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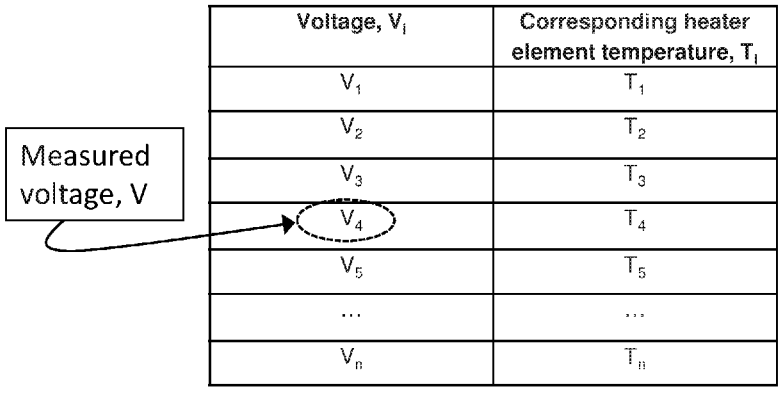


FIG. 6

(57) **Abstract:** An aerosol-generating device for generating an aerosol from an aerosol-forming substrate is disclosed. The aerosol-generating device comprises an electrically-powered heater element for heating the aerosol-forming substrate; a temperature sensor coupled to the heater element, a power source configured to supply power to the heater element and the temperature sensor, and control electronics. The temperature sensor has a resistivity dependent on the temperature of the heater element. The control electronics is configured to measure a voltage associated with the temperature sensor, the voltage being dependent on the resistivity of the heater element. The control electronics comprises or is communicably coupled to a memory storing pre-configured data. The pre-configured data comprise a plurality of voltage values and a corresponding plurality of temperature values. The control electronics is further configured to correlate the measured voltage with the pre-configured data and determine a value for the heater element temperature based on the correlation.

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MEASUREMENT OF TEMPERATURE OF A HEATER ELEMENT FOR AN AEROSOL-GENERATING DEVICE

The present disclosure relates to measurement of temperature of a heater element for an aerosol-generating device. In particular, the present disclosure relates to an aerosol-generating device which is configured to determine the temperature of a heater element of the device based on a relationship between a measured voltage and temperature. The present disclosure also relates to a method of determining a temperature of such a heater element of an aerosol-generating device.

Aerosol-generating devices which generate an aerosol by heating rather than burning an aerosol-forming substrate are known. Such aerosol-generating devices employ an electrically-powered heater element which is controlled in accordance with a heating profile defining a target operating temperature for the heater element over a usage session. To provide a satisfactory user experience, it is important to control the heater element such that its temperature tracks the target operating temperature defined by the heating profile as accurately as possible. Such accurate tracking requires correspondingly accurate determination of the heater element temperature in or close to real time. The aerosol-generating device includes temperature sensing circuitry including a temperature sensor positioned in close proximity to the heater element, in which the temperature sensor has a temperature-dependent resistivity. During use of the aerosol-generating device, a known voltage is provided to the temperature sensing circuitry and a voltage associated with the temperature sensor is measured. The measured voltage will be dependent on the resistivity of the temperature sensor, and ultimately upon the temperature to be measured. However, the correlation between measured voltage and temperature is complex and non-linear. Accordingly, the accurate determination of heater element temperature imposes computational complexity in order to enable the heater element temperature to be accurately determined at or close to real-time.

It is therefore desirable to provide an improved methodology for more efficiently determining the temperature of a heater element of an aerosol-generating device.

According to a first aspect of the present disclosure, there is provided an aerosol-generating device for generating an aerosol from an aerosol-forming substrate. The aerosol-generating device comprises: an electrically-powered heater element for heating the aerosol-forming substrate; a temperature sensor coupled to the heater

element, the temperature sensor having a resistivity dependent on the temperature of the heater element; a power source configured to supply power to the heater element and the temperature sensor; and control electronics. The control electronics are configured to measure a voltage associated with the temperature sensor, the voltage being dependent on the resistivity of the heater element. The control electronics comprise or are communicably coupled to a memory storing pre-configured data. The pre-configured data comprise a plurality of voltage values and a corresponding plurality of temperature values. The control electronics are further configured to correlate the measured voltage with the pre-configured data and determine a value for the heater element temperature based on the correlation.

The correlation of the measured voltage with the pre-configured data of voltage and corresponding temperature values may allow the value of the heater element temperature corresponding to the measured voltage to be determined with reduced computational burden and complexity, relative to the methodology employed by existing aerosol-generating devices.

The pre-configured data may be in the form of a look-up table. The look-up table may comprise the plurality of voltage values and corresponding plurality of temperature values. The control electronics may be configured to associate the measured voltage to the voltage value in the look-up table closest in magnitude to the measured voltage, and to the temperature value in the look-up table corresponding to that voltage value. The control electronics may then use the temperature value in the look-up table associated with the measured voltage as the value of the heater element temperature. In this manner, the control electronics may efficiently determine the value of the heater element temperature.

The heater element may be an electrically resistive heating element. By way of example, the heating element may comprise one or a plurality of heating tracks. The heating tracks may be made from stainless steel having a thickness of about 50 micrometres, or preferably about 25 micrometres. Alternatively, the heating tracks may be made from inconel having a thickness of about 50.8 micrometres, or about 25.4 micrometres. In further alternatives, the heating tracks may be made from copper having a thickness of about 35 micrometres, or from constantan having a thickness of about 25 micrometres, or from nickel having a thickness of about 12 micrometres, or from brass having a thickness of about 25 micrometres.

The temperature sensor may be a resistance temperature detector, such as a Pt100 or Pt1000 temperature sensor. However, other forms of temperature sensor/resistance temperature detector may be employed.

Preferably, each of the voltage values of the pre-configured data is associated with a corresponding one of the temperature values of the pre-configured data. The association of each of the voltage values with a corresponding one of the temperature values allows for improved correlation of the measured voltage with the pre-configured data. The improved correlation may also improve the speed at which the control electronics is able to determine the value of the heater element temperature corresponding to the measured voltage.

Advantageously, the control electronics is further configured to compare the determined value of the heater element temperature with a target temperature for the heater element. The control electronics may further be configured to adjust the supply of power from the power source to the heater element so as to reduce any difference between the determined value of the heater element temperature and the target temperature for the heater element. In this manner, the heater element temperature may better track the target temperature for the heater element. A feedback loop or similar means may be employed to perform this comparison.

Preferably, the control electronics is configured to control the supply of power to the heater element according to a heating profile, in which the heating profile defines the target temperature for the heater element over a usage session. The heating profile may be stored in a memory forming part of or communicably coupled to the control electronics; this memory may be the same as or different to the memory which stores the pre-configured data of voltage and temperature values.

The plurality of temperature values of the pre-configured data encompasses a temperature range of between 0 degrees Celsius and 425 degrees Celsius, or between 0 degrees Celsius and 400 degrees Celsius, or between 0 degrees Celsius and 375 degrees Celsius. These exemplary ranges encompass the temperatures commonly used in aerosol-generating devices configured for generating an aerosol from an aerosol-forming substrate through heating rather than burning of the aerosol-forming substrate. By limiting the temperature range encompassed by the pre-configured data to the range of temperatures likely to be used by the heater element during use of the aerosol-generating device, the data storage requirements for the pre-configured data are reduced and the speed of correlating the measured voltage with the pre-configured data may be improved for a given level of granularity of the pre-configured data.

The plurality of temperature values of the pre-configured data may have a granularity between successive ones of the plurality of temperature values of between 0.5 degrees Celsius and 5 degrees Celsius, or between 0.5 degrees Celsius and 3 degrees Celsius, or between 0.5 degrees Celsius and 1.5 degrees Celsius. Reducing the spacing between successive ones of the plurality of temperature values of the pre-configured data may provide improved correlation of the measured voltage with the pre-configured data and improve the accuracy of the determined value for the heater element temperature.

The temperature sensor may be electrically coupled to a resistor, the resistor having a resistivity substantially invariant with temperature over a predetermined temperature range. The temperature sensor and the resistor may collectively form at least part of a resistor divider. The predetermined temperature range may be between 0 degrees Celsius and 425 degrees Celsius, or between 0 degrees Celsius and 400 degrees Celsius, or between 0 degrees Celsius and 375 degrees Celsius. Preferably, the resistivity being substantially invariant with temperature over the predetermined temperature range corresponds to the resistivity varying by no more than 15%, or by no more than 10%, or by no more than 5% over the predetermined temperature range.

