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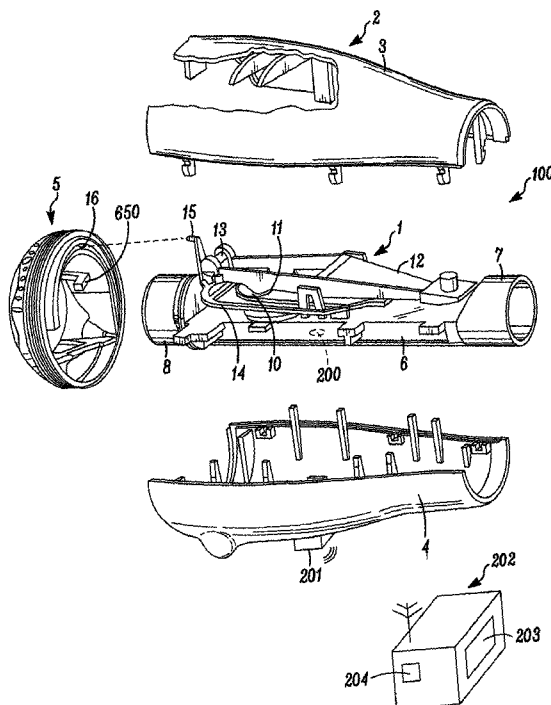
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(54) Title: RESPIRATORY MONITORING APPARATUS



(57) Abstract: A respiratory monitor including a sensor (200) responsive to substance in exhaled breath is mounted in or connected to a respiratory therapy device (100) of the kind that provides an alternating resistance to expiratory flow. The sensor (200) is exposed to biomarkers or other substances in exhaled breath. The vibration in the lungs produced by the therapy device (100) helps release an increased amount of the biomarkers or other substances in the exhaled breath.

EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV,
MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM,
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KM, ML, MR, NE, SN, TD, TG).

Declarations under Rule 4.17:

- *as to the identity of the inventor (Rule 4.17(i))*
- *as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii))*
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RESPIRATORY MONITORING APPARATUS

This invention relates to respiratory monitoring apparatus of the kind including a sensor responsive to a biomarker in exhaled breath.

It is well known that the presence or progress of some diseases can be monitored by sensing various biomarkers in exhaled breath. Markers indicative of such diseases include hydrogen sulphide, acetone, pentane, toluene ammonia and nitrogen oxides. Various sensing technologies have been proposed, such as, gas chromatography, mass spectroscopy, ion mobility spectrometry and chemiresistive sensors. Diseases that can be monitored from biomarkers in exhaled breath include diabetes, lung cancer, kidney failure, asthma, cystic fibrosis and COPD. One problem with such disease monitoring apparatus is that the breath supplied to the sensor tends to be mainly from the upper part of the bronchial system where the biomarkers may be in low concentrations. Also, normal inspiratory and expiratory breathing may not release very much of the biomarkers.

It is an object of the present invention to provide alternative respiratory apparatus.

According to one aspect of the present invention there is provided respiratory monitoring apparatus of the above-specified kind, characterised in that the apparatus includes a vibratory expiratory therapy device arranged to provide an alternating resistance to expiratory flow of the user, and that the sensor is located in an expiratory flow path such that it is exposed to vibratory expiratory flow from the user.

According to another aspect of the present invention there is provided respiratory monitoring apparatus including a sensor responsive to a substance in exhaled breath indicative of a disease, characterised in that the apparatus includes a vibratory expiratory

therapy device arranged to provide an alternating resistance to expiratory flow of the user, and that the sensor is located in an expiratory flow path such that it is exposed to vibratory expiratory flow from the user.

