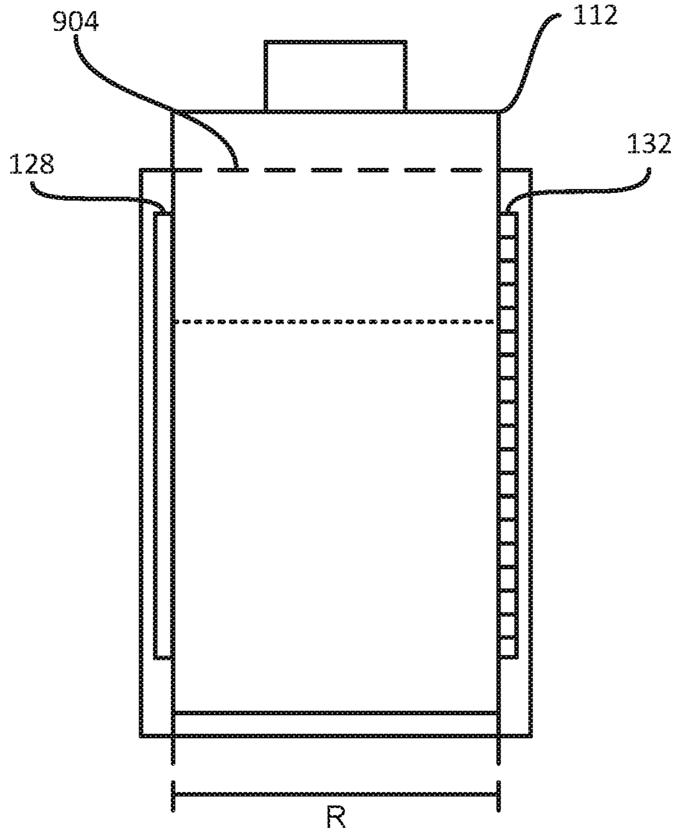

FIG. 9B

INTERNATIONAL SEARCH REPORT

International application No.
PCT/IB2024/060280

A. CLASSIFICATION OF SUBJECT MATTER

IPC: ***G01F 23/292*** (2006.01)

CPC:

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC: ***G01F 23/292*** (2006.01)

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

Electronic database(s) consulted during the international search (name of database(s) and, where practicable, search terms used)
Keywords: IEEE Xplore, CPD (Canadian Patent Database), Questel Orbit
Databases: medication, substance, container, substance level, light emitter, diode, photoluminescent strip, polymer, substrate, array, processor, detector, substrate, measure and report, calibrate, generate notification, liquid, emission

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US2022057335A1 24 February 2022 (24-02-2022) by Atkinson et al. ** see abstract, entire application**	1-21
A	US8858607B1 14 October 2014 (14-10-2014) by Jones et al. ** see abstract, entire application**	1-21
A	US10816939B1 27 October 2020 (27-10-2020) by Coleman ** see abstract, entire application**	1-21

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"D" document cited by the applicant in the international application
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search
14 January 2025 (14-01-2025)

Date of mailing of the international search report
20 January 2025 (20-01-2025)

Name and mailing address of the ISA/CA
Canadian Intellectual Property Office
Place du Portage I, C114 - 1st Floor, Box PCT
50 Victoria Street
Gatineau, Quebec K1A 0C9
Facsimile No.: 819-953-2476

Authorized officer

Karen Oprea (819) 639-8255

Patent Document Cited in Search Report	Publication Date	Patent Family Member(s)	Publication Date
US2022057335A1	24 February 2022 (24-02-2022)	US2022057335A1	24 February 2022 (24-02-2022)
		US2019219514A1	18 July 2019 (18-07-2019)
		US10613035B2	07 April 2020 (07-04-2020)
		US2020309712A1	01 October 2020 (01-10-2020)
		US11204331B2	21 December 2021 (21-12-2021)
US8858607B1	14 October 2014 (14-10-2014)	US2014288351A1	25 September 2014 (25-09-2014)
		US8858607B1	14 October 2014 (14-10-2014)
		CA2907416A1	18 September 2014 (18-09-2014)
		EP2967747A1	20 January 2016 (20-01-2016)
		EP2967747A4	30 November 2016 (30-11-2016)
		WO2014146029A1	18 September 2014 (18-09-2014)
US10816939B1	27 October 2020 (27-10-2020)	US10816939B1	27 October 2020 (27-10-2020)
		US2021112647A1	15 April 2021 (15-04-2021)
		US11184967B2	23 November 2021 (23-11-2021)
		US2022086988A1	17 March 2022 (17-03-2022)
		US11576243B2	07 February 2023 (07-02-2023)
		US2023389161A1	30 November 2023 (30-11-2023)
		US11889603B2	30 January 2024 (30-01-2024)
		US2024172349A1	23 May 2024 (23-05-2024)
		US12185442B2	31 December 2024 (31-12-2024)

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US8858607B1, 14 October 2014 (14-10-2014)
US10816939B1, 27 October 2020 (27-10-2020)