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## SOUTH AFRICAN COMPLETE
## PATENT APPLICATION

**Title:** GAS FLOW MEASUREMENT APPARATUS

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**Applicant:**

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FORM P1

REPUBLIC OF SOUTH AFRICA

PATENTS ACT, 1978

**APPLICATION FOR A PATENT AND ACKNOWLEDGEMENT OF RECEIPT**

**[Section 30 (1)-Regulation 22]**

The granting of a patent is hereby requested by the undermentioned applicant on the basis of the present application.

| Official Application No. | | | Applicant's or Agent's Reference |
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| 54 | Title of invention |
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GAS FLOW MEASUREMENT APPARATUS

The applicant claims priority as set out on the accompanying Form P.2. The earliest priority claimed is
COUNTRY: ZA NUMBER: 2019/02574 DATE: 2019/04/24

~~This application is for a patent of addition to patent application No.~~

| 21 | 01 | |
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~~This application is a fresh application in terms of section 37 and based on Application No.~~

| 21 | 01 | |
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This application is accompanied by:

| | | |
|---|---|---|
| X | 1. | A single copy of a complete specification of 17 pages. |
| X | 2. | Drawings of 4 sheet(s). |
| X | 3. | Publication particulars and abstract(Form P8) |
| X | 4. | A copy of a figure of the drawing (if any) for the abstract |
| | 5. | Assignment of invention |
| | 6. | Certified priority document(s) |
| | 7. | Translation(s) of the priority document(s) |
| | 8. | Assignment of priority rights |
| X | 9. | A copy of the Form P.2 and the specification of S.A Patent Application (if applicable). |
| | 10. | A declaration and power of attorney on Form P3 |
| | 11. | Statement on the use of indigenous Biological Resource, Genetic Resource, Traditional Knowledge or Use on Form P26 |
| X | 12. | Other Supporting Document |
| X | 13. | Other Supporting Document |
| X | 14. | Other Supporting Document |
| X | 15. | Other Supporting Document |

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Dated this 4th day of May 2020

**Submitted online by : Von Seidels**

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Signature of Applicant(s)

This is returned to the applicant's address for service as proof of lodging.

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Official Date Stamp

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Registrar of Patents

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REPUBLIC OF SOUTH AFRICA
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**COMPLETE SPECIFICATION**
**[Section 30(1) – Regulation 28]**

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TITLE OF INVENTION

| | |
|---|---|
| 54 | **GAS FLOW MEASUREMENT APPARATUS** |

# GAS FLOW MEASUREMENT APPARATUS

## CROSS-REFERENCE TO RELATED APPLICATIONS

This application claims priority from South African provisional patent application number 2019/02574 filed on 24 April 2019, which is incorporated by reference herein.

## FIELD OF THE INVENTION

This invention relates to apparatuses and methods for measuring the flow of a gas. It finds particular application in the measurement of airflow in the artificial ventilation of a patient.

## BACKGROUND TO THE INVENTION

Patients often require artificial ventilation for a number of medical reasons. When a patient is being artificially ventilated it is critical to ensure that the patient is adequately ventilated without causing trauma to the lungs by, for example, overinflating the lungs. Modern ventilator machines enable an operator to configure the volume of air to be moved into and out of the lungs, which is referred to as the tidal volume. These machines may be equipped with air flow sensors that enable the machine to maintain the tidal flow as configured.

Generally, such sensors work on one of two principles. In a first principle of operation, movement of gas through the sensor causes an impeller to rotate. A conversion factor is used to obtain a flow rate of the gas, such as air, from the number of revolutions per time interval. A second principle uses a thermal measurement principle. One such sensor is the so-called "hot wire anemometer" in which a heated element is temperature regulated using electrical current. The flow of gas causes a thermal transfer from the element, which in turn requires a change in the electrical current to restore the element to its regulated temperature. This change in electrical current is measurable and a conversion factor is used to convert the change in electrical current to a gas flow rate.

Patients may also be artificially ventilated using a hand-operated self-inflating bag, referred to as a bag valve mask ("BVM"), which generally is not equipped with a tidal flow sensor. The so-called "bagging" of a patient carries with it a particular danger of hyperventilation in that the operator may administer too many breaths per time interval or may administer a volume of air to the patient that exceeds their natural lung capacity.

The lung capacity of prematurely born babies is so minute, in the order of a few millilitres, that the risk of overinflating their lungs when artificially ventilated is very high. Although BVM’s are manufactured in different sizes, e.g. adult, small adult/paediatric, and paediatric, even the smallest BVM’s have a capacity far exceeding that of some premature babies’ lungs. Furthermore, while the above-mentioned flow sensors may provide adequate sensitivity and accuracy for tidal flow measurement of adult patients and even some paediatric patients, the minute lung capacity of premature babies renders these sensors inadequate.

The invention disclosed herein addresses these issues, at least to some extent, and may offer further advantages.

The preceding discussion of the background to the invention is intended only to facilitate an understanding of the present invention. It should be appreciated that the discussion is not an acknowledgment or admission that any of the material referred to was part of the common general knowledge in the art as at the priority date of the application.

**SUMMARY OF THE INVENTION**

A gas flow measurement apparatus comprising a tube having a first gas permeable electrode and a second gas permeable electrode axially spaced apart within the tube, each electrode having a substantially planar shape and extending transverse a central axis of the tube, wherein at least the first electrode has a plurality of protrusions extending from a surface thereof, the electrodes being electrically connectable to an electricity source such that a resulting electric field at or near the protrusions causes ionisation of gas in the vicinity of the first electrode, the electrodes further being electrically connectable to a detection circuit configured to detect movement of the ionised gas from the first electrode to the second electrode.

Further features provide for the electrodes to have ports spaced about and extending through each electrode to render the electrode gas permeable between its major opposed sides; for the ports to be formed by a honeycomb structure, alternatively by a lattice structure, and further alternatively by parallel slits.

Further features provide for the protrusions extending from the surface of the first electrode to extend in the direction of the second electrode; and for the protrusions to have sharp outermost tips. In one embodiment, the protrusions are elongate needle-like protrusions. In another embodiment, the protrusions are conical.

Further features provide for the electrodes to be manufactured from, or the surface thereof at least partially coated with, a metal with a conductivity of at least 1 x $10^7$ Siemens per metre at 20℃; and for the electrodes to be manufactured from, or the surface thereof at least partially coated with, a metal selected from the group consisting of Aluminium, Copper, Silver, and Gold.