The sensor may be selected from a group including chemiresistive sensors, gas chromatography sensors and ion mobility sensors. The vibratory expiratory therapy device may include a rocker arranged to open and close an opening to atmosphere during exhalation. The sensor may be exposed only to expiratory flow and not to inspiratory flow. The sensor may be responsive to a biomarker indicative of a respiratory disease. The sensor may be mounted with a housing of the therapy device. Alternatively, the sensor may be located remotely of the therapy device and be connected with the therapy device via a gas sampling tube. The sensor may also be responsive to substances in the therapy device indicative that the device needs cleaning. The apparatus may be arranged to monitor selectively substances in a part only of the respiratory cycle. The apparatus may include a display arranged to provide a display of detected substance or of a disease associated with the detected substance.

Respiratory monitoring apparatus according to the present invention will now be described, by way of example, with reference to the accompanying drawing which is an exploded view of the apparatus.

The apparatus comprises a respiratory therapy device 100 and a breath sensor 200.

The respiratory therapy device is in the form of a hand-held positive expiratory pressure (PEP) device, that is, a device that presents a resistance to expiration through the device. Such devices are now widely used to help treat patients suffering from a range of respiratory impairments, such as chronic obstructive pulmonary disease, bronchitis, cystic fibrosis and atelectasis. More recently, such devices that provide an alternating resistance to flow have been found to be particularly effective. One example of such a device is sold under

the trade mark Acapella (a registered trade mark of Smiths Medical) by Smiths Medical and is described in US6581598, US6776159, US7059324 and US7699054.

The respiratory therapy device 100 comprises a rocker assembly 1 contained within an outer housing 2 provided by an upper part 3 and a lower part 4 of substantially semi-cylindrical shape. The device is completed by an adjustable dial 5 of circular section. The outer housing 2 contains an air flow tube 6 with a breathing inlet 7 at one end and an inspiratory inlet 8 at the opposite end including a one-way valve (not shown) that allows air to flow into the air flow tube but prevents air flowing out through the inspiratory inlet. The air flow tube 6 has an outlet opening 10 with a non-linear profile that is opened and closed by a conical valve element 11 mounted on a rocker arm 12 pivoted midway along its length about a transverse axis. The air flow tube 6 and housing 2 provide a structure with which the rocker arm 12 is mounted. At its far end, remote from the breathing inlet 7, the rocker arm 12 carries an iron pin 13, which interacts with the magnetic field produced by a permanent magnet (not visible) mounted on an adjustable support frame 14. The magnet arrangement is such that, when the patient is not breathing through the device, the far end of the rocker arm 12 is held down such that its valve element 11 is also held down in sealing engagement with the outlet opening 10. A cam follower projection 15 at one end of the support frame 14 locates in a cam slot 16 in the dial 5 such that, by rotating the dial, the support frame 14, with its magnet, can be moved up or down to alter the strength of the magnetic field interacting with the iron pin 13. The dial 5 enables the frequency of operation and the resistance to flow of air through the device to be adjusted for maximum therapeutic benefit to the user.

When the patient inhales through the breathing inlet 7 air is drawn through the inspiratory inlet 8 and along the air flow tube 6 to the breathing inlet. When the patient exhales, the one-way valve in the inspiratory inlet 8 closes, preventing any air flowing out along this path. Instead, the expiratory pressure is applied via the air flow tube 6 to the underside of the valve element 11 on the rocker arm 12 causing it to be lifted up out of the opening 10 against the magnetic attraction, thereby allowing air to flow out to atmosphere. The opening 10 has a non-linear profile, which causes the effective discharge area to increase

as the far end of the rocker arm 12 lifts, thereby allowing the arm to fall back down and close the opening. As long as the user keeps applying sufficient expiratory pressure, the rocker arm 12 will rise and fall repeatedly as the opening 10 is opened and closed, causing a vibratory, alternating or oscillating interruption to expiratory breath flow through the device. Further information about the construction and operation of the device is not essential for an understanding of the invention but can be found in US6581598, US7059324 and US7699054.