The temperature sensor and the heater element may be disposed on opposed surfaces of an electrically-insulative substrate layer. The electrically-insulative substrate layer may be made from polyimide. The electrically-insulative substrate layer may be configured to withstand between 220 degrees Celsius and 320 degrees Celsius, preferably between 240 degrees Celsius and 300 degrees Celsius, preferably around 280 degrees Celsius. The electrically-insulative substrate layer may be made from Pyralux. The electrically-insulative substrate layer may be flexible, with a flexible substrate layer having an advantage that the layer can be rolled or formed into a desired shape; by way of example, the desired shape may be a tubular shape. The electrically-insulative substrate layer may comprise two or more sub-layers. Preferably, the electrically-insulative substrate layer comprises a first portion and a second portion, the electrically-insulative substrate material rolled into a tubular shape such that the heater element is disposed between the first and second portions of the electrically-insulative substrate layer. Conveniently, the temperature sensor is disposed on an outward-facing surface of the electrically-insulative substrate layer.

The heater element may be disposed between distinct first and second electrically-insulative substrate layers. The temperature sensor may be disposed between the second electrically-insulative substrate layer and a third electrically-insulative substrate

layer. The first electrically-insulative substrate layer, the heater element, the second electrically-insulative substrate layer, the temperature sensor and the third electrically insulative substrate layer are successively laid over each other. Conveniently, an adhesive may be provided between each of the successive layers. A through hole may be provided through the thickness of the third electrically-insulative substrate layer to provide access to the temperature sensor. The first, second and third electrically-insulative substrate layers may be made from the same or different electrically-insulative materials; for example, polyimide as described in the preceding paragraph.

In a second aspect of the present disclosure, there is provided a method of determining a temperature of an electrically-powered heater element of an aerosol-generating device, the aerosol-generating device comprising a temperature sensor coupled to the heater element, the temperature sensor having a resistivity dependent on the temperature of the heater element. The method comprises: measuring a voltage associated with the temperature sensor, the voltage being dependent on the resistivity of the heater element; correlating the measured voltage with pre-configured data comprising a plurality of voltage values and a corresponding plurality of temperature values; and determining a value for the heater element temperature based on the correlation.

Preferably, the method further comprises comparing the determined value of the heater element temperature with a target temperature for the heater element; and adjusting a supply of power to the heater element so as to reduce any difference between the determined value of the heater element temperature and the target temperature.

Preferably, each of the voltage values of the pre-configured data is associated with a corresponding one of the temperature values of the pre-configured data.

The plurality of temperature values of the pre-configured data may encompass a temperature range of between 0 degrees Celsius and 425 degrees Celsius, or between 0 degrees Celsius and 400 degrees Celsius, or between 0 degrees Celsius and 375 degrees Celsius.

The plurality of temperature values of the pre-configured data may have a granularity between successive ones of the plurality of temperature values of between 0.5 degrees Celsius and 5 degrees Celsius, or between 0.5 degrees Celsius and 3 degrees Celsius, or between 0.5 degrees Celsius and 1.5 degrees Celsius.

Preferably, the correlating comprises associating the measured voltage with a voltage value of the plurality of voltage values of the pre-configured data closest to the value of the measured voltage.

As used herein, the term "aerosol-generating device" is used to describe a device that interacts with an aerosol-forming substrate of an aerosol-generating article to generate an aerosol. Preferably, the aerosol-generating device is a smoking device that interacts with an aerosol-forming substrate of an aerosol-generating article to generate an aerosol that is directly inhalable into a user's lungs thorough the user's mouth. The aerosol-generating device may be a holder for a smoking article. Preferably, the aerosol-generating article is a smoking article that generates an aerosol that is directly inhalable into a user's lungs through the user's mouth. More preferably, the aerosol-generating article is a smoking article that generates a nicotine-containing aerosol that is directly inhalable into a user's lungs through the user's mouth.

As used herein, the term "aerosol-forming substrate" denotes a substrate consisting of or comprising an aerosol-forming material that is capable of releasing volatile compounds upon heating to generate an aerosol.

Preferably, the aerosol-forming substrate is a solid aerosol-forming substrate. However, the aerosol-forming substrate may comprise both solid and liquid components. Alternatively, the aerosol-forming substrate may be a liquid aerosol-forming substrate.

Preferably, the aerosol-forming substrate comprises nicotine. More preferably, the aerosol-forming substrate comprises tobacco. Alternatively or in addition, the aerosol-forming substrate may comprise a non-tobacco containing aerosol-forming material.

If the aerosol-forming substrate is a solid aerosol-forming substrate, the solid aerosol-forming substrate may comprise, for example, one or more of: powder, granules, pellets, shreds, strands, strips or sheets containing one or more of: herb leaf, tobacco leaf, tobacco ribs, expanded tobacco and homogenised tobacco.

Optionally, the solid aerosol-forming substrate may contain tobacco or non-tobacco volatile flavour compounds, which are released upon heating of the solid aerosol-forming substrate. The solid aerosol-forming substrate may also contain one or more capsules that, for example, include additional tobacco volatile flavour compounds or non-tobacco volatile flavour compounds and such capsules may melt during heating of the solid aerosol-forming substrate.

Optionally, the solid aerosol-forming substrate may be provided on or embedded in a thermally stable carrier. The carrier may take the form of powder, granules,

pellets, shreds, strands, strips or sheets. The solid aerosol-forming substrate may be deposited on the surface of the carrier in the form of, for example, a sheet, foam, gel or slurry. The solid aerosol-forming substrate may be deposited on the entire surface of the carrier, or alternatively, may be deposited in a pattern in order to provide a non-uniform flavour delivery during use.

In a preferred embodiment, the aerosol-forming substrate comprises homogenised tobacco material. As used herein, the term "homogenised tobacco material" refers to a material formed by agglomerating particulate tobacco.

Preferably, the aerosol-forming substrate comprises a gathered sheet of homogenised tobacco material. As used herein, the term "sheet" refers to a laminar element having a width and length substantially greater than the thickness thereof. As used herein, the term "gathered" is used to describe a sheet that is convoluted, folded, or otherwise compressed or constricted substantially transversely to the longitudinal axis of the aerosol-generating article. Preferably, the aerosol-forming substrate comprises an aerosol former. As used herein, the term "aerosol former" is used to describe any suitable known compound or mixture of compounds that, in use, facilitates formation of an aerosol and that is substantially resistant to thermal degradation at the operating temperature of the aerosol-generating article.

Suitable aerosol-formers are known in the art and include, but are not limited to: polyhydric alcohols, such as propylene glycol, triethylene glycol, 1,3-butanediol and glycerine; esters of polyhydric alcohols, such as glycerol mono-, di- or triacetate; and aliphatic esters of mono-, di- or polycarboxylic acids, such as dimethyl dodecanedioate and dimethyl tetradecanedioate. Preferred aerosol formers are polyhydric alcohols or mixtures thereof, such as propylene glycol, triethylene glycol, 1,3-butanediol and, most preferred, glycerine.

The aerosol-forming substrate may comprise a single aerosol former. Alternatively, the aerosol-forming substrate may comprise a combination of two or more aerosol formers.

As used herein, the term "usage session" refers to a period in which a series of puffs are applied by a user to extract aerosol from an aerosol-forming substrate. The usage session may be a finite usage session; that is a usage session having a start and an end. The duration of the usage session as measured by time may be influenced by use during the usage session. The duration of the usage session may have a maximum duration determined by a maximum time from the start of the usage session. The duration of the usage session may be less than the maximum time if one or more

monitored parameters reaches a predetermined threshold before the maximum time from the start of the usage session. By way of example, the one or more monitored parameters may comprise one or more of: i) a cumulative puff count of a series of puffs drawn by a user since the start of the usage session, and ii) a cumulative volume of aerosol evolved from the aerosol-forming substrate since the start of the usage session.

The invention is defined in the claims. However, below there is provided a non-exhaustive list of non-limiting examples. Any one or more of the features of these examples may be combined with any one or more features of another example, embodiment, or aspect described herein.

Examples will now be further described with reference to the figures, in which:

Figure 1 shows an aerosol-generating system formed of an aerosol-generating device and an aerosol-generating article comprising an aerosol-forming substrate.

Figure 2 shows the components of a first embodiment of a heating assembly of the aerosol-generating device of Figure 1, before being rolled into a tubular shape.

Figure 3 shows an axial section view of the heating assembly of Figure 2 after being rolled into a tubular shape.

