Methods and devices for determining salt concentration in a bioliquid

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(54) **Title:** METHODS AND DEVICES FOR DETERMINING SALT CONCENTRATION IN A BIOLIQUID

(57) **Abstract:** Electronic device and method for determining salt concentration in a bioliquid is disclosed, the method comprising obtaining sensor data comprising first sensor data from a first electrode pair associated with a polymer composition comprising hydrocolloids and having at least some of the bioliquid absorbed therein; determining, based on the sensor data, a first parameter indicative of a first electrical property of the polymer composition; determining, based on the sensor data, a second parameter indicative of a second electrical property of the polymer composition; determining, based on the first parameter and the second parameter, a salt concentration of the bioliquid; and providing, via an interface, concentration data indicative of the salt concentration.

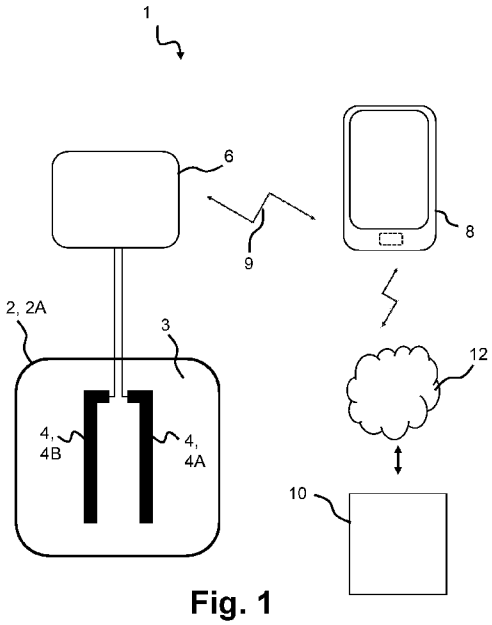

Fig. 1

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METHODS AND DEVICES FOR DETERMINING SALT CONCENTRATION IN A BIOLIQUID

The present disclosure relates to analysis of bioliquids and in particular to methods and devices for determining salt concentration in a bioliquid.

Brief Description of the Drawings

The accompanying drawings are included to provide a further understanding of embodiments and are incorporated into and a part of this specification. The drawings illustrate embodiments and together with the description serve to explain principles of embodiments. Other embodiments and many of the intended advantages of embodiments will be readily appreciated as they become better understood by reference to the following detailed description. The elements of the drawings are not necessarily to scale relative to each other. Like reference numerals designate corresponding similar parts.

Fig. 1 illustrates an exemplary sensor system according to the present disclosure,
Fig. 2 illustrates an exemplary sensor device according to the present disclosure,
Fig. 3 is a flow diagram of an example method for determining salt concentration according to the present disclosure,
Fig. 4A shows graph of measurements of bioliquids with different salt concentrations,
Fig. 4B shows graph of measurements of bioliquids with different salt concentrations,
Fig. 4C shows graph of measurements of bioliquids with different salt concentrations, and
Fig. 4D shows graph of measurements of bioliquids with different salt concentrations.

Detailed Description

Various exemplary embodiments and details are described hereinafter, with reference to the figures when relevant. It should be noted that the figures may or may not be drawn to scale and that elements of similar structures or functions are represented by like reference numerals throughout the figures. It should also be noted that the figures are only intended to facilitate the description of the embodiments. They are not intended as an exhaustive description of the invention or as a limitation on the scope of the invention. In addition, an illustrated embodiment needs not have all the aspects or advantages shown. An aspect or an advantage described in conjunction with a particular embodiment is not necessarily

limited to that embodiment and can be practiced in any other embodiments even if not so illustrated, or if not so explicitly described.

The use of the word “substantially” or “about” as a qualifier to certain features or effects in this disclosure is intended to simply mean that any deviations are within tolerances that would normally be expected by the skilled person in the relevant field.

The use of the word “generally” as a qualifier to certain features or effects in this disclosure is intended to simply mean – for a structural feature: that a majority or major portion of such feature exhibits the characteristic in question, and – for a functional feature or an effect: that a majority of outcomes involving the characteristic provide the effect, but that exceptionally outcomes do not provide the effect.

The present disclosure relates to a sensor system and devices thereof, such as an electrode assembly/sensor patch/sensor, and one or more electronic devices, such as a sensor device and/or one or more accessory devices. The sensor system may comprise an accessory device. Further, methods related to the sensor system and devices thereof are disclosed. A sensor device (also referred to as an external device), may be a personal computer, a mobile phone or other handheld device, such as a tablet computer. A sensor device may be a personal electronic device, e.g., a wearable, such as a watch or other wrist-worn electronic device. An accessory device (also referred to as an external device), may be a personal computer, a smart device, such as a smartphone, a mobile phone, or other handheld device, such as a tablet computer. An accessory device may be a personal electronic device, e.g., a wearable, such as a watch or other wrist-worn electronic device. The sensor device and the accessory device may be different and/or separate devices. The sensor system may comprise a server device. The server device may be operated and/or controlled by a service centre.

The present disclosure provides a sensor system and devices thereof, such as a sensor patch/sensor, a sensor device, and optionally one or more accessory devices which either alone or together facilitate reliable classification, determination, and monitoring of salt concentration in a bioliquid.

A sensor is disclosed, the sensor comprising a polymer composition and one or more electrode pairs including a first electrode pair associated with, such as integrated in or in contact with, the polymer composition. The sensor may be a sensor patch. The polymer

composition optionally comprises hydrocolloids and is configured to absorb at least some bioliquid therein.

The polymer composition may be an adhesive layer, such as a skin adhesive layer, i.e., an adhesive layer configured to adhere to the skin of a user.