The sensor 200 is mounted in the housing 2 where it is exposed to expiratory breath from the patient, such as within the air flow tube 6. In this location it can be seen that the sensor 200 is exposed to both inspiratory and expiratory breath. This may not be a problem. However, it may be that the gas flowing over the sensor 200 during the inspiratory breath (directly from atmosphere) dilutes the responsive of the sensor to the biomarker or other substance of interest. If this is the case, the sensor could be located instead at a point downstream from the valved opening 10, in an extension of the opening, so that the sensor is only exposed to exhaled breaths. The sensor 200 could be of various different types or could include two or more different types of sensor depending on the biomarker being monitored. For example, the sensor could be a gas chromatography sensor, a mass spectroscopy sensor, an ion mobility spectrometer sensor or other type of conventional sensor.

In the present example the sensor 200 is a chemiresistive sensor of the kind including an array of elements of different mixtures of polymer and conductive powder such as carbon. The resistance of each element varies as volatile organic compounds are absorbed by the polymers causing them to expand and increase resistance through the conductive powder. By monitoring the responses of different ones of the elements in the array it is possible to identify the nature of the compound. Further details of such sensors can be seen in US6716638, US6703241, US6627154, US6746960, US6537498, US5571401, US5698089, US5788833, US5911872, US6093308, US6331244, US6010616, US6017440, US5959191, US5951846, US7040139, US7201035, US7819803 and others.

By incorporating the sensor into a vibratory expiratory therapy device the sensor is exposed to an increased proportion of deep lung breath and an increased proportion of biomarkers released more readily from the lung tissue by the vibration produced. A further advantage is that the sensor is exposed to multiple breaths during the progress of the therapy session, thereby enabling more reliable sensing by averaging and or alternatively by integration.

If the sensor is too large or heavy to be contained within the housing of the therapy device it could be located remotely and connected with it via a gas sampling tube, which may require some form of pump to supply a sample of the exhaled gas to the sensor.

The apparatus may include a display of the detected substance or of a disease associated with the detected substance. If the sensor is light enough and small enough it may be possible to provide a display on the housing 2 of the therapy device but, more usually, the output of the sensor 200 is supplied by a unit 201 on the housing, which transmits a signal to a remote processing unit 202 via a cable or by a wireless link, such as by radiofrequency signals with the Bluetooth protocol. The processing unit 202 may have a display 203 and a store 204 for recording the sensor output for subsequent downloading.

The processing unit 202 may have various features. For example, it may be arranged to respond to change in the output of the sensor 200 over time, that is, from session to session, so as to indicate an improvement or deterioration in the user's condition. The processing unit may employ artificial intelligence software to analyse the sensor output and provide an indication of the user's condition. The sensor and processing unit could be arranged to detect whether or not the user has been smoking. The processing unit may be arranged also to receive signals representative of use of the therapy device and provide information showing how the user's condition varies with use of the therapy device. Various upper and lower baselines could be set and information given to the user if these baselines are crossed. Signals could be averaged, filtered or integrated as necessary to provide information

in an appropriate form. The sensor and processing unit could be arranged to respond to the presence of specific biomarkers in users with specific diseases, such as the presence of pseudomonas aeruginosa pathogen in cystic fibrosis patients. The invention is particularly suitable for detecting the respiratory diseases.

The apparatus may have a test feature whereby the sensor is arranged to detect the presence of substances, such as pathogens, inside the therapy device indicating that the device needs cleaning. This could be achieved, for example, by monitoring for the presence of such substances during both inspiratory and expiratory flow through the device. If the pathogen-indicating response is substantially the same during inspiratory and expiratory breaths this is indicative that the pathogen is within the therapy device and not in the user's lungs.

The apparatus could be arranged to detect the presence of airborne pollutants in the lungs that could be harmful to the user, such as benzene and formaldehyde.

The processing unit could be arranged to monitor selectively for substances in a particular part of the respiratory cycle, such as during deep lung expiration only. This could be achieved by selecting a particular part of the waveform of the output from the sensor. Alternatively, the device could have some form of valve arrangement that exposes the sensor to breath flow only during selected parts of the respiratory cycle.