Figure 4 illustrates how a voltage, V, associated with a temperature sensor of the heating assembly of the aerosol-generating device is measured.

Figure 5 provides a graphical representation showing an example of how the voltage, V, associated with the temperature sensor may vary with temperature.

Figure 6 illustrates an exemplary representation of a pre-configured look-up table of voltage and corresponding temperature values for the temperature sensor, and visually indicates how a measured voltage associated with the temperature sensor may be correlated with the pre-configured data to enable determination of heater element temperature.

Figure 7 shows a radial section view of a second embodiment of a heating assembly suitable for use in the aerosol-generating device of Figure 1.

Figure 8 shows a radial section view of a third embodiment of a heating assembly suitable for use in the aerosol-generating device of Figure 1.

It is to be understood that the above figures are schematic representations and are not to scale.

Figure 1 shows an aerosol-generating system 1 formed by a combination of an aerosol-generating device 10 and an aerosol-generating article 50 containing an aerosol-forming substrate 51. The aerosol-generating device 10 has an elongate housing 11 containing a power source 12, a controller 13 and a heating assembly 14.

The power source 12 is a rechargeable power source, in the form of a rechargeable battery. The heating assembly 14 is generally tubular in form and circumscribes a tubular wall of a cavity 15 of the aerosol-generating device 10. The tubular heating assembly 14 is formed of various components, including a resistive heating element 141 and a temperature sensor 142 (see Figures 2 and 3). The construction of the heating assembly 14 is described in more detail in subsequent paragraphs by reference to Figures 2 and 3.

Figure 2 shows a view of a first embodiment of the heating assembly 14 prior to being rolled into a tubular form. For the state shown in Figure 2, the heating assembly 14 has a generally planar form. The heating assembly 14 has a substrate layer 143. The substrate layer 143 is electrically insulative. For the example shown and described in these figures, the substrate layer 143 is made from polyimide; however, alternative electrically-insulative materials may be chosen for the substrate layer 143. The substrate layer 143 is flexible. The substrate layer 143 has first and second portions 144, 145 located adjacent to each other; the dashed line in Figure 2 represents the interface between the first portion 144 and the second portion 145 of the substrate layer 143. The length, L, of the substrate layer 143 is around two times the width, W, of the substrate layer 143.

The heating element 141 is an electrically-resistive heating element and is provided as a sheet comprising a plurality of electrically conductive heating tracks (not shown). The heating element 141 is arranged on the first portion 144 of the substrate layer 143. First heating element contact area 146a and second heating element contact area 146b are arranged on the first portion 144 adjacent to and electrically coupled to the heating element 141. A first electrical contact 131a is provided contacting the first heating element contact area 146a. A second electrical contact 131b is provided contacting the second heating element contact area 146b. The first and second electrical contacts 131a, 131b are formed from electrical wire and are coupled to the controller 13. The controller 13 is coupled to the heating element 141 through contact between the first electrical contact 131a and the first heating element contact area 146a, and also through contact between the second electrical contact 131b and the second heating element contact area 146b. As shown in Figure 1, the controller 13 is also coupled to the power source 12. The controller 13 is thereby able to control the supply of electric current to and through the electrically conductive tracks of the heating element 141.

A first temperature sensor contact area 147a and a second temperature sensor contact area 147b are arranged on the second portion 145 of the substrate layer 143. A third electrical contact 131c is provided contacting the first temperature sensor contact area 147a. A fourth electrical contact 131d is provided contacting the second temperature sensor contact area 147b. The third and fourth electrical contacts 131c, 131d are formed from electrical wire and are coupled to the controller 13. Third and fourth temperature sensor contact areas 147c, 147d are arranged on the surface of the second portion 145 of the substrate layer 143. The third temperature sensor contact area 147c is electrically connected to the first temperature sensor contact area 147a. The fourth temperature sensor contact area 147d is electrically connected to the second temperature sensor contact area 147b. The temperature sensor 142 is coupled between the third and fourth temperature sensor contact areas 147c, 147d. The temperature sensor 142 is a resistance temperature detector, such as a Pt100 or Pt1000 temperature sensor. However, in other embodiments, other forms of temperature sensor/resistance temperature detector may be employed.

The heating assembly 14 of Figure 2 is rolled into a tubular shape and wrapped around a tube 16 - as shown in Figure 3. The longitudinal axis LA of the tube 16 extends into/out from the page for Figure 3, with the width, W, of the substrate layer 143 extending parallel to the longitudinal axis LA. The tube 16 defines the tubular wall of the cavity 15 of the aerosol-generating device 10. The tube 16 is formed of metal, such as stainless steel. However, in other embodiments, other metals or materials may be chosen for the tube 16. The heating assembly 14 is wrapped around the tube 16 such that the first portion 144 of the substrate layer 143 contacts the outer surface of the tube. The substrate layer 143 of the heating assembly 14 is wrapped over itself such that the second portion 145 of the substrate layer 143 defines an outward-facing surface of the tubular heating assembly 14, with the heating element 141 sandwiched between the first and second portions 144, 145.

Although not shown in the Figures, a glue layer or adhesive layer may be provided between the first portion 144 of the substrate layer 143 and the metal tube 16 to improve the connection between the substrate layer 143 and the tube 16. A further glue layer or adhesive layer may be provided between the first portion 144 of the substrate layer 143 and the second portion 145 of the substrate layer 143.

Once the heating assembly 14 is formed into the tubular shape shown in Figure 3, the temperature sensor 142 is positioned on an outward-facing surface of the second portion 145 of the substrate layer 143. The temperature sensor 142 is arranged

adjacent the heating element 141 at a position corresponding to a mid-point of the length L_{141} of the heating element, but distanced from the heating element 141 by the thickness of the second portion 145 of the substrate layer 143. In this manner, the temperature sensor 142 is thermally coupled to the heating element 141 and positioned so as to measure the hottest area of the heating element 141 during operation of the heating assembly 14 of the aerosol-generating device 10.

The aerosol-generating article 50 is inserted into the cavity 15 so that the tubular heating assembly 14 substantially encloses the entire length of the aerosol-forming substrate 51 of the article 50. The controller 13 is coupled to the power source 12 and the heating assembly 14 by electrical wiring. The controller 13 includes a memory module 131 containing a heating profile for a usage session of the aerosol-generating device 10. The heating profile defines a target operating temperature for the heating element 141 over the usage session. In use, the controller 13 controls the supply of electrical energy from the power source 12 to the heating element 141 in accordance with the heating profile stored in the memory module 131. The heating element 141 operates, under the control of controller 13, so as to heat the aerosol-forming substrate 51 of the aerosol-generating article 50 received in the cavity 15 and thereby generate an inhalable aerosol. A user draws directly on a mouth end 52 of the aerosol-generating article 50 to inhale the aerosol generated by the heating of the aerosol-forming substrate 51.

As shown in Figure 4, the temperature sensor 142 is coupled to a resistor 149. The temperature sensor 142 is coupled in series with the resistor 149. The resistor 149 has a known resistivity which is substantially invariant over the range of target operating temperatures for the heating element 141 defined in the heating profile stored in the memory module 131. In contrast, the resistivity of the temperature sensor 142 is variable with temperature. The relationship between resistance and temperature is known for the temperature sensor 142; such data may be provided by the manufacturer/supplier of the temperature sensor. The controller 13 controls the supply of electrical energy from the power source 12 so as to apply a voltage V_T, as shown in Figure 4, thereby causing current flow, I, through the resistor 149. The controller 13 is also configured to measure a voltage, V, associated with the temperature sensor 142 (see Figure 4). For the example illustrated in Figure 4, the associated voltage, V, being measured is the voltage across the temperature sensor 142. As indicated below, the relationship between the measured voltage, V, and the resistance, R_{142}, of the temperature sensor 142 and the known resistance, R_{149}, of the resistor 149 is as follows:

$$V = \frac{V_T . R_{142}}{R_{142} + R_{149}}$$

So, by knowing voltages V and V_T and the temperature invariant resistance R_{149} of the resistor 149, the resistance R_{142} of the temperature sensor 142 may be determined. In turn, knowledge of the relationship between the resistance R_{142} and temperature for the temperature sensor 142 means that it is possible to formulate pre-configured data correlating the measured voltage value, V, with the temperature of the temperature sensor 142.

Figure 5 illustrates an exemplary correlation between the measured voltage, V, and the temperature of the temperature sensor 142.