In one or more examples, the polymer composition is or comprises a first composition. The first composition can comprise one or more polyisobutenes and/or styrene-isoprene-styrene. The first composition can comprise one or more hydrocolloids. The first composition can comprise one or more water soluble or water swellable hydrocolloids. The first composition can be a pressure sensitive adhesive composition suitable for medical purposes comprising a rubbery elastomeric base and optionally one or more water soluble and/or water swellable hydrocolloids. The first composition can comprise one or more polybutenes, one or more styrene copolymers, one or more hydrocolloids, or any combination thereof. The combination of the adhesive properties of the polybutenes and the absorbing properties of the hydrocolloids renders the first composition suitable for use in sensors including sensors for attachment to the skin of a person. The styrene copolymer can for example be a styrene-butadiene-styrene block copolymer or a styrene-isoprene-styrene block copolymer. Preferably, one or more styrene-isoprene-styrene (SIS) block type copolymers are employed. The amount of styrene block-copolymer can be from 5 % to 20 % of the total polymer composition. The butene component is suitably a conjugated butadiene polymer selected from polybutadiene, polyisoprene. The polybutenes are preferably present in an amount of from 35 – 50 % of the total polymer composition. Preferably, the polybutene is polyisobutylene (PIB). Suitable hydrocolloids for incorporation in the first composition are selected from naturally occurring hydrocolloids, semisynthetic hydrocolloids and synthetic hydrocolloids. In one or more examples, the first composition can comprise 20-60 % hydrocolloids. The first composition can optionally contain other components, such as one or more of fillers, tackifiers, plasticizers, and other additives.

The polymer composition, such as the adhesive layer, can have a substantially uniform thickness. The adhesive layer can have a thickness, e.g., defined as distance between an outer surface of the polymer composition and first electrodes of the first electrode pair, in the range from 0.1 mm to 1.5 mm, e.g., in the range from 0.2 mm to 1.2 mm, such as 0.8 mm or 1.0 mm. In one or more example sensors, the polymer composition may have a thickness larger than 1.5 mm, e.g., where the first electrodes are embedded, i.e., surrounded by polymer composition.

In one or more examples, the polymer composition is hydroxyethyl cellulose (HEC). In other words, the polymer composition may comprise hydroxyethyl cellulose (HEC). In an embodiment, the HEC is the only type of hydrocolloid of the polymer composition/adhesive layer.

In one or more examples, the polymer composition is carboxymethyl cellulose (CMC). In other words, the polymer composition/adhesive layer may comprise carboxymethyl cellulose (CMC). In an embodiment, the CMC is the only type of hydrocolloid of the polymer composition/adhesive layer.

Methods of determining salt concentration in a bioliquid is disclosed.

In one or more examples, the bioliquid is sweat and/or urine. Thus, the present disclosure may facilitate reliable monitoring and determination of the salt concentration of sweat and/or urine, which may be of importance, e.g., to optimize liquid intake, e.g., during sports and other activities.

In one or more examples, the bioliquid is bodily waste, e.g., from a human or an animal.

In one or more examples, the bioliquid is sewage or blood, such as blood plasma. In one or more examples, the bioliquid may have a dry matter content of at least 5% v/v.

A method, e.g. performed in an electronic device, such as a sensor device, an accessory device or a server device, for determining salt concentration of and/or in a bioliquid is disclosed, the method comprising: obtaining sensor data comprising first sensor data from a first electrode pair associated with, e.g. integrated in and/or in contact with, a polymer composition comprising hydrocolloids and having at least some of the bioliquid absorbed therein; determining, based on the sensor data, such as the first sensor data, a first parameter indicative of a first electrical property of the polymer composition; determining, based on the sensor data, such as the first sensor data, a second parameter indicative of a second electrical property of the polymer composition; determining, based on the first parameter and the second parameter, a salt concentration of the bioliquid; and providing, via an interface, concentration data indicative of the salt concentration. The methods as disclosed herein may be performed in a sensor device, such as a sensor device mechanically and electrically coupled to the sensor, such as coupled to electrodes of the sensor. The methods as disclosed herein may be performed in an accessory device of the sensor system, wherein the obtaining of sensor data may comprise obtaining the sensor

data from a sensor device coupled to the sensor. The methods as disclosed herein may be performed by a server device. The methods as disclosed herein and different parts thereof may be shared between respective processing power of a sensor device, an accessory device and/or a server device. In other words, the methods as disclosed herein may be distributed between and performed by a sensor device, an accessory device and/or a server device.

When exposed to liquid, the polymer composition or adhesive layer (and in particular the hydrocolloids thereof) is hydrated, e.g., the hydrocolloids absorb liquid/moisture, and the electrical properties of the polymer composition change. The changes in the electrical properties depend on the nature and/or the volume of the bioliquid hydrating and/or absorbed in the polymer composition. In other words, the changes in the electrical properties are associated with the nature (contents, type) of the bioliquid causing the changes. In further other words, methods as described herein allow for determining one or more properties, such as salt concentration, of the bioliquid causing the hydration of the polymer composition/adhesive layer. Thus, methods as described herein allow for distinguishing and/or characterizing bioliquids in the polymer composition/adhesive layer by means of the measuring principles forming part of the method as disclosed. Methods as disclosed herein allow for communicating to the user, via an appropriately determined operating state, whether it is bioliquid with first or second salt concentration absorbed in the polymer composition. Thereby, the user may take appropriate action.

The sensor data may comprise first sensor data from a first electrode pair associated with, such as integrated in and/or in contact with, the polymer composition. In other words, the method may comprise obtaining first sensor data from a first electrode pair associated with the polymer composition. The first sensor data may be indicative of impedance between electrodes of the first electrode pair. The sensor data, such as the first sensor data, may be obtained by applying a voltage at one or more frequencies, such as at a primary frequency and/or a secondary frequency, and measure the resulting current. In other words, obtaining sensor data may comprise applying a voltage to one or more electrode pairs including a first electrode pair and measure a resulting current passing through the polymer composition between the respective electrode pair(s). The sensor data, such as the first sensor data, may be obtained by applying a current at one or more frequencies, such as at a primary frequency and/or a secondary frequency, and measure the resulting voltage. In other words, obtaining sensor data may comprise applying a current to one or more electrode pairs including a first electrode pair and measuring a resulting current passing through the polymer composition between the respective

electrode pair(s). The first sensor data may be indicative of impedance at one or a plurality of frequencies, e.g., at a primary frequency and/or a secondary frequency. The first electrode pair may comprise a first and a second electrode associated with the polymer composition/adhesive layer such that current may propagate through the polymer composition from the first electrode to the second electrode (or vice versa).