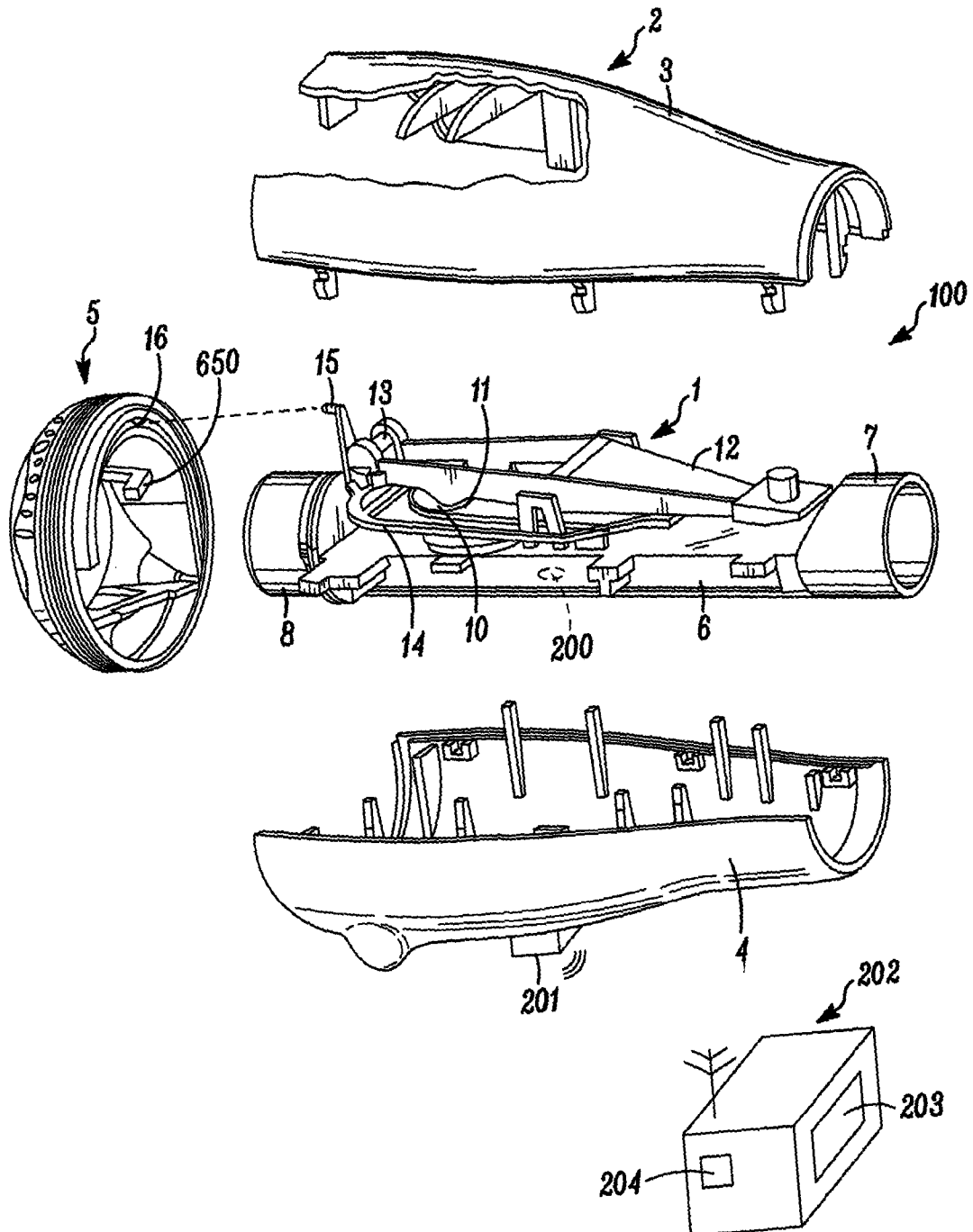
In this application the term "gas" is used to include "vapour".