As shown in Figure 6, the pre-configured data is provided in the form of a look-up table consisting of a plurality of voltage values, V_i, and corresponding temperature values, T_i. The memory module 131 of the controller 13 stores this pre-configured data.

During operation of the aerosol-generating device 10, the controller 13 measures the voltage, V (as indicated in Figure 4), and then correlates the measured voltage, V, with the look-up table stored in the memory module 131. As illustrated in Figure 6, the measured voltage, V, is matched with the voltage value in the look-up table closest in magnitude to the value of the measured voltage - in this example, voltage value V_4 . Based on the look-up table, the controller 13 determines the heating element 141 temperature to be the temperature value T_4 in the look-up table corresponding to voltage value V_4. In this way, the controller 13 is able to determine the heating element 141 temperature by correlating the voltage, V, as measured by the controller 13 with the look-up table of voltage values, V_i, and corresponding temperature values, T_i.

Figure 7 shows a radial section view of a second embodiment of a heating assembly 14'. As for the heating assembly 14 of Figure 3, the heating assembly 14' of Figure 7 is tubular once fully assembled. However, whereas the heating assembly 14 of Figures 2 and 3 uses a single substrate layer 143 of electrically insulative material, the heating assembly 14' of Figure 7 employs distinct first and second substrate layers 143a, 143b of electrically insulative material. The distinct electrically insulative substrate layers 143a, 143b are both made from polyimide; however, in other embodiments, other materials may be chosen for the substrate layers 143a, 143b. The heating assembly 14' is fabricated by combining a first heating sub-assembly 1401 with a second heating sub-assembly 1402.

The first electrically insulative substrate layer 143a, a first adhesive layer 31, and the tracks of the heating element 141 are sequentially laid over each other to form the first heating sub-assembly 1401.

A second adhesive layer 32, the second electrically insulative substrate layer 143b, a third adhesive layer 33, and the temperature sensor 142 are sequentially laid over each other to form the second heating sub-assembly 1402.

The first and second heating sub-assemblies 1401, 1402 are brought together and adhere to each other by the adhesive action of the second adhesive layer 32, thereby forming the heating assembly 14'.

The heating assembly 14' is wrapped around and adheres to the stainless steel tube 16 by the use of a fourth adhesive layer 34 there-between.

Figure 7 illustrates the relative positions of each of the layers which form the heating assembly 14' relative to the longitudinal axis LA.

Figure 7 indicates exemplary thicknesses of each of the discrete layers which form the heating assembly 14', as well as of the tube 16. The thickness of each of these elements is as follows: the tube 16 is of 100 micrometres thickness; the first and second electrically insulative substrate layers 143a, 143b are each of 25 micrometres thickness; the first, second, third and fourth adhesive layers 31, 32, 33, 34 are of 5 micrometres thickness; the heating element 141 is of 40 micrometres thickness; and the temperature sensor 142 is of 50 micrometres thickness.

Figure 8 shows a view of a third embodiment of a heating assembly 14''. The heating assembly 14'' of Figure 8 includes all of the features of the heating assembly 14' of Figure 7, but additionally includes a distinct third substrate layer 143c of electrically insulative material. In common with the distinct first and second substrate layers 143a, 143b, the third substrate layer 143c is formed from polyimide; however, in other embodiments, other materials may be chosen for the substrate layer 143c. The third substrate layer 143c (being of 25 micrometres thickness) is applied over the temperature sensor 142 by use of a fifth adhesive layer 35 (being of 5 micrometres thickness). However, a through hole 41 is provided through the thickness of the third substrate layer 143c to allow the temperature sensor 142 to be electrically coupled to the controller 13. The third substrate layer 143c is also thermally insulative, with the thermally insulative properties helping to reduce the likelihood of a user's fingers from being exposed to excessively high temperatures when holding the aerosol-generating device 10.

For the purpose of the present description and of the appended claims, except where otherwise indicated, all numbers expressing amounts, quantities, percentages, and so forth, are to be understood as being modified in all instances by the term "about". Also, all ranges include the maximum and minimum points disclosed and include any intermediate ranges therein, which may or may not be specifically enumerated herein. In this context, therefore, a number “A” is understood as “A” ± 10% of “A”. Within this context, a number “A” may be considered to include numerical values that are within general standard error for the measurement of the property that the number “A” modifies. The number “A”, in some instances as used in the appended claims, may deviate by the percentages enumerated above provided that the amount by which “A” deviates does not materially affect the basic and novel characteristic(s) of the claimed invention. Also, all ranges include the maximum and minimum points disclosed and include any intermediate ranges therein, which may or may not be specifically enumerated herein.

CLAIMS

1. An aerosol-generating device for generating an aerosol from an aerosol-forming substrate, the aerosol-generating device comprising:

an electrically-powered heater element for heating the aerosol-forming substrate;

a temperature sensor coupled to the heater element, the temperature sensor having a resistivity dependent on the temperature of the heater element;

a power source configured to supply power to the heater element and the temperature sensor; and

control electronics;

the control electronics configured to measure a voltage associated with the temperature sensor, the voltage being dependent on the resistivity of the heater element;

the control electronics comprising or communicably coupled to a memory storing pre-configured data, the pre-configured data comprising a plurality of voltage values and a corresponding plurality of temperature values;

the control electronics further configured to correlate the measured voltage with the pre-configured data and determine a value for the heater element temperature based on the correlation.

2. An aerosol-generating device according to claim 1, in which each of the voltage values of the pre-configured data is associated with a corresponding one of the temperature values of the pre-configured data.

3. An aerosol-generating device according to either one of claim 1 or claim 2, in which the control electronics is further configured to compare the determined value of the heater element temperature with a target temperature for the heater element, and adjust the supply of power from the power source to the heater element so as to reduce any difference between the determined value of the heater element temperature and the target temperature for the heater element.

4. An aerosol-generating device according to any one of the preceding claims, in which the plurality of temperature values of the pre-configured data encompasses a temperature range of between 0 degrees Celsius and 425 degrees Celsius, or between 0 degrees Celsius and 400 degrees Celsius, or between 0 degrees Celsius and 375 degrees Celsius.

5. An aerosol-generating device according to any one of the preceding claims, in which the plurality of temperature values of the pre-configured data have a granularity between successive ones of the plurality of temperature values of between 0.5 degrees Celsius and 5 degrees Celsius, or between 0.5 degrees Celsius and 3 degrees Celsius, or between 0.5 degrees Celsius and 1.5 degrees Celsius.

6. An aerosol-generating device according to any one of the preceding claims, in which the temperature sensor is electrically coupled to a resistor, the resistor having a resistivity substantially invariant with temperature over a predetermined temperature range, in which the temperature sensor and the resistor collectively form at least part of a resistor divider.

7. An aerosol-generating device according to claim 6, in which the predetermined temperature range is between 0 degrees Celsius and 425 degrees Celsius, or between 0 degrees Celsius and 400 degrees Celsius, or between 0 degrees Celsius and 375 degrees Celsius.

8. An aerosol-generating device according to either one of claim 6 or claim 7, in which the resistivity being substantially invariant with temperature over the predetermined temperature range corresponds to the resistivity varying by no more than 15%, or by no more than 10%, or by no more than 5% over the predetermined temperature range.

9. An aerosol-generating device according to any one of the preceding claims, in which the temperature sensor and the heater element are disposed on opposed surfaces of an electrically-insulative substrate layer.

10. An aerosol-generating device according to any claim 8, in which the electrically-insulative substrate layer comprises two or more sub-layers.

11. An aerosol-generating device according to either one of claim 9 or claim 10, in which the electrically-insulative substrate layer comprises a first portion and a second portion, the electrically-insulative substrate material rolled into a tubular shape such that the heater element is disposed between the first and second portions of the electrically-insulative substrate layer.

12. An aerosol-generating device according to claim 11, in which the temperature sensor is disposed on an outward-facing surface of the electrically-insulative substrate layer.

13. An aerosol-generating device according to any one of claims 1 to 10, in which the heater element is disposed between distinct first and second electrically-insulative substrate layers.

14. An aerosol-generating device according to claim 13, in which the temperature sensor is disposed between the second electrically-insulative substrate layer and a third electrically-insulative substrate layer, in which the first electrically-insulative substrate layer, the heater element, the second electrically-insulative substrate layer, the temperature sensor and the third electrically-insulative substrate layer are successively laid over each other.

15. An aerosol-generating device according to claim 14, in which an adhesive is provided between each of the successive layers.

16. An aerosol-generating device according to either one of claim 14 or claim 15, in which a through hole is provided through the thickness of the third electrically-insulative substrate layer to provide access to the temperature sensor.