The impedance Z of the polymer composition comprises a real part Z' that has been shown to depend on both hydration level and ion concentration of the polymer composition. Further, the impedance Z of the polymer composition comprises an imaginary part Z'' that has been shown to depend mainly on hydration level of the polymer composition.

$$Z = Z' + iZ'' = R_{el} + \frac{1}{Q_0(i\omega)^n}$$

where R_{el} is the resistance of the polymer composition/adhesive layer (indicative of mobile electrolytes/ions absorbed therein), and Q_0 is a constant phase constant and is a measure of the hydration level of the polymer composition/adhesive layer and may be representative of the double layer capacitance formed in the system. R_{el} relates to conductance G in that G = 1 / R_{el}, which may be normalized by electrode area and distance d to determine conductivity σ by σ = G d / A = d / (A R_{el}) The impedance Z is dominated by Q_0 at low frequencies and by R_{el} (i.e., the conductivity σ) at high frequencies.

The present invention allows for a decoupling of hydration level and ion concentration effects in the polymer composition which is then used for classifying/determining a salt concentration of or in the bioliquid being absorbed in the polymer composition.

In one or more examples, determining a first parameter comprises determining the first parameter at a first time and at a second time, and wherein determining a salt concentration of the bioliquid comprises determining the salt concentration based on the first parameter at the first time and at the second time.

In one or more examples, determining a second parameter comprises determining the second parameter at the first time and at the second time, and wherein determining a salt concentration of the bioliquid comprises determining the salt concentration based on the first parameter at the first time and at the second time.

In one or more example methods, determining, based on the sensor data, such as the first sensor data, one or more parameters indicative of respective electrical properties of the polymer composition may comprise determining, based on the sensor data, such as the first sensor data and/or second sensor data, a first parameter indicative of a first electrical property of the polymer composition. In one or more examples, the first parameter is electrical conductivity or conductance. The electrical conductivity, also denoted σ, may be representative of the real part of the impedance. In other words, the first parameter may be a conductance or conductivity parameter. The first parameter may be indicative of a conductance.

The first parameter may be electrical resistivity. In other words, the first parameter may be a resistance or resistivity parameter. The first parameter may be indicative of a resistance.

In one or more example methods, determining, based on the sensor data, such as the first sensor data, one or more parameters indicative of respective electrical properties of the polymer composition may comprise determining, based on the sensor data, such as the first sensor data and/or second sensor data, a second parameter indicative of a second electrical property of the polymer composition. The second electrical property may be different from the first electrical property. The second parameter may be different from the first parameter. In one or more examples, the second parameter is capacitance or capacity. The capacitance, also denoted C, may be representative of the imaginary part of the impedance. In other words, the second parameter may be a capacitance or capacity parameter. The second parameter may be indicative of a capacitance.

The second parameter may be a constant phase parameter or double layer capacitance also denoted Q_0, which may be derived from or based on the imaginary part of the impedance. In other words, the second parameter may be indicative of a constant phase impedance of a constant phase element.

In one or more examples, the second parameter may be indicative of a capacity and/or a change in capacitance of the polymer composition. Thus, in one or more examples, the second parameter being capacitance is measured or determined at high frequencies, such as larger than 200 kHz or even larger than 1 MHz and the above equation would extend to:

$$Z = \frac{1}{R} + i\omega C + \frac{1}{Q_0 (i\omega)^n}$$

In one or more examples, the second parameter may be indicative of an effective capacitance of the adhesive layer.

In one or more example methods, determining, based on the one or more parameters, such as the first parameter and/or the second parameter, a salt concentration of the bioliquid may comprise determining, based on the first parameter and the second parameter, a salt concentration of the bioliquid, e.g., by mapping the first parameter and the second parameter to the salt concentration. Determining a salt concentration may comprise inputting the first parameter and/or the second parameter to a function, look-up table, a neural network, or a model, such as a machine-learning model. In other words, determining the salt concentration may be based on a function, look-up table, a neural network, or a model, such as a machine-learning model. In one or more examples, the salt concentration may be based on a relationship, such as a ratio and/or a difference, between the first parameter and the second parameter.

The method comprises providing, via an interface, concentration data indicative of the salt concentration. Providing, via an interface, concentration data may comprise transmitting the concentration data and/or displaying a salt concentration representation, such as a number, indicative of the salt concentration.

In one or more examples, determining a salt concentration of the bioliquid comprises determining, e.g., based on the first parameter and/or the second parameter, an ion concentration in the polymer composition and determining the salt concentration based on the ion concentration, e.g., by mapping the ion concentration to the salt concentration. In other words, determining a salt concentration of the bioliquid may comprise determining an ion concentration in the polymer composition based on the first parameter and/or the second parameter and mapping the ion concentration to the salt concentration.

Determining an ion concentration may comprise one or more of inputting the first parameter and/or the second parameter to a function, look-up table, a neural network, or a model, such as a machine-learning model. In other words, determining the ion concentration may be based on a function, look-up table, a neural network, or a model, such as a machine-learning model.

In one or more examples, determining a salt concentration of the bioliquid comprises determining a hydration level and/or an ion mobility in the polymer composition based on the first parameter and/or the second parameter and determining the salt concentration

based on the hydration level and/or ion mobility, e.g., by mapping the hydration level and/or ion mobility to the salt concentration. In other words, determining a salt concentration of the bioliquid may comprise determining a hydration level and/or an ion mobility in the polymer composition based on the first parameter and/or the second parameter and mapping the hydration level and/or ion mobility to the salt concentration.

In one or more example methods, determining a salt concentration of the bioliquid comprises determining the salt concentration based on the ion concentration and/or the hydration level of the polymer composition.

Determining a hydration level may comprise one or more of inputting the first parameter and/or the second parameter to a function, look-up table, a neural network, or a model, such as a machine-learning model. In other words, determining the hydration level may be based on a function, look-up table, a neural network, or a model, such as a machine-learning model.