Further features provide for the diameter of the tube to be between 1.5 millimeter (mm) and 25mm; for the diameter of the tube to be between 1.5mm and 10mm; for the diameter of the tube to be between 1.5mm and 5mm; and for the diameter of the tube to be between 1.5mm and 2.5mm, preferably 2mm.

Further features provide for the electrodes to be spaced apart within the tube at a distance between 0,5mm and 5mm; for the electrodes to be spaced apart within the tube at a distance between 0,5mm and 2,5mm, preferably 1mm.

Further features provide for the apparatus to include an inlet connector in fluid communication with a first end of the tube and adapted to connect the apparatus to an air supply; for the inlet connector to be adapted to connect the apparatus to an artificial ventilation device; and for the inlet connector to be connectable to a standard 22mm or 15mm ventilator or BVM output connector.

Further features provide for the apparatus to include an outlet connector in communication with a second end of the tube, opposite the first end, and adapted to connect the apparatus to a patient ventilation component; and for the outlet connector to be adapted to connect the apparatus to a patient ventilation component selected from the group consisting of an endotracheal tube, a ventilation mask, and a tracheostomy tube.

The invention extends to an electrode for a gas flow measuring apparatus, the electrode comprising a substantially planar gas permeable body with a plurality of protrusions extending from a surface thereof, the electrode arranged to be positioned in a tube axially spaced apart from a complementary electrode such that the electrodes are electrically connectable to an electricity source with a resulting electric field at or near the protrusions causing ionisation of gas in the vicinity of the electrode.

Further features provide for the electrode to have ports spaced about and extending through the planar electrode to render the electrode gas permeable between its major opposed sides; for the ports to be formed by a honeycomb structure, alternatively by a lattice structure, and further alternatively by parallel slits.

Further features provide for the protrusions extending from the surface of the electrode to have sharp outermost tips. In one embodiment, the protrusions are elongate needles. In another embodiment, the protrusions are substantially conical in shape.

Further features provide for the electrode to be manufactured from, or the surface thereof at least partially coated with, a metal with a conductivity of at least 1 x $10^7$ Siemens per metre at 20℃; and for the electrode to be manufactured from, or the surface thereof at least partially coated with, a metal selected from the group consisting of Aluminium, Copper, Silver, and Gold.

Further features provide for the electrode to be round with a diameter between 1.5millimeter (mm) and 25mm; for the diameter of the electrode to be between 1.5mm and 10mm; for the diameter of the electrode to be between 1.5mm and 5mm; and for the diameter of the electrode to be between 1.5mm and 2.5mm, preferably 2mm.

The invention further extends to a method of measuring gas flow comprising providing a tube having a first and a second gas permeable electrode axially spaced apart within the tube, each electrode having a substantially planar shape and extending transverse a central axis of the tube, wherein at least the first electrode has a plurality of protrusions extending from a surface thereof; electrically connecting the electrodes to an electricity source such that a resulting electric field at or near the protrusions causes ionisation of gas in the vicinity of the first electrode; electrically connecting the electrodes to a detection circuit configured to detect movement of the ionised gas from the first electrode to the second electrode by a flow of gas through the tube; and producing an output signal at an output of the detection circuit indicative of a flow of gas through the tube.

Further features provide for the step of electrically connecting the electrodes to an electricity source to comprise applying an electrical potential below 300 Volt (V) to the electrodes, preferably below 80V, and more preferably below 50V.

Further features provide for the method to include monitoring the output signal of the detection circuit for a signal associated with an alarm condition and, in response to an alarm condition being detected, activating an indicator of the apparatus. The indicator may be a visual indicator such as an LCD display or an LED, or an audible indicator such as a buzzer, or a combination thereof.

An embodiment of the invention will now be described, by way of example only, with reference to the accompanying drawings.

## BRIEF DESCRIPTION OF THE DRAWINGS

In the drawings:

| | |
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| Figure 1 | is a schematic representation of a gas flow measurement apparatus in accordance with a first aspect of the invention; |
| Figure 2 | is a schematic representation of a detection circuit that is connectable to the apparatus of Figure 1 to detect gas flow; |
| Figure 3 | is a screen capture of an oscilloscope display displaying a voltage measured across the electrodes of the apparatus of Figure 1; |
| Figure 4A | is a three-dimensional view of a first embodiment of an electrode suitable for use in the apparatus of Figure 1; |
| Figure 4B | is a front view of the electrode of Figure 4A; |
| Figure 5A | is a three-dimensional view of a complementary electrode to the electrode of Figure 4A; |
| Figure 5B | is a front view of the complementary electrode of Figure 5A; |
| Figure 6 | is a section view of the electrode of Figure 4A and complementary electrode of Figure 5A positioned in a tube; |
| Figure 7 | is a front view of a second embodiment of an electrode suitable for use in the apparatus of Figure 1; |
| Figure 8 | is a front view of a complementary electrode to the electrode of Figure 7; and |
| Figure 9 | is a flow chart of a method for measuring gas flow. |

## DETAILED DESCRIPTION WITH REFERENCE TO THE DRAWINGS

Embodiments of a gas flow measurement apparatus and electrodes therefor are disclosed below.

The gas flow measurement apparatus may comprise a tube having two spaced apart electrodes therein. The electrodes are gas permeable and each has a substantially planar shape. On at least one of the electrodes protrusions are provided, such as needles or spikes, extending from a surface of the relevant electrode.

When connected to a source of electricity an electric field that is produced at or near the protrusions causes ionisation of gas in the vicinity of the relevant electrode. Movement of the ionised gas (due to gas flow) is detectable by a detection circuit attached to the electrodes.

A gas flow measurement apparatus is shown schematically in Figure 1. The apparatus (1) includes a tube (3) with a first and second electrode (10, 20) therein. Both electrodes (10, 20) are substantially planar, or disc-like, in shape with a pair of major opposed surfaces (11, 12, 21, 22) and are gas permeable. In the present embodiment, the gas permeability is provided by a number of apertures or ports (13, 23) provided in each of the respective electrodes (10, 20) that extend through the planar body of the electrodes from one surface (11, 21) to the other (12, 22). The gas permeability is schematically indicated in Figure 1 by the arrows extending axially through these ports (23) in the second electrode (20). The electrodes (10, 20) are located at axially spaced apart positions within the tube (3) with their planar bodies orientated parallel to each other, transverse a central axis of the tube.