17. A method of determining a temperature of an electrically-powered heater element of an aerosol-generating device, the aerosol-generating device comprising a temperature sensor coupled to the heater element, the temperature sensor having a resistivity dependent on the temperature of the heater element;
the method comprising:

measuring a voltage associated with the temperature sensor, the voltage being dependent on the resistivity of the heater element;

correlating the measured voltage with pre-configured data comprising a plurality of voltage values and a corresponding plurality of temperature values; and

determining a value for the heater element temperature based on the correlation.

18. A method according to claim 17, in which the method further comprises:

comparing the determined value of the heater element temperature with a target temperature for the heater element; and

adjusting a supply of power to the heater element so as to reduce any difference between the determined value of the heater element temperature and the target temperature.

19. A method according to either one of claim 17 or claim 18, in which each of the voltage values of the pre-configured data is associated with a corresponding one of the temperature values of the pre-configured data.

20. A method according to any one of claims 17 to 19, in which the plurality of temperature values of the pre-configured data encompasses a temperature range of between 0 degrees Celsius and 425 degrees Celsius, or between 0 degrees Celsius and 400 degrees Celsius, or between 0 degrees Celsius and 375 degrees Celsius.

21. A method according to any one of claims 17 to 20, in which the plurality of temperature values of the pre-configured data have a granularity between successive ones of the plurality of temperature values of between 0.5 degrees Celsius and 5 degrees Celsius, or between 0.5 degrees Celsius and 3 degrees Celsius, or between 0.5 degrees Celsius and 1.5 degrees Celsius.

22. A method according to any one of claims 17 to 21, in which the correlating comprises associating the measured voltage with a voltage value of the plurality of voltage values of the pre-configured data closest to the value of the measured voltage.