In one or more examples, determining a salt concentration of the bioliquid comprises determining whether the polymer composition is in a first operating state indicative of the polymer composition being wetted with bioliquid having a first salt concentration.

In one or more examples, determining a salt concentration of the bioliquid comprises determining whether the polymer composition is in a second operating state indicative of the polymer composition being wetted with bioliquid having a second salt concentration.

In one or more examples, determining a first parameter comprises determining the first parameter at one or more (electrical) frequencies, e.g., including a first primary frequency and/or a first secondary frequency. Thus, determining a first parameter optionally comprises determining the first parameter at a first primary frequency and/or at a first secondary frequency,

The first primary frequency may be in a primary frequency range, such as from 10 Hz to 500 Hz or from 500 Hz to 100 kHz. In one or more examples, first primary frequency is less than 200 kHz, such as 100 Hz or 64 kHz. A first primary frequency from 500 Hz to 100 kHz may allow power efficient sensing. The primary frequency, such as the first primary frequency and/or the second primary frequency may be less than 200 kHz, such as about 47 kHz, 62.5 kHz, 93.75 kHz, 100 kHz, 125 kHz, or 187.5 kHz. The primary

frequency, such as the first primary frequency and/or the second primary frequency may be less than 10 Hz.

Determining a salt concentration of the bioliquid is optionally based on the first parameter at the first primary frequency. The first parameter at the first primary frequency is also denoted the first primary parameter.

In one or more examples, the first secondary frequency is in a secondary frequency range, such as from 10 kHz to 200 kHz or from 200 kHz to 15 MHz. Determining a salt concentration of the bioliquid may be based on the first parameter at the first secondary frequency. The first parameter at the first secondary frequency is also denoted the first secondary parameter. In one or more examples, the first secondary frequency is 100 kHz or 4 MHz. A first secondary frequency from 10 kHz to 200 kHz may allow power efficient sensing. The secondary frequency, such as the first secondary frequency and/or the second secondary frequency may be larger than 200 kHz, such as larger than 500 kHz or even larger than 1 MHz. In one or more examples, the secondary frequency, such as the first secondary frequency and/or the second secondary frequency, is 250 kHz, 375 kHz, 750 kHz, 1 MHz, 1.5 MHz, 2 MHz, 3 MHz, 4 MHz, 6 MHz, 8 MHz, or 12 MHz.

In one or more examples, determining the second parameter comprises determining the second parameter at one or more (electrical) frequencies, e.g., including a second primary frequency and/or a second secondary frequency. Thus, determining a second parameter optionally comprises determining the second parameter at a second primary frequency and/or at a second secondary frequency.

The second primary frequency may be in a primary frequency range from 10 Hz to 500 Hz or from 500 Hz to 100 kHz. In one or more examples, the second primary frequency is less than 200 kHz, such as 100 Hz or 64 kHz. A second primary frequency from 500 Hz to 100 kHz may allow power efficient sensing. Determining a salt concentration of the bioliquid is optionally based on the second parameter at the second primary frequency. The second parameter at the second primary frequency is also denoted the second primary parameter. The second primary frequency may be the same as the first primary frequency and then commonly denoted the primary frequency.

In one or more examples, the second secondary frequency is in a secondary frequency range, such as from 10 kHz to 200 kHz or from 200 kHz to 15 MHz. Determining a salt concentration of the bioliquid may be based on the second parameter at the second

secondary frequency. The second parameter at the second secondary frequency is also denoted the second secondary parameter. The second secondary frequency may be the same as the first secondary frequency and then commonly denoted the secondary frequency.

In one or more examples, the secondary frequency range may be different from, such as non-overlapping, the primary frequency range. The secondary frequency range may overlap the primary frequency range, either in parts (e.g., one end-point of the secondary frequency range may be within the primary frequency range and one end-point of the secondary frequency range may be outside the primary frequency range) or in totality (i.e., from end-point to end-point).

It is to be understood that the first parameter and the second parameter may be determined at a respective primary frequency and/or secondary frequency.

In one or more examples, obtaining sensor data comprises obtaining second sensor data from a second electrode pair associated with the polymer composition comprising hydrocolloids and having at least some of the bioliquid absorbed therein. One or both of determining a first parameter and determining a second parameter may be based on the second sensor data.

An electronic device, such as a sensor device and/or an accessory device, is disclosed, the electronic device comprising an interface and one or more processors, and optionally a memory, wherein the one or more processors are configured to perform a method as disclosed herein.

An electronic device, such as a sensor device and/or an accessory device, is disclosed, the electronic device comprising an interface and one or more processors, and optionally a memory, wherein the one or more processors are configured to obtain, via the interface, sensor data comprising first sensor data from a first electrode pair associated with a polymer composition comprising hydrocolloids and having at least some of a bioliquid absorbed therein; determine, based on the first sensor data, a first parameter indicative of a first electrical property of the polymer composition; determine, based on the first sensor data, a second parameter indicative of a second electrical property of the polymer composition; determine, based on the first parameter and the second parameter, a salt concentration of the bioliquid; and provide, via the interface, concentration data indicative of the salt concentration.

In one or more examples, the interface comprises a first interface configured to couple to at least the first electrode pair of the polymer composition. The interface may comprise a second interface configured to provide the concentration data. The second interface is optionally configured to provide the concentration data by means of a wireless signal, by means of a user interface on a display, and/or by storing the concentration data in a memory.

In one or more example electronic devices, e.g., where the electronic device is a sensor device, the interface comprises a first interface configured to couple to at least the first electrode pair of the polymer composition. The interface may comprise a second interface configured to provide the concentration data. The second interface is optionally configured to provide the concentration data by means of a wireless signal, by means of a user interface on a display, and/or by storing the concentration data in a memory of the electronic device.

The first interface and the second interface may be identical or connected. The first interface may be an interface adapted to obtain or collect sensor data, e.g., via an electrical or wireless connection, e.g., to the sensor. The second interface may be an interface adapted to communicate the concentration data, e.g., wirelessly and/or the second interface may comprise a display/graphical user interface configured to communicate the concentration data by means of displaying a representation of the concentration data.