The first electrode (10), has a plurality of protrusions (14) extending from a surface (12) thereof. In the present embodiment of the apparatus (1), the protrusions (14) are substantially conical in shape, with sharp points, and extend normally from the surface (12) in the direction of the second electrode (20). The electrodes (10, 20) are provided with electrical terminals or wires (30) that enable the electrodes to be electrically connected to an electricity source (40), optionally with additional electronic components (42) in series and/or parallel therewith. The voltage of the electricity source (40), applied to the electrodes (10, 20), results in an electric field between the electrodes. Those skilled in the art will appreciate that electric fields are stronger at conductor edges and sharp points thereof. This is therefore the case in the vicinity of the first electrode (10) and, more particularly, in the vicinity of the sharp protrusions (14).

If a sufficiently high voltage is applied, so as to result in a sufficiently high electric field near the first electrode (10), ionisation of gas in the vicinity of the first electrode will occur. This is indicated schematically in Figure 1 as a cloud of ionised gas (50). The presence of the sharp protrusions (14) has the effect that a lower voltage may be required to cause ionisation of gas in the vicinity of the electrode than would be required in the absence thereof.

If a flow of gas through the tube is induced, for example if a person breathes through the tube, the ions will move in the direction of the second electrode (20) as indicated by the arrows with dashed lines. This, in turn, will cause a change in voltage measured between the two electrodes (10, 20) which is detectable by a detection circuit (60) connected thereto. The spacing between the first electrode (10) and the second electrode (20) is selected to enable the detection of the ions and the required spacing depends on a number of factors, such as the overall scale of the apparatus, the shape and configuration of the protrusions (14), the magnitude of the applied voltage, humidity, and the required upper and lower measurement limits of the apparatus, to name a few examples. The spacing between electrodes (10, 20) may therefore have to be carefully selected for each particular configuration and intended environment.

Figure 2 shows an exemplary detection circuit (60) that may be connected to the electrodes (10, 20) to detect the flow of gas through the tube (3). The supply voltage of the electricity source (40) is rectified by a series diode (D1) and connected to the electrode (10) through a series resistor (R1). An inverting operational amplifier circuit, as is well known in the art, followed by a low pass filter stage produces an output voltage ($V_o$) that varies as a result of gas flow through the apparatus (1). Figure 3 shows a screen capture of an oscilloscope used to measure the voltage across the electrodes (10, 20) as air is blown through the tube (3). The dip or drop in the output voltage ($V_o$) shown in Figure 3 occurs as a user exhales through the tube (3).

The detection circuit (60) amplifies the voltage across the electrodes (10, 20) and filters out high frequency noise. When correctly calibrated, the output voltage ($V_o$) of the detection circuit (60) may be computationally converted into a volume of gas having flowed through the apparatus (1). It will be appreciated by those skilled in the art that numerous other circuits may be utilised as detection circuit and may be followed by a number of further stages, such as converting the output to a digital value by means of an analogue-to-digital converter. Further computation of the output signal may be performed on the digitised readings by means of a microcontroller or a field programmable gate array (FPGA), for example.

Figures 4A and 4B show an embodiment of an electrode (100) that is suitable for use in the apparatus (1) as the electrode (10) provided with protrusions (14). The electrode (100) is disc-like with a round, planar body (102) with hexagonally shaped ports (104) spaced about the body. The hexagonally shaped ports (104) extend through the body (102) thus rendering the electrode (100) gas permeable between its major opposed surfaces (105, 107), and gives the electrode a honeycomb-like appearance. The ports (104) near the perimeter of the electrode (100) may only comprise a section of a hexagon where the relevant port is intersected by the outer border (106) of the electrode. The electrode (100) furthermore has conically shaped protrusions (108) spaced about and extending normally from a surface (107) of the electrode, substantially surrounding each of the hexagonally shaped ports (104). The electrode (100) furthermore has two diametrically opposite tabs (110) extending radially therefrom which may be utilised for mechanical and electrical connections to other components of the apparatus.

Figures 5A and 5B show a complementary electrode (120) to the electrode (100) in Figures 4A and 4B. The complementary electrode (120) is substantially similar to the electrode (100) of Figure 4A except that it does not have protrusions, and like features are indicated with like reference numerals.

Both electrodes (100, 120) are coated with a metal having a high conductivity, gold in the present embodiment of each electrode. The electrodes (100, 120) may be coated by means of a sputter process. The high electrical conductivity of the gold further enables the ionisation of gas in the vicinity of the protrusions (108) of the first electrode (100).

Figure 6 is a sectional view of an embodiment of a gas flow measurement apparatus (200) including a tube (202) having the electrode (100) of Figure 4A and the complementary electrode (120) of Figure 5A axially spaced apart within the tube. The tabs (110) of each electrode (100, 120) is affixed or secured in the tube (202) by means of an adhesive or epoxy. To enable the electrodes (100, 120) to be properly positioned in the tube (202) and spaced apart at the appropriate spacing, the tube may be provided with longitudinally extending slots (204) along its inner surface (205) and shaped to each receive a tab (110). A pair of diametrically opposite slots (204) may thus extend from outer ends of the tube (202) partway along the length of the inner surface (205) of the tube and terminate at an axial distance from opposing slots corresponding to the required axial spacing distance of the electrodes (100, 120). The slots (204) may therefore act as guides when the electrodes (100, 120) are inserted into the tube (202) during assembly. It should be appreciated that the apparatus (200) shown in Figure 6 may itself be positioned within a larger tube as may be required for the intended use of the apparatus.

Figure 7 shows a second embodiment of an electrode (150) that is suitable for use in the apparatus (1) as the electrode (10) provided with protrusions (14). Like features of this electrode (150) found in the electrode (100) of Figure 4A are indicated with like reference numerals. The electrode (150) has a disc-like or round, planar body (102) with parallel slits (154) spaced along and extending through the planar body (102) of the electrode. The parallel slits (154) render the electrode (150) gas permeable between its major opposed surfaces (156, 160). The electrode (150) furthermore has conically shaped protrusions (158) arranged in rows and extending normally from the surface (156) on one side between the slits (154). The electrode (150) also has two diametrically opposite, radially extending tabs (110) which may be utilised for mechanical and electrical connections to other components of the apparatus.

Figure 8 shows a complementary electrode (170) to the electrode (150) of Figure 7. The complementary electrode (170) is substantially identical to the electrode (150) of Figure 7 except that it does not have protrusions, and like features are indicated with like reference numerals.

Figure 9 is a flow chart indicating steps in a method (900) for measuring gas flow. The method (900) may be performed using an apparatus (1) as described above. The method includes providing (902) a tube having a first and a second gas permeable electrode axially spaced apart within the tube. As described above with reference to Figures 1 to 8, the electrodes each have a substantially planar or disc-like shape and are positioned in the tube so that they extend transverse a central axis of the tube. The first electrode has a plurality of protrusions extending from a surface thereof.