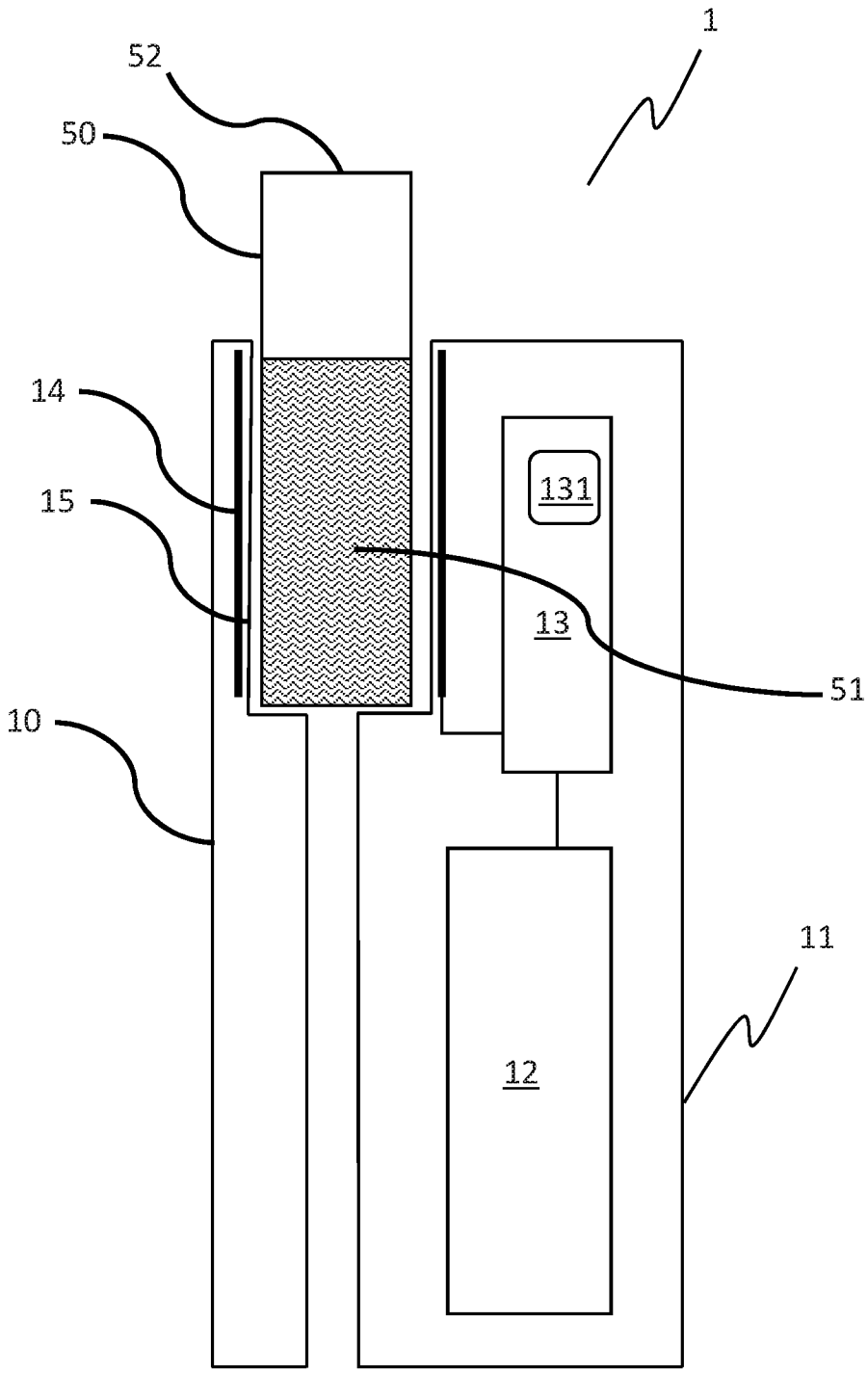


FIG. 1

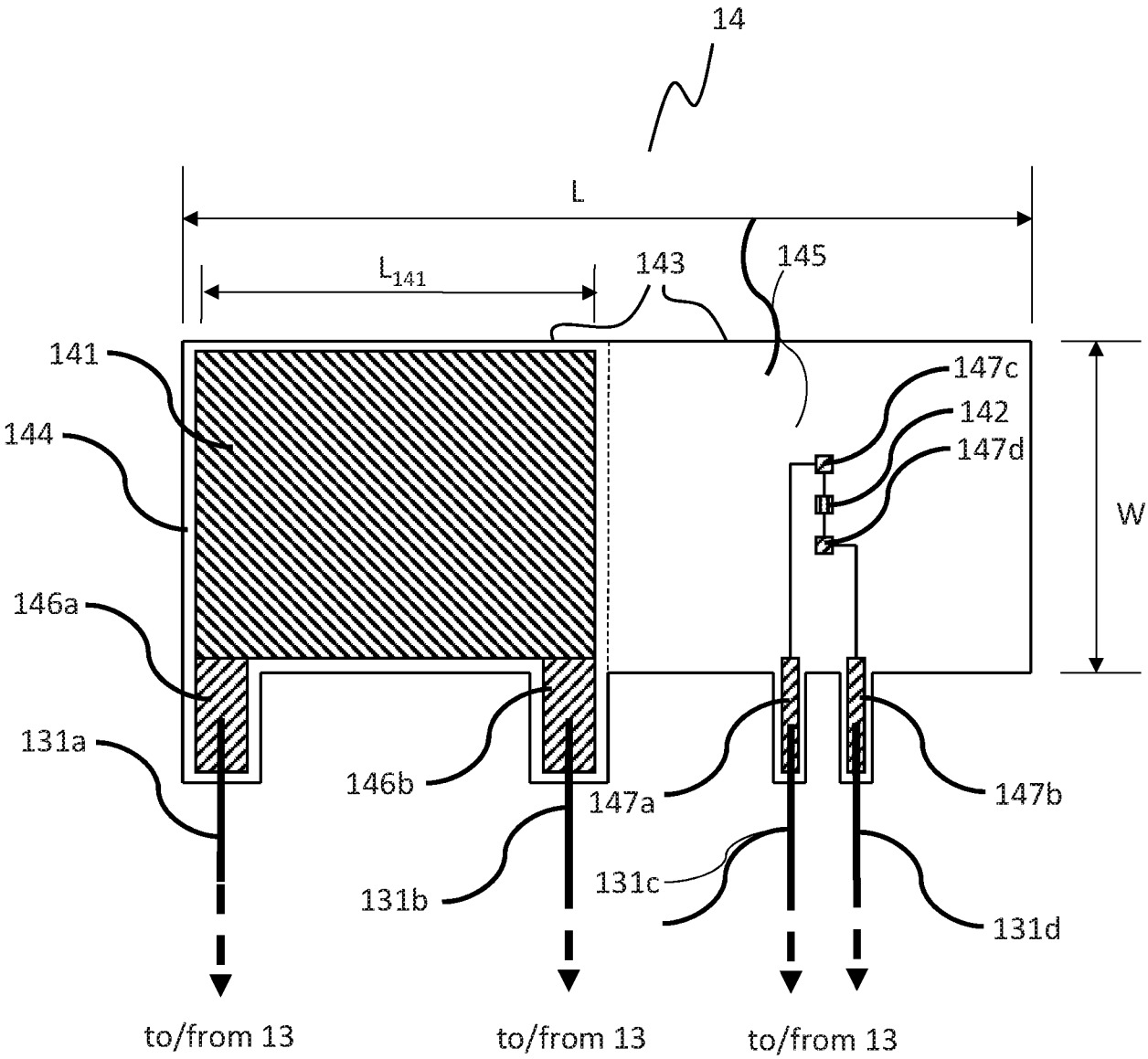

14
L
L_{141}
143
145
141
144
146a
131a
147c
142
147d
W
146b
147a
147b
131b
131c
131d
to/from 13
to/from 13
to/from 13

FIG. 2

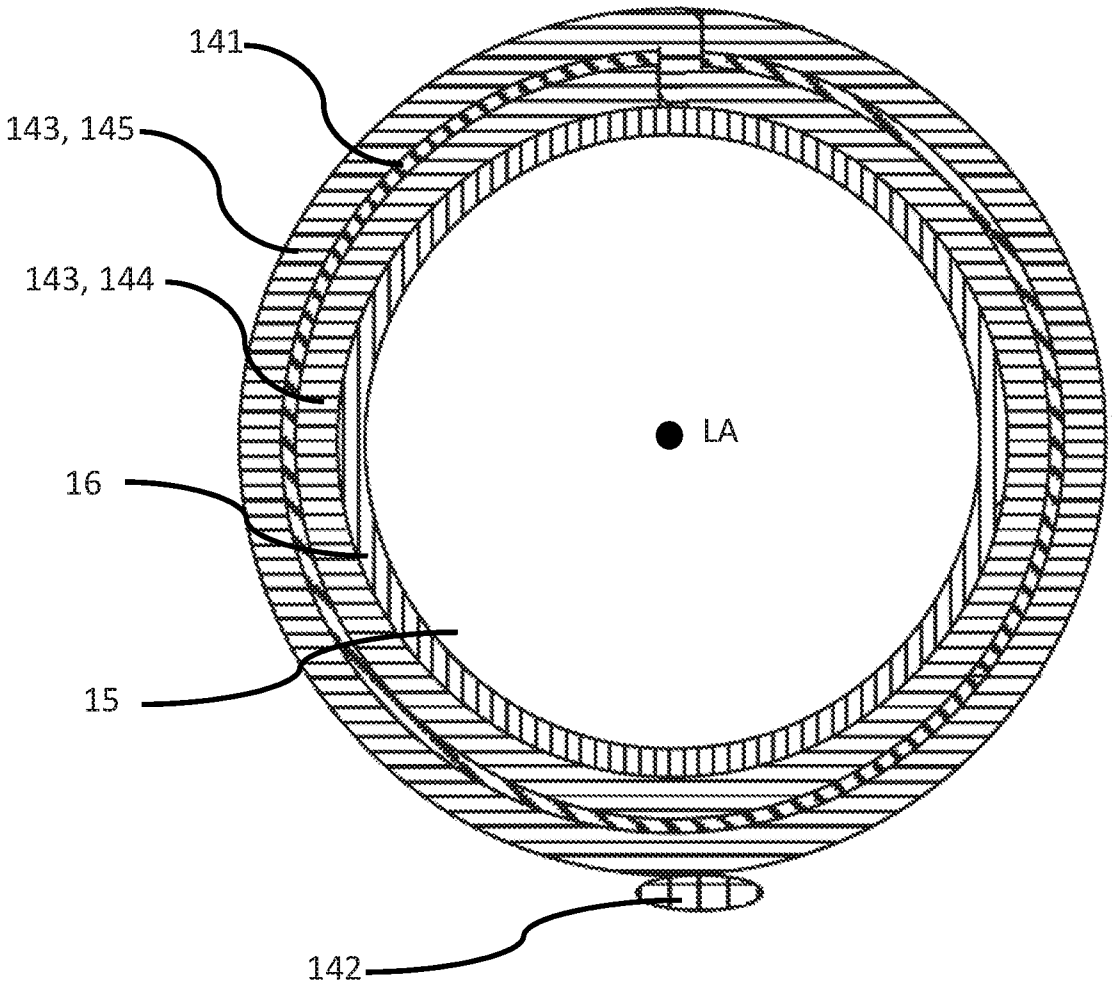


FIG. 3

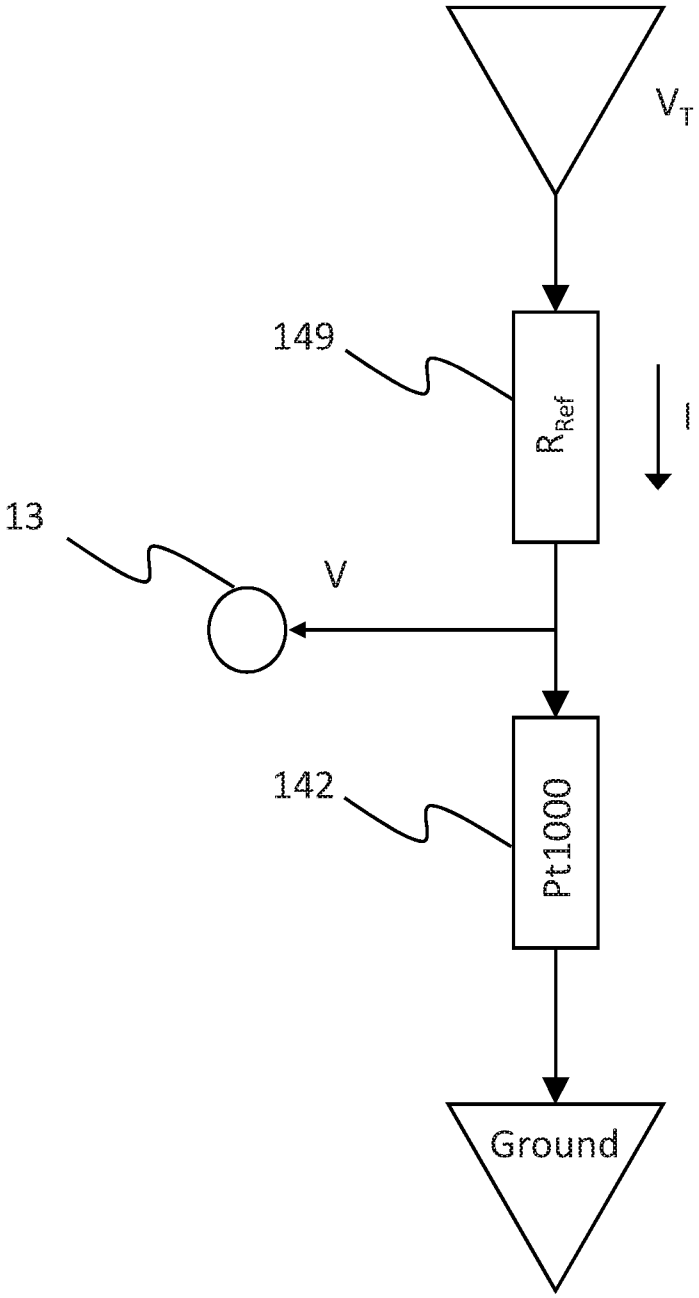


FIG. 4

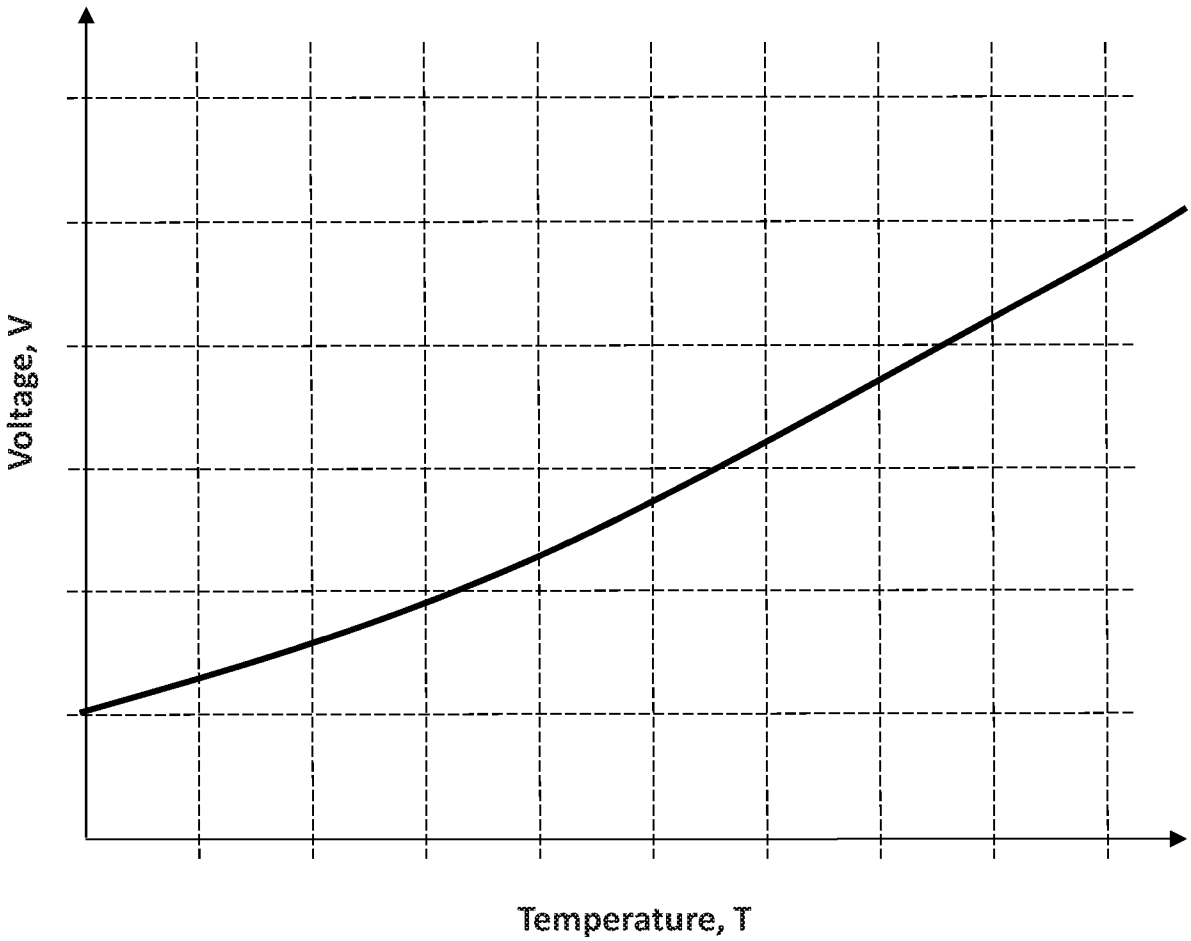


FIG. 5

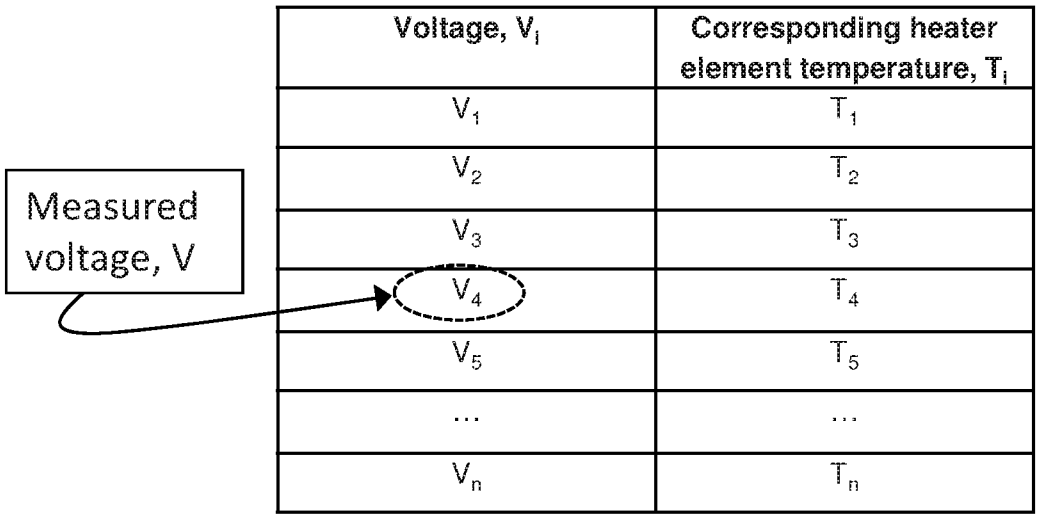

Measured voltage, V