The sensor may comprise an electrode assembly. The electrode assembly comprises a first electrode pair (first sensor) optionally arranged on or embedded in the polymer composition, the first electrode pair forming a first sensor for provision of first sensor data. The electrode assembly may comprise a plurality of electrode pairs including a second electrode pair (second sensor) optionally arranged on or embedded in the polymer composition, the second electrode pair forming a second sensor for provision of second sensor data. The first electrode pair and the second electrode pair may share a common electrode. The sensor/electrode assembly may comprise a sensor interface for connecting electrodes of the electrode assembly to terminals of the first interface of the sensor device.

Also disclosed is a computer readable storage medium storing one or more programs, the one or more programs comprising instructions, which when executed by an electronic

device with an interface and one or more processors cause the electronic device to be configured to operate in accordance with methods as described herein.

It is to be noted that descriptions of the electronic device, such as sensor device and/or accessory device, being configured to perform acts also apply to the corresponding acts in the methods and vice versa.

The present disclosure provides a reliable and accurate determination of salt concentration in a bioliquid, which may otherwise be difficult due to, e.g., dry matter and other components of the bioliquid.

Detailed description of the drawings

Fig. 1 illustrates an exemplary sensor system 1 for determining a salt concentration in a bioliquid, such as sweat. The sensor system 1 comprises a sensor 2 embodied as a sensor patch 2A, the sensor patch comprising a polymer composition 3 and a first electrode pair 4, the polymer composition forming an adhesive layer and having at least the first electrode pair embedded therein or in contact therewith. Further, the sensor system 1 comprises a sensor device 6, and optionally an accessory device 8 (e.g., a mobile telephone, tablet, or smartphone). The sensor device 6 is connectable to the sensor 2, such as to an electrode assembly with first electrode pair, or mounted to the sensor 2, via respective first connectors of the sensor device 6 and sensor 2. The sensor device 6 is optionally configured for wireless communication via connection 9 with the accessory device 8. Optionally, the accessory device 8 is configured to communicate with an optional server device 10 of the sensor system 1, e.g., via network 12. The server device 10 may be operated and/or controlled by the sensor manufacturer and/or a service centre. Sensor data including first sensor data are obtained with/by the sensor device 6 from first electrode pair 4 (first electrode 4A and second electrode 4B) of an electrode assembly embedded in or in contact with (e.g., arranged on a distal side of) the polymer composition 3 forming the adhesive layer of the sensor 2. The sensor device 6 processes and/or transmits to the accessory device 8 one or more of sensor data, first parameter, second parameter, and salt concentration. In the illustrated sensor system, the accessory device 8 is a mobile phone, however the accessory device 8 may be embodied as another electronic device, such as a handheld device, such as a tablet device, or a wearable, such as a watch or other wrist-worn electronic device.

Fig. 2 is a schematic block diagram of an exemplary electronic device, such as a sensor device 6. The sensor device 6 comprises a sensor device housing 100, a processor 101,

and an interface, the interface including a first interface 102 (sensor interface) and a second interface 104 (accessory interface). The sensor device 6 comprises a memory 106. The memory 106 is optionally connected to the processor 101.

The first interface 102 is configured as an appliance interface for electrically and/or mechanically connecting the sensor device 6 to the sensor 2. The first interface 102 comprises a plurality of terminals for forming electrical connections with respective terminals/electrodes 4A, 4B of the sensor 2 (electrode assembly). The first interface 102 comprises a first terminal 110 and a second terminal 112 configured for electrical connection to the first electrode 4A and the second electrode 4B of the sensor 2, respectively. Further terminals, such as third terminal 114 and/or fourth terminal 116 may be provided in the first interface 102, e.g., for electrical connection to further electrodes, such as a second electrode pair, of the sensor 2. The first interface 102 of the sensor device 6 comprises a coupling part 120 for forming a mechanical connection, such as a releasable coupling between the sensor device 6 and the sensor 2, e.g., with a sensor patch. The coupling part 120 and the terminals 110, 112, 114, and 116 of the first interface 102 form (at least part of) a first connector of the sensor device 6. The second interface 104 of sensor device 6 is optionally configured as an accessory interface for connecting the sensor device 6 to an accessory device 8. Thus, the second interface 104 optionally comprises an antenna 122 and a wireless transceiver 124 also denoted transceiver module, the wireless transceiver 124 connected to the processor 101 and configured for wireless communication with accessory device(s), such as configured for connecting the sensor device 6 to accessory device 8 of the sensor system and optionally transmitting concentration data to accessory device 8. Optionally, the second interface 104 comprises a loudspeaker 126 and/or a visual interface, such as a display 128 and/or a set of indicators, such as LEDs, for provision of respective audio signal and/or visual display representing concentration data/salt concentration to the user.

The processor 101 is optionally configured to obtain, via the first interface 102, sensor data comprising first sensor data from a first electrode pair associated with a polymer composition comprising hydrocolloids and having at least some of the biofluid absorbed therein; determine, based on the sensor data, such as the first sensor data, a first parameter indicative of a first electrical property of the polymer composition; determine, based on the sensor data, such as the first sensor data, a second parameter indicative of a second electrical property of the polymer composition; determine, based on the first parameter and the second parameter, a salt concentration of the bioliquid; and provide, via the second interface 104, concentration data indicative of the salt concentration.

Providing the concentration data via the second interface may comprise to transmit a signal indicative of the concentration data to an accessory device. Providing the concentration data via the second interface may comprise to display a representation of the operating state in a graphical user interface of the second interface.

The processor 101 may be configured to perform any of the operations disclosed in Fig. 3 (such as any one or more of S202, S204, S206, S208). The operations of the sensor device 6 may be embodied in the form of executable logic routines (such as, lines of code, software programs, etc.) that are stored on a non-transitory computer readable medium, such as internal memory in the processor 101 and/or external memory 106, and are executed by the processor 101.

Furthermore, the operations of the sensor device 6 may be considered a method that the sensor device 6 is configured to carry out. Also, while the described functions and operations may be implemented in software, such functionality may as well be carried out via dedicated hardware or firmware, or some combination of hardware, firmware and/or software.