The electrodes are then electrically connected (904) to an electricity source, causing (906) a resulting electric field at or near the protrusions. This causes (908) ionisation of gas in the vicinity of the first electrode. The voltage required to cause a sufficiently high electric field to, in turn, cause gas ionisation is dependent on the shape of the protrusions, the size of the electrodes and the spacing of the electrodes. The Applicant anticipates that, using electrodes as shown in Figures 4A and 5A having a diameter of approximately 2mm, and spaced apart at about 0.5 to 1mm, the voltage required is between about 50V and 80V. As mentioned above, the electrodes may be coated by means of a sputter process to aid gas ionisation. The Applicant anticipates that the electrodes shown in Figure 4A and 5A having a gold coating may enable the ionisation of gas at such low voltages, i.e. between 50V and 80V. Other metals having a conductivity in the same order, such as silver, aluminium, and the like may also suffice.

The electrodes are electrically connected (910) to a detection circuit configured to detect movement of the ionised gas from the first electrode to the second electrode by a flow of gas through the tube. An output signal is produced (912) at an output of the detection circuit to indicate a flow of gas through the tube.

In some embodiments, the apparatus may be provided with indicators that allow an operator to monitor the flow of gas through the apparatus. For example, in an application where the apparatus is used to monitor the respiration of a patient, the apparatus may be configured to alert the user when the patient is under- or over-ventilated. Exemplary indicators are LCD screens, 7-segment displays, LED indicators, and even audible indicators such as a buzzer.

The electrodes described above have, in those particular embodiments, protrusions that are conical in shape with sharp points. In some embodiments, the protrusions may be needle-like, elongate protrusions optionally having sharpened outer tips. The electrodes described above are furthermore gas permeable, in the direction of their major opposed surfaces, due to the apertures or ports defined therein. In other embodiments, the electrodes may have a mesh-like construction to provide gas permeability.

The electrodes in the embodiments above have also been arranged such that the protrusions of the first electrode point toward the second electrode. However, in some embodiments the electrodes may be arranged such that the protrusions of the first electrode point away from the second electrode.

The embodiments described above include two electrodes that detect gas flow from the first electrode to the second electrode and thus measures gas in one direction. It is envisaged that the apparatus may have three spaced apart electrodes of which the centre electrode may be provided with protrusions. The apparatus may then detect the flow of gas in a first direction from the centre electrode to one of the outer electrodes, and to detect the flow of gas in a second direction from the centre electrode to the other of the two outer electrodes. This will therefore provide bi-directional measurement.

Alternatively, two of the apparatuses as described above may be connected in-line in a “back-to-back” fashion such that the first apparatus is arranged to measure gas flow in a first direction and the second apparatus is arranged to measure gas flow in a second direction, opposite the first direction.

The invention disclosed herein therefore provides a gas flow measurement apparatus that has no moving parts and which is capable of being miniaturised. This miniaturisation allows the apparatus to be utilised for measuring the artificial ventilation of neonates and even prematurely born neonates. What is more, the design of the apparatus enables it to be a disposable component. This is especially advantageous for use in medical applications where the prevention of the spread of pathogens is paramount, particularly with immunocompromised patients. The tube of the apparatus containing the electrodes may simply be detached from the back-end device, such as the ventilator, and discarded to be replaced by a new and sterile tube for a following patient.

The apparatus may be provided in a sterile package, thereby allowing rapid removal from the packaging and replacement of a discarded apparatus without requiring any further disinfecting.

To further facilitate the use of the apparatus with artificial ventilation protocols, one end of the apparatus may have a standardised inlet connector that forms a complementary fit with an output connector of a ventilation device, such as a ventilator or a BVM. Exemplary standard connectors are 15mm and 22mm connectors. An opposite end of the apparatus may have a standardised output connector that forms a complementary fit with a patient ventilation component, such as an endotracheal tube, a ventilation mask, or a tracheostomy tube. The apparatus may therefore fit in-line between a ventilation source and the relevant ventilation component engaging the patient, thereby enabling the apparatus to measure the tidal flow.

During protracted periods of ventilation, the humidity of a patent’s breath may cause condensation to form on the electrodes of the apparatus. A ventilation protocol in which the apparatus is used may therefore require the tube containing the electrodes to be replaced periodically. Due to the tube being easily detachable from the ventilator, and easily and quickly replaceable, the apparatus will enable any such prescribed replacement to be performed without undue interference with the ventilation procedure.

The extent of miniaturisation that the design of the electrodes allow furthermore enables the apparatus to utilise the principle of operation, i.e. the ionisation of gas and detecting the movement thereof, using voltages that do not pose a danger to a patient. The miniaturisation of the electrode design has furthermore enabled the apparatus to be sensitive enough to measure volumetric flow rates as low as 3ml per second and with an operational range of between 3ml per second and 30ml per second.

It is further envisaged that the apparatus may be connectable to a mobile device of an operator, such as a smartphone, from which it may be powered and which may provide a user interface. The mobile device may furthermore be utilised to perform at least some of the processing of the output signal produced by the detection circuitry.

The application of the apparatus is also by no means limited to measuring the ventilation of a patient. The apparatus may also have applications in industrial gas flow measuring and wind speed in weather instruments, for example. In such applications, the apparatus and its components need not be miniaturised and may require a considerably scaled-up embodiment of the apparatus.

The foregoing description has been presented for the purpose of illustration; it is not intended to be exhaustive or to limit the invention to the precise forms disclosed. Persons skilled in the relevant art can appreciate that many modifications and variations are possible in light of the above disclosure.

The language used in the specification has been principally selected for readability and instructional purposes, and it may not have been selected to delineate or circumscribe the inventive subject matter. It is therefore intended that the scope of the invention be limited not by this detailed description, but rather by any claims that issue on an application based hereon. Accordingly, the disclosure of the embodiments of the invention is intended to be illustrative, but not limiting, of the scope of the invention, which is set forth in the following claims.

Finally, throughout the specification and accompanying claims, unless the context requires otherwise, the word ‘comprise’ or variations such as ‘comprises’ or ‘comprising’ will be understood to imply the inclusion of a stated integer or group of integers but not the exclusion of any other integer or group of integers.