Voltage, V_i
Corresponding heater element temperature, T_i
V_1 T_1
V_2 T_2
V_3 T_3
V_4 T_4
V_5 T_5
... ...
V_n T_n

FIG. 6

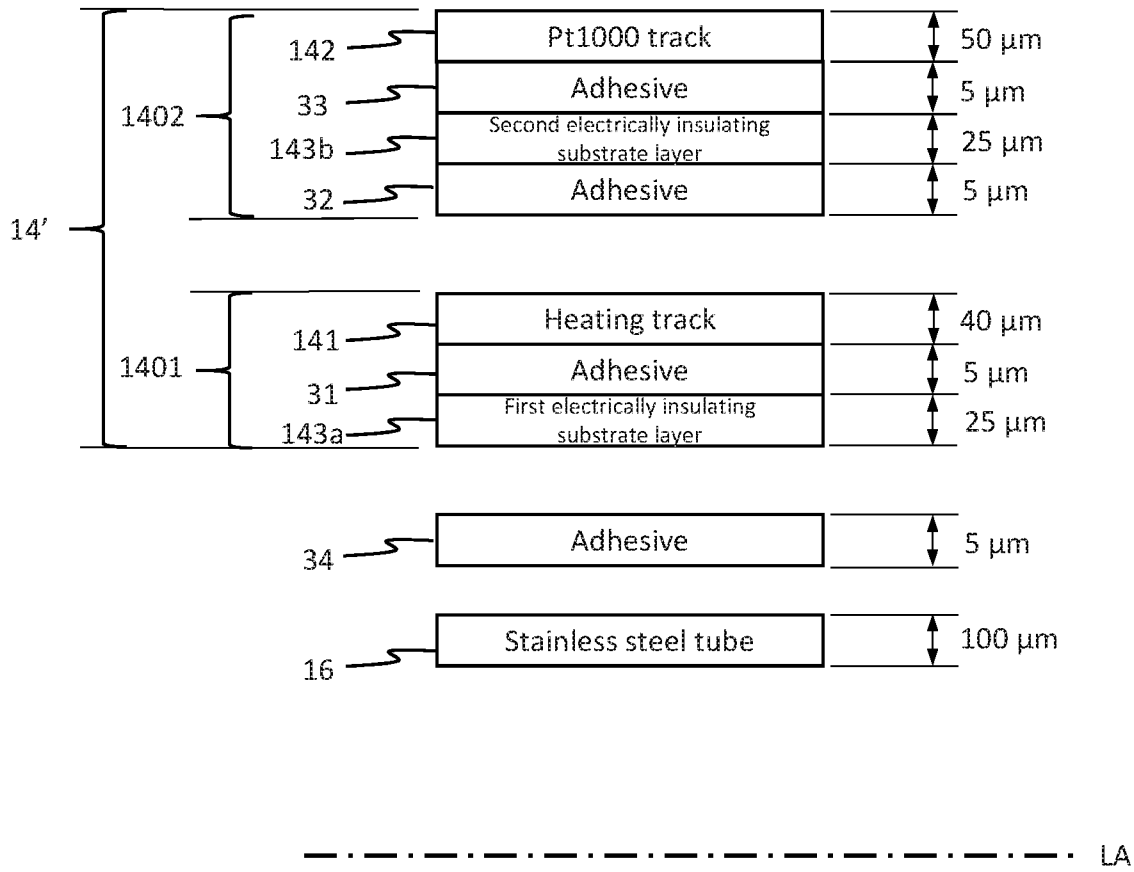

14'
1402
142
33
143b
32
Pt1000 track
Adhesive
Second electrically insulating substrate layer
Adhesive
50 µm
5 µm
25 µm
5 µm
1401
141
31
143a
Heating track
Adhesive
First electrically insulating substrate layer
40 µm
5 µm
25 µm
34
Adhesive
5 µm
16
Stainless steel tube
100 µm
LA