The memory 106 may be one or more of a buffer, a flash memory, a hard drive, a removable media, a volatile memory, a non-volatile memory, a random access memory (RAM), or other suitable device. In a typical arrangement, the memory 106 may include a non-volatile memory for long term data storage and a volatile memory that functions as system memory for the processor 101. The memory 106 may exchange data with the processor 101 over a data bus. Control lines and an address bus between the memory 106 and the processor 101 also may be present (not shown in Figs. 1 and 2). The memory 106 is considered a non-transitory computer readable medium.

Fig. 3 shows a flow diagram of an example method 200 for determining salt concentration in a bioliquid, e.g., with an electronic device, such as a sensor device 6 and/or an accessory device 8, as disclosed herein. The method 200 comprises obtaining S202 sensor data comprising first sensor data from a first electrode pair associated with a polymer composition comprising hydrocolloids and having at least some of the biofluid absorbed therein; determining S204, based on the sensor data, such as the first sensor data, one or more parameters including determining S204A, based on the sensor data, such as the first sensor data, a first parameter indicative of a first electrical property, such as electrical conductivity, of the polymer composition and determining S204B, based on the sensor data, such as the first sensor data, a second parameter indicative of a second

electrical property, such as capacitance, of the polymer composition; determining S206, based on the first parameter and the second parameter, a salt concentration of the bioliquid; and providing S208, via an interface, concentration data indicative of the salt concentration.

In the method 200, determining S206 a salt concentration of the bioliquid comprises determining S206A an ion concentration in the polymer composition based on the first parameter and/or the second parameter and mapping S206B the ion concentration to the salt concentration.

In the method 200, determining S206 a salt concentration of the bioliquid comprises determining S206C a hydration level in the polymer composition based on the first parameter and/or the second parameter and mapping S206D the hydration level to the salt concentration.

In the method 200, determining S206 a salt concentration of the bioliquid optionally comprises determining S206E whether the polymer composition is in a first state indicative of the polymer composition being wetted with bioliquid having a first salt concentration or a salt concentration in a first range.

In the method 200, determining S206 a salt concentration of the bioliquid optionally comprises determining S206F whether the polymer composition is in a second state indicative of the polymer composition being wetted with bioliquid having a second salt concentration or a salt concentration in a second range.

In the method 200, determining S204A a first parameter comprises determining S204C the first parameter at one or more frequencies including a first primary frequency, wherein the first primary frequency optionally is in a primary frequency range from 10 Hz to 500 Hz, and wherein determining S206 a salt concentration of the bioliquid is based on the first parameter at the first primary frequency.

In the method 200, determining S204A a first parameter comprises determining S204D the first parameter at a first secondary frequency, wherein the first secondary frequency optionally is in a secondary frequency range from 10 kHz to 200 kHz, and wherein determining S206 a salt concentration of the bioliquid is based on the first parameter at the first secondary frequency.

Determining S204A a first parameter, such as S204C and/or S204D, optionally comprises determining the first parameter at a first time and/or at a second time, and wherein determining S206 a salt concentration of the bioliquid comprises determining the salt concentration based on the first parameter at the first time and/or at the second time.

In the method 200, determining S204B a second parameter comprises determining S204E the second parameter at one or more electrical frequencies including a second primary frequency, wherein the second primary frequency is in a primary frequency range from 10 Hz to 500 Hz, and wherein determining an operating state of the adhesive layer is based on the second parameter at the second primary frequency.

In the method 200, determining S204B a second parameter comprises determining S204F the second parameter at a second secondary frequency, wherein the second secondary frequency is in a secondary frequency range from 10 kHz to 200 kHz, and wherein determining an operating state of the adhesive layer is based on the second parameter at the second secondary frequency.

Determining S204B a first parameter, such as S204E and/or S204F, optionally comprises determining the second parameter at a first time and/or at a second time, and wherein determining S206 a salt concentration of the bioliquid comprises determining the salt concentration based on the second parameter at the first time and/or at the second time.

In the method 200, obtaining S202 sensor data comprises obtaining S202B second sensor data from a second electrode pair associated with the adhesive layer; and wherein one or both of determining a first parameter and determining a second parameter is based on the second sensor data.

Figs. 4A-D show graphs of measurements with polymer composition having an adhesive layer comprising CMC hydrocolloids only and exposed to various aqueous solutions: 1000 mM NaCl (dotted line), 150 mM NaCl (small-dashed line), and 50 mM NaCl (large-dashed line), at skin temperature (32 °C). The measurements are made using a first electrode pair associated with, such as embedded in or contacting, the adhesive layer, and measured during constant exposure to the solutions with different NaCl content.

In Fig. 4A, the complex impedance $|Z|$ is measured as a function of time. The conductivity σ and the constant phase parameter Q_0 may be derived from this measurement, see Fig. 4C and Fig. 4B, respectively.

The electrical conductivity σ, see Fig. 4C, as a first parameter is representative of number and mobility of ions in the adhesive and increases with the number of ions in the liquid, the amount of liquid in the adhesive, and the number of ions in the hydrocolloid. As time increases, the adhesive layer absorbs more and more liquid, and as such, the number of ions in the liquid, the amount of liquid in the adhesive, and the number of ions in the particles increases.

The constant phase parameter Q_0, see Fig. 4B, as a second parameter is representative of the hydration level or amount of liquid in the adhesive layer.

Fig. 4D shows electrical conductivity σ as a function of constant phase parameter Q_0. Fig. 4D clearly shows the benefits of the combination of using a first parameter and a second parameter for the classification of the operating state of the adhesive layer. The operating state may for example be indicative of concentration data indicative of the salt concentration. In particular, Fig. 4D clearly shows that the different salt concentrations are distinguishable when performing a method comprising the steps of obtaining sensor data comprising first sensor data from a first electrode pair associated with a polymer composition comprising hydrocolloids and having at least some of the biofluid absorbed therein; determining, based on the sensor data, a first parameter σ indicative of a first electrical property of the polymer composition; determining, based on the sensor data, a second parameter Q_0 indicative of a second electrical property of the polymer composition; determining, based on the first parameter and the second parameter, an operating state, such as a salt concentration, of the bioliquid; and providing, via an interface, concentration data indicative of the salt concentration.