**CLAIMS:**

1. A gas flow measurement apparatus comprising a tube having a first gas permeable electrode and a second gas permeable electrode axially spaced apart within the tube, each electrode having a substantially planar shape and extending transverse a central axis of the tube, wherein at least the first electrode has a plurality of protrusions extending from a surface thereof, the electrodes being electrically connectable to an electricity source such that a resulting electric field at or near the protrusions causes ionisation of gas in the vicinity of the first electrode, the electrodes further being electrically connectable to a detection circuit configured to detect movement of the ionised gas from the first electrode to the second electrode .

2. The apparatus of claim 1 wherein the electrodes have ports spaced about and extending through each electrode to render the electrode gas permeable between its major opposed sides.

3. The apparatus as claimed in claim 2 wherein the ports are formed by one or more selected from the group consisting of a honeycomb structure, a lattice structure, and parallel slits.

4. The apparatus as claimed in any one of the previous claims wherein the protrusions extend from the surface of the first electrode in the direction of the second electrode.

5. The apparatus as claimed in any one of the previous claims wherein the protrusions have sharp outermost tips.

6. The apparatus as claimed in any one of the previous claims wherein the protrusions are elongate needle-like protrusions.

7. The apparatus as claimed in any one of claims 1 to 5 wherein the protrusions are conical.

8. The apparatus as claimed in any one of the previous claims wherein the electrodes are manufactured from, or the surface thereof at least partially coated with, a metal with a conductivity of at least $1 \times 10^7$ Siemens per metre at 20℃.

9. The apparatus as claimed in any one of claims 1 to 7 wherein the electrodes are manufactured from, or the surface thereof at least partially coated with, a metal selected from the group consisting of Aluminium, Copper, Silver, and Gold.

10. The apparatus as claimed in any one of the previous claims wherein the diameter of the tube is between 1.5 millimetre (mm) and 25mm.

11. The apparatus as claimed in any one of the previous claims wherein the diameter of the tube is between 1.5mm and 10mm.

12. The apparatus as claimed in any one of the previous claims wherein the diameter of the tube is between 1.5mm and 5mm.

13. The apparatus as claimed in any one of the previous claims wherein the diameter of the tube is between 1.5mm and 2.5mm.

14. The apparatus as claimed in any one of the previous claims wherein the electrodes are spaced apart within the tube at a distance between 0,5mm and 5mm.

15. The apparatus as claimed in any one of the previous claims wherein the electrodes are spaced apart within the tube at a distance between 0,5mm and 2,5mm.

16. The apparatus as claimed in any one of the previous claims further including an inlet connector in fluid communication with a first end of the tube and adapted to connect the apparatus to an air supply.

17. The apparatus as claimed in claim 16 wherein the inlet connector is adapted to connect the apparatus to an artificial ventilation device.

18. The apparatus as claimed in any one of claims 1 to 16 wherein the inlet connector is connectable to a standard 22mm or 15mm ventilator or to a bag valve mask output connector.

19. The apparatus as claimed in any one of claims 16 to 18 further including an outlet connector in communication with a second end of the tube, opposite the first end, and adapted to connect the apparatus to a patient ventilation component.

20. The apparatus as claimed in claim 19 wherein the outlet connector is adapted to connect the apparatus to a patient ventilation component selected from the group consisting of an endotracheal tube, a ventilation mask, and a tracheostomy tube.

21. An electrode comprising a substantially planar gas permeable body with a plurality of protrusions extending from a surface thereof, the electrode arranged to be positioned in a tube axially spaced apart from a complementary electrode such that the electrodes are electrically connectable to an electricity source with a resulting electric field at or near the protrusions causing ionisation of gas in the vicinity of the electrode.

22. The electrode of claim 21 having ports spaced about and extending through the electrode to render the electrode gas permeable between its major opposed sides.

23. The electrode as claimed in claim 22 wherein the ports are formed by one or more selected from the group consisting of a honeycomb structure, a lattice structure, and parallel slits.

24. The electrode as claimed in any one of claims 21 to 23 wherein the protrusions have sharp outermost tips.

25. The electrode as claimed in any one of claims 21 to 24 wherein the protrusions are elongate needle-like protrusions.

26. The electrode as claimed in any one of claims 21 to 24 wherein the protrusions are conical.

27. The electrode as claimed in any one of claims 21 to 26 wherein the electrode is manufactured from, or the surface thereof at least partially coated with, a metal with a conductivity of at least $1 \times 10^7$ Siemens per metre at 20℃.

28. The electrode as claimed in any one of claims 21 to 26 wherein the electrode is manufactured from, or the surface thereof at least partially coated with, a metal selected from the group consisting of Aluminium, Copper, Silver, and Gold.

29. The electrode as claimed in any one of claims 21 to 28 having a diameter between 1.5mm and 25mm.

30. The electrode as claimed in any one of claims 21 to 29 having a diameter between 1.5mm and 10mm.

31. The electrode as claimed in any one of claims 21 to 30 having a diameter between 1.5mm and 5mm.

32. The electrode as claimed in any one of claims 21 to 31 having a diameter between 1.5mm and 2.5mm.

33. A method of measuring gas flow comprising:

providing a tube having a first and a second gas permeable electrode axially spaced apart within the tube, each electrode having a substantially planar shape and extending transverse a central axis of the tube, wherein at least the first electrode has a plurality of protrusions extending from a surface thereof;

electrically connecting the electrodes to an electricity source such that a resulting electric field at or near the protrusions causes ionisation of gas in the vicinity of the first electrode;

electrically connecting the electrodes to a detection circuit configured to detect movement of the ionised gas from the first electrode to the second electrode by a flow of gas through the tube; and

producing an output signal at an output of the detection circuit indicative of a flow of gas through the tube.

34. The method as claimed in claim 33 wherein electrically connecting the electrodes to an electricity source includes applying an electrical potential below 300 Volt (V) to the electrodes.

35. The method as claimed in either claim 33 or claim 34 wherein electrically connecting the electrodes to an electricity source includes applying an electrical potential below 80V to the electrodes.

36. The method as claimed in any one of claims 33 to 35 wherein electrically connecting the electrodes to an electricity source includes applying an electrical potential below 50V to the electrodes.

37. The method as claimed in any one of claims 33 to 36 including monitoring the output signal of the detection circuit for a signal associated with an alarm condition and, in response to an alarm condition being detected, activating either or both of a visual indicator and an audible indicator of the apparatus.