FIG. 7

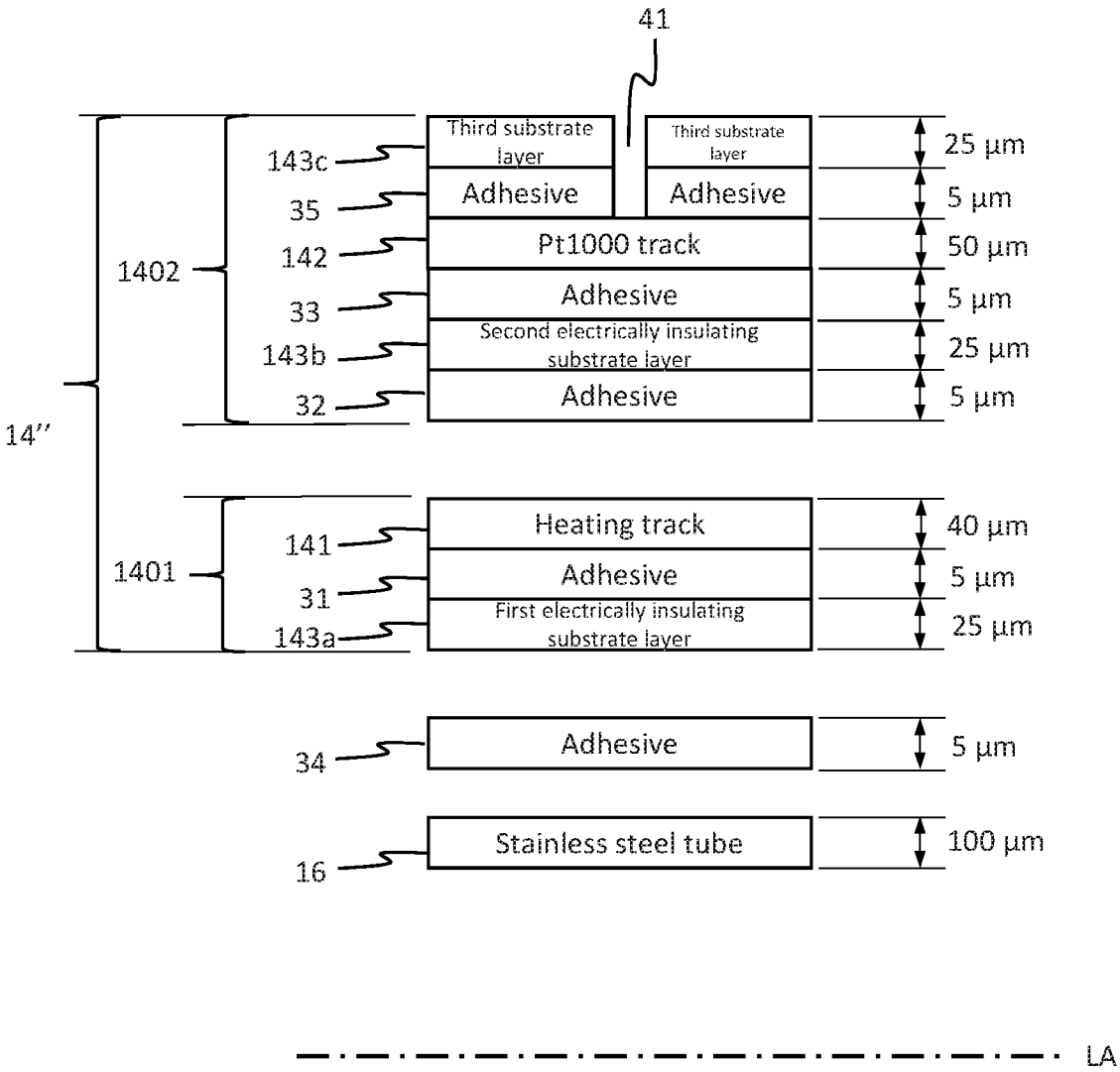

41
Third substrate layer
Third substrate layer
Adhesive
Adhesive
Pt1000 track
Adhesive
Second electrically insulating substrate layer
Adhesive
Heating track
Adhesive
First electrically insulating substrate layer
Adhesive
Stainless steel tube
143c
35
142
33
143b
32
141
31
143a
34
16
1402
1401
14''
25 µm
5 µm
50 µm
5 µm
25 µm
5 µm
40 µm
5 µm
25 µm
5 µm
100 µm
LA

FIG. 8

INTERNATIONAL SEARCH REPORT

International application No
PCT/CN2021/131159

A. CLASSIFICATION OF SUBJECT MATTER
INV. A24F40/57 A24F40/50 H05B3/40
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)
A24F H05B

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.
X	WO 2021/176224 A1 (NICOVENTURES TRADING LTD [GB]) 10 September 2021 (2021-09-10) abstract figures 1-12 page 14 - page 64	1-22
X	US 2019/342950 A1 (BERNAUER DOMINIQUE [CH] ET AL) 7 November 2019 (2019-11-07) abstract figures 1-7 paragraph [0038] - paragraph [0090]	1-7,9-21
X	WO 2013/098398 A2 (PHILIP MORRIS PROD [CH]) 4 July 2013 (2013-07-04) abstract figures 1-6 page 11 - page 26	1-7,9-21

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[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
6 May 2022	17/05/2022

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Juvenelle, Cyril

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PCT/CN2021/131159

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	WO 2021/140018 A1 (PHILIP MORRIS PRODUCTS SA [CH]) 15 July 2021 (2021-07-15) abstract figures 1-8 page 2 - page 20	1-22
A	CN 104 799 438 A (YUNNAN KUNCHUAN DIGITAL TECHNOLOGY CO LTD) 29 July 2015 (2015-07-29) abstract figures 1-6 paragraph [0012] - paragraph [0032]	1-22

1

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/CN2021/131159

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO 2021176224 A1	10-09-2021	NONE	
US 2019342950 A1	07-11-2019	AR 104251 A1	05-07-2017
		AU 2016248879 A1	17-08-2017
		BR 112017019913 A2	19-06-2018
		CA 2982512 A1	20-10-2016
		CN 107407941 A	28-11-2017
		DK 3282871 T3	08-07-2019
		EP 3282871 A1	21-02-2018
		EP 3533351 A1	04-09-2019
		ES 2734135 T3	04-12-2019
		HU E044316 T2	28-10-2019
		IL 253548 A	28-02-2021
		JP 6808639 B2	06-01-2021
		JP 2018514197 A	07-06-2018
		JP 2021045162 A	25-03-2021
		KR 20170137066 A	12-12-2017
		LT 3282871 T	25-07-2019
		MY 186867 A	26-08-2021
		PH 12017501315 A1	05-02-2018
		PL 3282871 T3	31-12-2019
		PL 3533351 T3	17-05-2021
		PT 3282871 T	30-09-2019
		RU 2017134676 A	05-04-2019
		RU 2019120817 A	20-08-2019
		SG 11201708374U A	29-11-2017
		SI 3282871 T1	30-08-2019
		TR 201910396 T4	21-08-2019
		TW 201637514 A	16-10-2016
		US 2018084608 A1	22-03-2018
		US 2019342950 A1	07-11-2019
		WO 2016166064 A1	20-10-2016
		ZA 201704863 B	31-07-2019
WO 2013098398 A2	04-07-2013	AU 2012360820 A1	21-08-2014
		BR 112014012734 A2	13-06-2017
		CA 2858479 A1	04-07-2013
		CN 103997921 A	20-08-2014
		EP 2797447 A2	05-11-2014
		ES 2635092 T3	02-10-2017
		HK 1198241 A1	20-03-2015
		IL 232369 A	27-02-2020
		JP 6143784 B2	07-06-2017
		JP 2015507477 A	12-03-2015
		KR 20140118985 A	08-10-2014
		MX 357545 B	13-07-2018
		MY 177353 A	14-09-2020
		NZ 624139 A	29-05-2015
		PL 2797447 T3	30-11-2017
		PT 2797447 T	26-10-2017
		RU 2014131454 A	20-02-2016
		SG 11201403681W A	30-07-2014
		US 2014345633 A1	27-11-2014
		WO 2013098398 A2	04-07-2013
		ZA 201402705 B	27-07-2016
WO 2021140018 A1	15-07-2021	NONE	

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/CN2021/131159

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
CN 104799438 A	29-07-2015	NONE	