The difference in behavior of bioliquid with different salt concentration allows to determine the salt concentration of the bioliquid. For example, a presence of sweat with a first salt concentration can be detected and communicated, e.g., as a first operating state of the polymer composition, and a presence of sweat with a second salt concentration can be detected and communicated, e.g., as a second operating state of the polymer composition.

The use of the terms “first”, “second”, “third” and “fourth”, “primary”, “secondary”, “tertiary” etc. does not imply any particular order but are included to identify individual elements. Moreover, the use of the terms “first”, “second”, “third” and “fourth”, “primary”, “secondary”, “tertiary” etc. does not denote any order or importance, but rather the terms “first”, “second”, “third” and “fourth”, “primary”, “secondary”, “tertiary” etc. are used to distinguish

one element from another. Note that the words “first”, “second”, “third” and “fourth”, “primary”, “secondary”, “tertiary” etc. are used here and elsewhere for labelling purposes only and are not intended to denote any specific spatial or temporal ordering.

Furthermore, the labelling of a first element does not imply the presence of a second element and vice versa.

It may be appreciated that the figures comprise some modules or operations which are illustrated with a solid line and some modules or operations which are illustrated with a dashed line. The modules or operations which are comprised in a solid line are modules or operations which are comprised in the broadest example embodiment. The modules or operations which are comprised in a dashed line are example embodiments which may be comprised in, or a part of, or are further modules or operations which may be taken in addition to the modules or operations of the solid line example embodiments. It should be appreciated that these operations need not be performed in order presented. Furthermore, it should be appreciated that not all of the operations need to be performed. The exemplary operations may be performed in any order and in any combination.

It is to be noted that the word "comprising" does not necessarily exclude the presence of other elements or steps than those listed.

It is to be noted that the words "a" or "an" preceding an element do not exclude the presence of a plurality of such elements.

It should further be noted that any reference signs do not limit the scope of the claims, that the exemplary embodiments may be implemented at least in part by means of both hardware and software, and that several "means", "units" or "devices" may be represented by the same item of hardware.

The various exemplary methods, devices, and systems described herein are described in the general context of method steps processes, which may be implemented in one aspect by a computer program product, embodied in a computer-readable medium, including computer-executable instructions, such as program code, executed by computers in networked environments. A computer-readable medium may include removable and non-removable storage devices including, but not limited to, Read Only Memory (ROM), Random Access Memory (RAM), compact discs (CDs), digital versatile discs (DVD), etc. Generally, program modules may include routines, programs, objects, components, data

structures, etc. that perform specified tasks or implement specific abstract data types. Computer-executable instructions, associated data structures, and program modules represent examples of program code for executing steps of the methods disclosed herein. The particular sequence of such executable instructions or associated data structures represents examples of corresponding acts for implementing the functions described in such steps or processes.

Although features have been shown and described, it will be understood that they are not intended to limit the claimed invention, and it will be made obvious to those skilled in the art that various changes and modifications may be made without departing from the spirit and scope of the claimed invention. The specification and drawings are, accordingly, to be regarded in an illustrative rather than restrictive sense. The claimed invention is intended to cover all alternatives, modifications, and equivalents.

List of references

1 sensor system
2 sensor
2A sensor patch
3 polymer composition
4 first electrode pair
4A first electrode
4B second electrode
6 sensor device
8 accessory device, smartphone
9 connection between the sensor device and the accessory device
10 server device
12 network
100 sensor device housing
101 processor
102 first interface
104 second interface
106 memory
110 first terminal of sensor device
112 second terminal of sensor device
114 third terminal of sensor device
116 fourth terminal of sensor device
120 coupling part
122 antenna
124 wireless transceiver, transceiver module
126 loudspeaker
128 display
200 method of monitoring an adhesive layer
S202 obtaining sensor data
S202A obtaining first sensor data from a first electrode pair associated with the polymer composition
S202B obtaining second sensor data from a second electrode pair associated with the polymer composition
S204 determining one or more parameters
S204A determining, based on the (first) sensor data, a first parameter
S204B determining, based on the (first) sensor data, a second parameter

S206 determining a salt concentration of the bioliquid

S206A determining an ion concentration in the polymer composition

S206B mapping the ion concentration to the salt concentration

S206C determining a hydration level in the polymer composition

S206D mapping the hydration level to the salt concentration

S206E determining whether the polymer composition is in a first state

S206F determining whether the polymer composition is in a second state

S208 providing, via an interface, concentration data indicative of the salt concentration

Claims

1. A method for determining salt concentration in a bioliquid, the method comprising:

obtaining sensor data comprising first sensor data from a first electrode pair associated with a polymer composition comprising hydrocolloids and having at least some of the biofluid absorbed therein;

determining, based on the sensor data, a first parameter indicative of a first electrical property of the polymer composition;

determining, based on the sensor data, a second parameter indicative of a second electrical property of the polymer composition;

determining, based on the first parameter and the second parameter, a salt concentration of the bioliquid; and

providing, via an interface, concentration data indicative of the salt concentration.

2. Method according to claim 1, wherein determining a first parameter comprises determining the first parameter at a first time and at a second time, and wherein determining a salt concentration of the bioliquid comprises determining the salt concentration based on the first parameter at the first time and at the second time.

3. Method according to any of claims 1-2, wherein the first parameter is electrical conductivity.

4. Method according to any of claims 1-3, wherein the second parameter is capacitance.

5. Method according to any of claims 1-4, wherein determining a salt concentration of the bioliquid comprises determining an ion concentration in the polymer composition and mapping the ion concentration to the salt concentration.

6. Method according to any of claims 1-5, wherein determining a salt concentration of the bioliquid comprises determining a hydration level in the polymer composition and mapping the hydration level to the salt concentration.

7. Method according to any of claims 1-6, wherein determining a first parameter comprises determining the first parameter at one or more frequencies including a first primary frequency, wherein the first primary frequency is in a primary frequency range

from 10 Hz to 500 Hz, and wherein determining a salt concentration of the bioliquid is based on the first parameter at the first primary frequency.