38. A gas flow measurement apparatus substantially as described herein with reference to Figure 1 and 2.

39. A gas flow measurement apparatus substantially as described herein with reference to Figure 6.

40. An electrode substantially as described herein with reference to Figure 4A and 4B.

41. An electrode substantially as described herein with reference to Figure 5A and 5B.

42. An electrode substantially as described herein with reference to Figures 7 and 8.

43. A method of measuring gas flow substantially as described herein with reference to Figure 9.

Dated this 1st day of May 2020

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VON SEIDELS Intellectual Property Attorneys

for the applicant

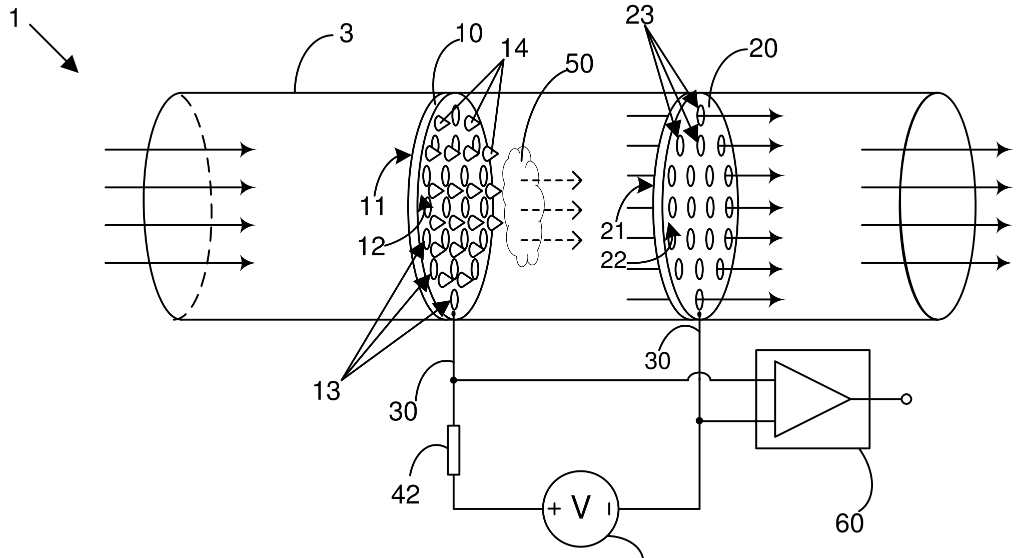


FIGURE 1

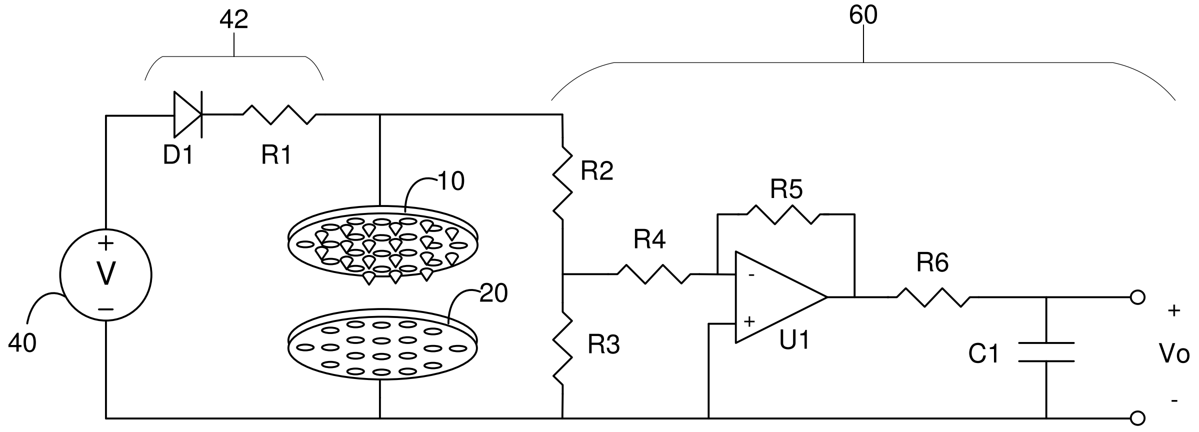


FIGURE 2

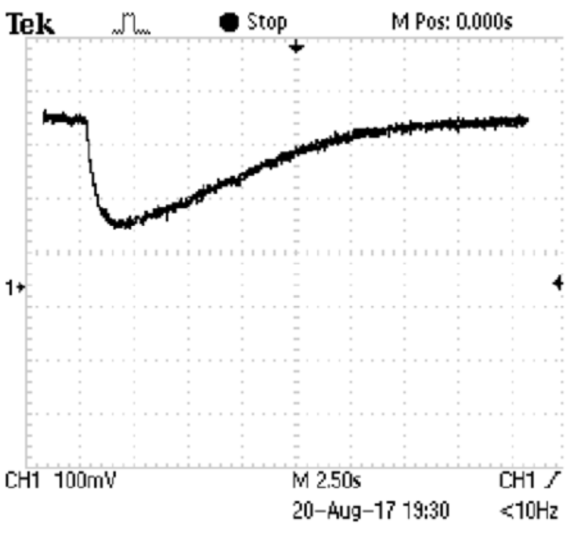


FIGURE 3

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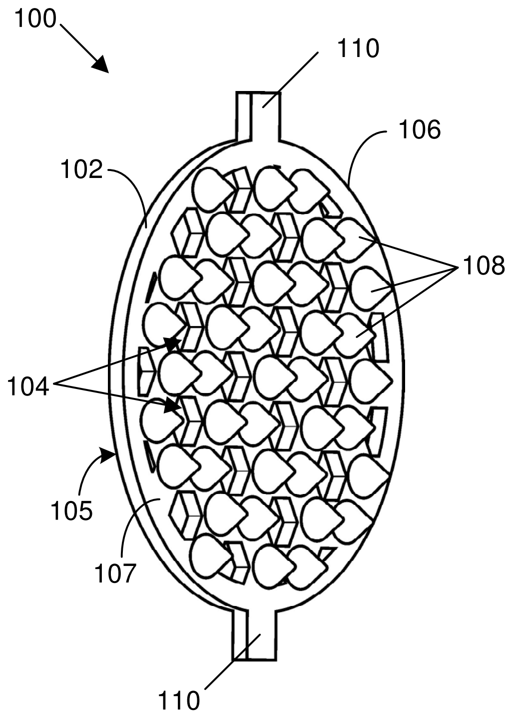