The invention is not limited to vibratory expiratory therapy devices of the kind described above but could be used with other expiratory therapy devices that produce a vibration within the bronchial passages.

CLAIMS

1. Respiratory monitoring apparatus including a sensor (200) responsive to a biomarker in exhaled breath, characterised in that the apparatus includes a vibratory expiratory therapy device (100) arranged to provide an alternating resistance to expiratory flow of the user, and that the sensor (200) is located in an expiratory flow path (6) such that it is exposed to vibratory expiratory flow from the user.
2. Respiratory monitoring apparatus including a sensor (200) responsive to a substance in exhaled breath indicative of a disease, characterised in that the apparatus includes a vibratory expiratory therapy device (100) arranged to provide an alternating resistance to expiratory flow of the user, and that the sensor (200) is located in an expiratory flow path (6) such that it is exposed to vibratory expiratory flow from the user.
3. Apparatus according to Claim 1 or 2, characterised in that the sensor (200) is selected from a group including chemiresistive sensors, gas chromatography sensors and ion mobility sensors.
4. Apparatus according to any one of the preceding claims, characterised in that the vibratory expiratory therapy device (100) includes a rocker (12) arranged to open and close an opening (10) to atmosphere during exhalation.
5. Apparatus according to any one of the claims, characterised in that the sensor (200) is exposed only to expiratory flow and not to inspiratory flow.
6. Apparatus according to any one of the preceding claims, characterised in that the sensor (200) is responsive to a biomarker indicative of a respiratory disease.

7. Apparatus according to any one of the preceding claims, characterised in that sensor (200) is mounted with a housing (2) of the therapy device (100).
8. Apparatus according to any one of Claims 1 to 6, characterised in that the sensor is located remotely of the therapy device and is connected with the therapy device via a gas sampling tube.
9. Apparatus according to any one of the preceding claims, characterised in that sensor (200) is also responsive to substances in the therapy device (100) indicative that the device needs cleaning.
10. Apparatus according to any one of the preceding claims, characterised in that the apparatus is arranged to monitor selectively substances in a part only of the respiratory cycle.
11. Apparatus according to any one of the preceding claims, characterised in that the apparatus includes a display (203) arranged to provide a display of detected substance or of a disease associated with the detected substance.



INTERNATIONAL SEARCH REPORT

International application No
PCT/GB2017/000034

A. CLASSIFICATION OF SUBJECT MATTER
INV. G01N33/497
ADD.

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)
G01N

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

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y A	US 2007/265509 A1 (BURCH TIMOTHY E [US] ET AL) 15 November 2007 (2007-11-15) paragraphs [0037], [0042] - [0047] -----	1-8,10, 11 9
Y A	WO 2015/008013 A1 (SMITHS MEDICAL INT LTD [GB]) 22 January 2015 (2015-01-22) page 1 - page 6; figures 1, 3 ----- -/--	1-8,10, 11 9



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

"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

31 May 2017

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08/06/2017

Name and mailing address of the ISA/

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INTERNATIONAL SEARCH REPORT

International application No

PCT/GB2017/000034

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	SIMONE SCARLATA ET AL: "Exhaled breath analysis by electronic nose in respiratory diseases", EXPERT REVIEW OF MOLECULAR DIAGNOSTICS, vol. 15, no. 7, 11 May 2015 (2015-05-11), pages 933-956, XP055375157, GB ISSN: 1473-7159, DOI: 10.1586/14737159.2015.1043895 sections entitled "Basic principles of breath analysis using electronic nose" and "Experimental evidences supporting potential clinical applications of the e-nose technology for exhaled breath analysis in respiratory devices" -----	1-11
A	US 2014/150792 A1 (CHRISTOPHER KENT L [US] ET AL) 5 June 2014 (2014-06-05) paragraphs [0027], [0085] -----	1-11

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/GB2017/000034

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