FIGURE 4A

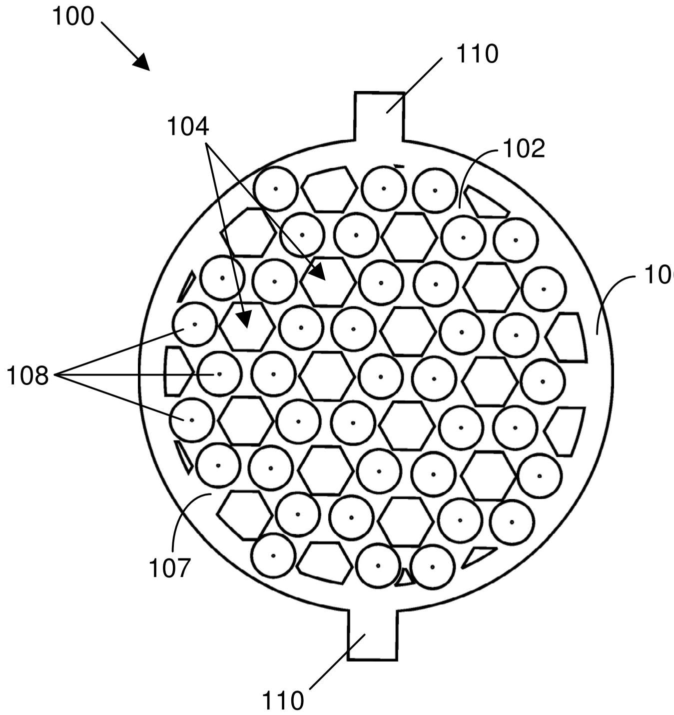


FIGURE 4B

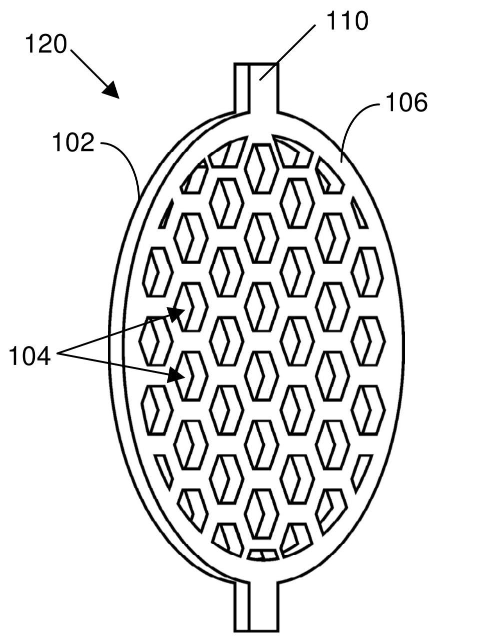


FIGURE 5A

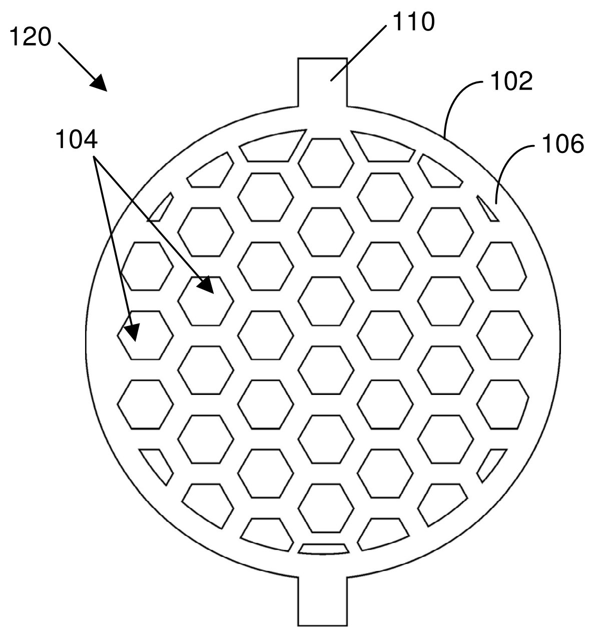


FIGURE 5B

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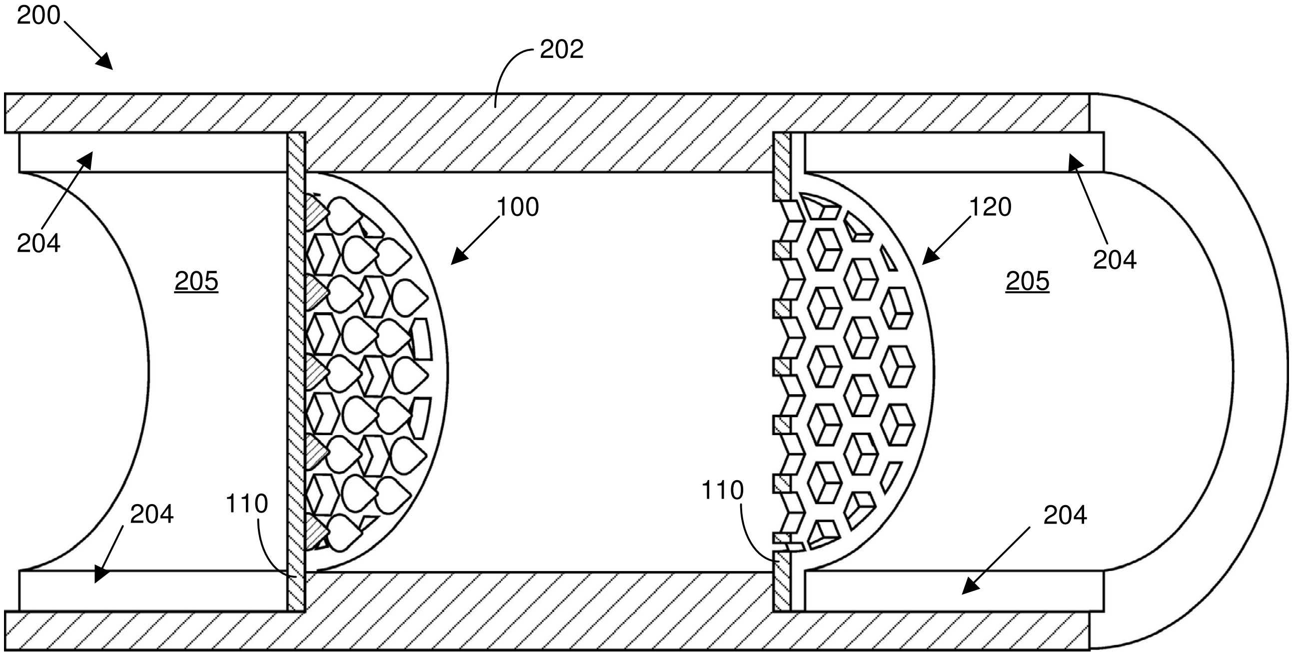


FIGURE 6

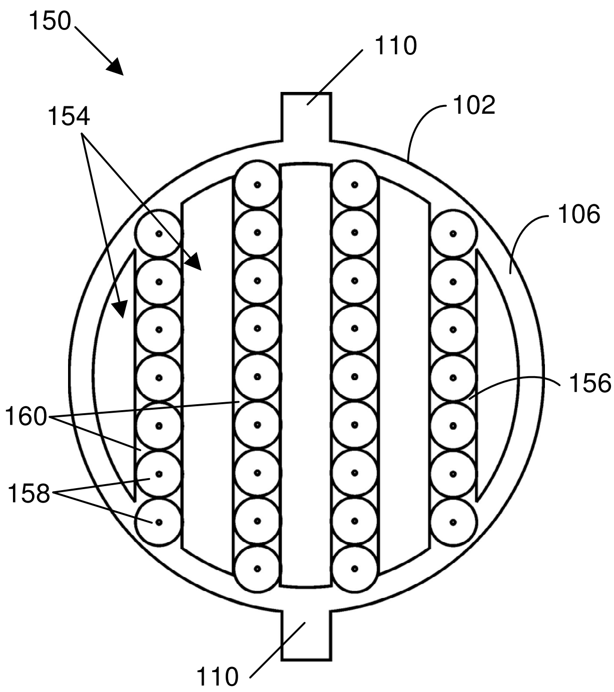


FIGURE 7

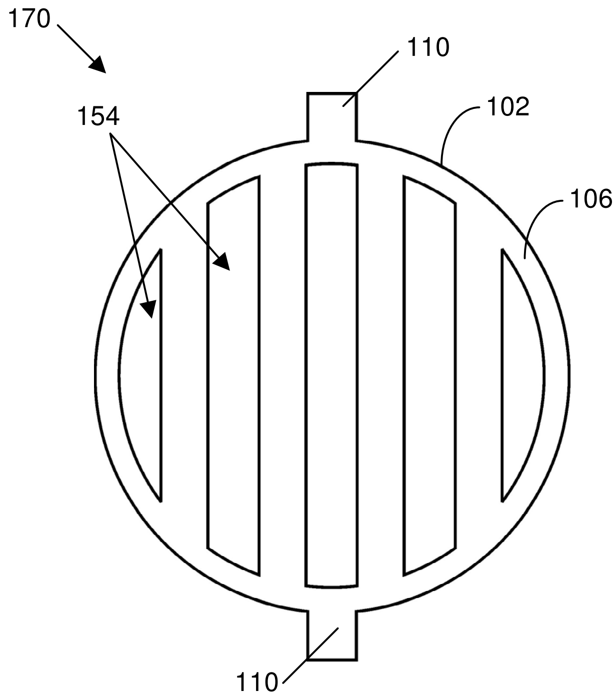


FIGURE 8

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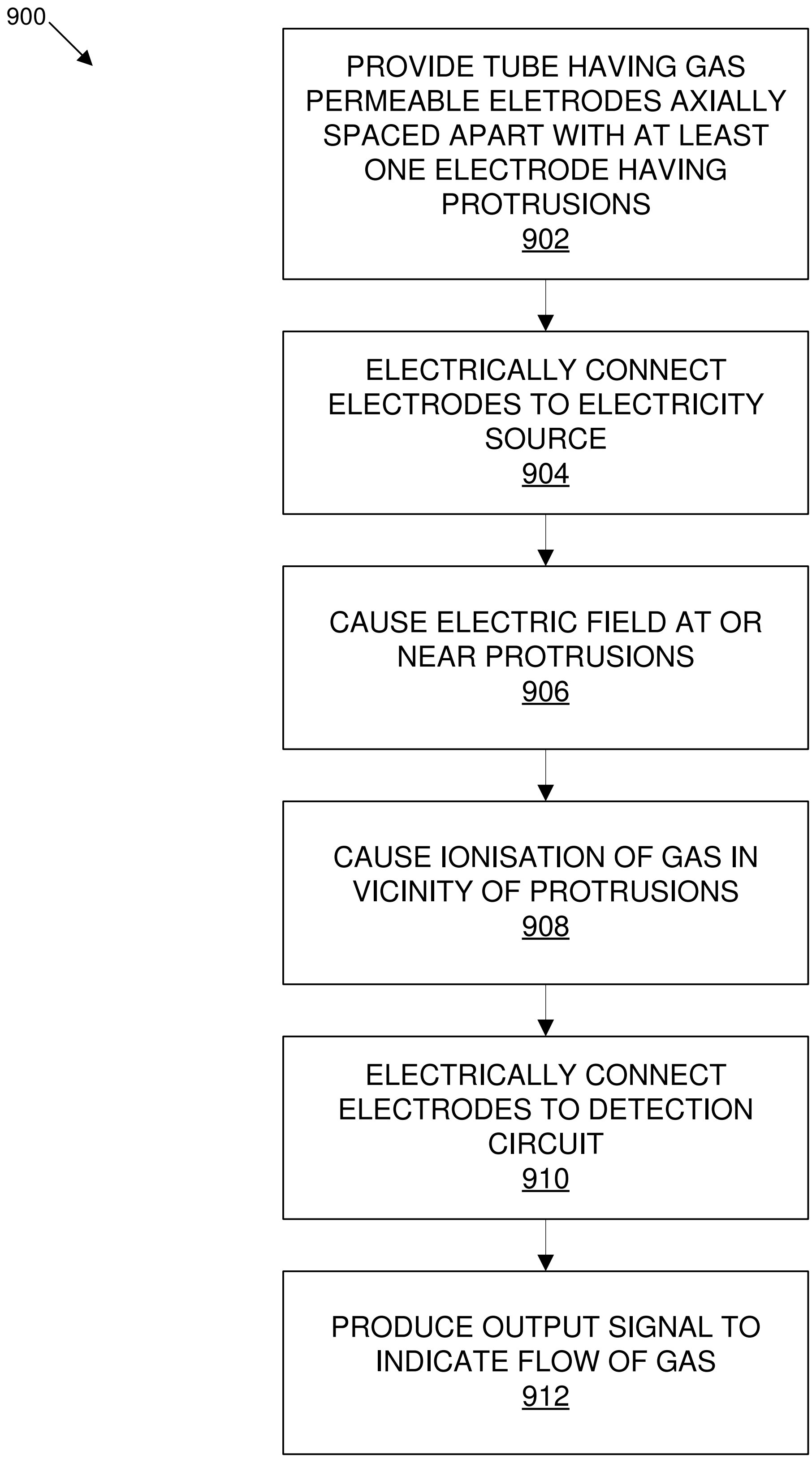


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