8. Method according to any of claims 1-7, wherein determining a first parameter comprises determining the first parameter at a first secondary frequency, wherein the first secondary frequency is in a secondary frequency range from 10 kHz to 200 kHz, and wherein determining a salt concentration of the bioliquid is based on the first parameter at the first secondary frequency.

9. Method according to any of claims 1-8, wherein determining a second parameter comprises determining the second parameter at one or more frequencies including a second primary frequency, wherein the second primary frequency is in a primary frequency range from 10 Hz to 500 Hz, and wherein determining a salt concentration of the bioliquid is based on the second parameter at the second primary frequency.

10. Method according to any of claims 1-9, wherein determining a second parameter comprises determining the second parameter at a second secondary frequency, wherein the second secondary frequency is in a secondary frequency range from 10 kHz to 200 kHz, and wherein determining a salt concentration of the bioliquid is based on the second parameter at the second secondary frequency.

11. Method according to any of claims 1-10, wherein obtaining sensor data comprises obtaining second sensor data from a second electrode pair associated with the polymer composition comprising hydrocolloids and having at least some of the bioliquid absorbed therein; and wherein one or both of determining a first parameter and determining a second parameter is based on the second sensor data.

12. An electronic device comprising an interface and one or more processors, wherein the one or more processors are configured to perform a method according to any of claims 1-11.

13. An electronic device comprising an interface and one or more processors, wherein the one or more processors are configured to:

obtain, via the interface, sensor data comprising first sensor data from a first electrode pair associated with a polymer composition comprising hydrocolloids and having at least some of a bioliquid absorbed therein;

determine, based on the sensor data, a first parameter indicative of a first electrical property of the polymer composition;

determine, based on the sensor data, a second parameter indicative of a second electrical property of the polymer composition;

determine, based on the first parameter and the second parameter, a salt concentration of the bioliquid; and

provide, via the interface, concentration data indicative of the salt concentration.

14. Electronic device according to claim 13, wherein the interface comprises a first interface configured to couple to at least the first electrode pair of the polymer composition and a second interface configured to provide the concentration data.

15. Electronic device according to claim 14, wherein the second interface is configured to provide the concentration data by means of a wireless signal.

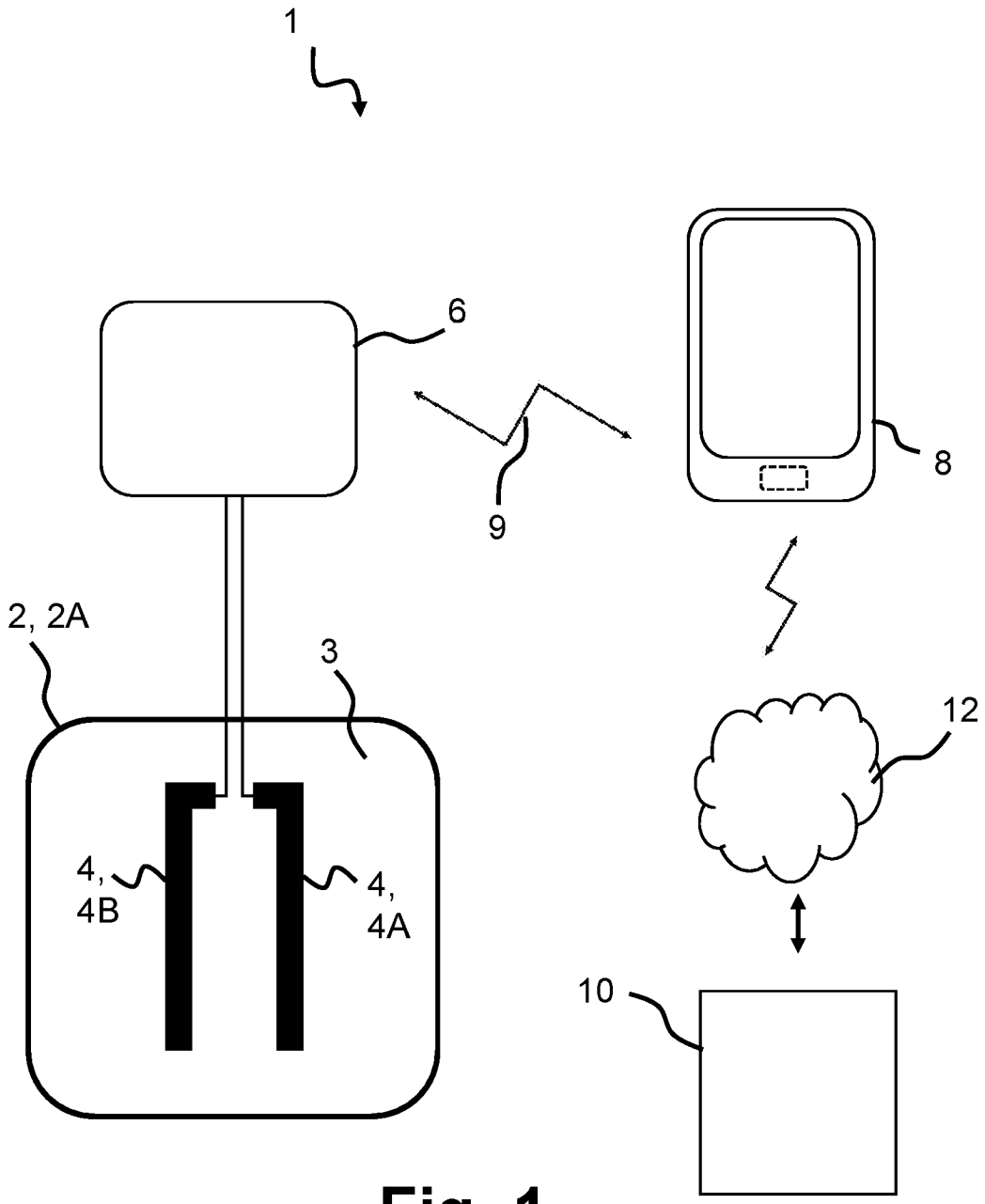

Fig. 1

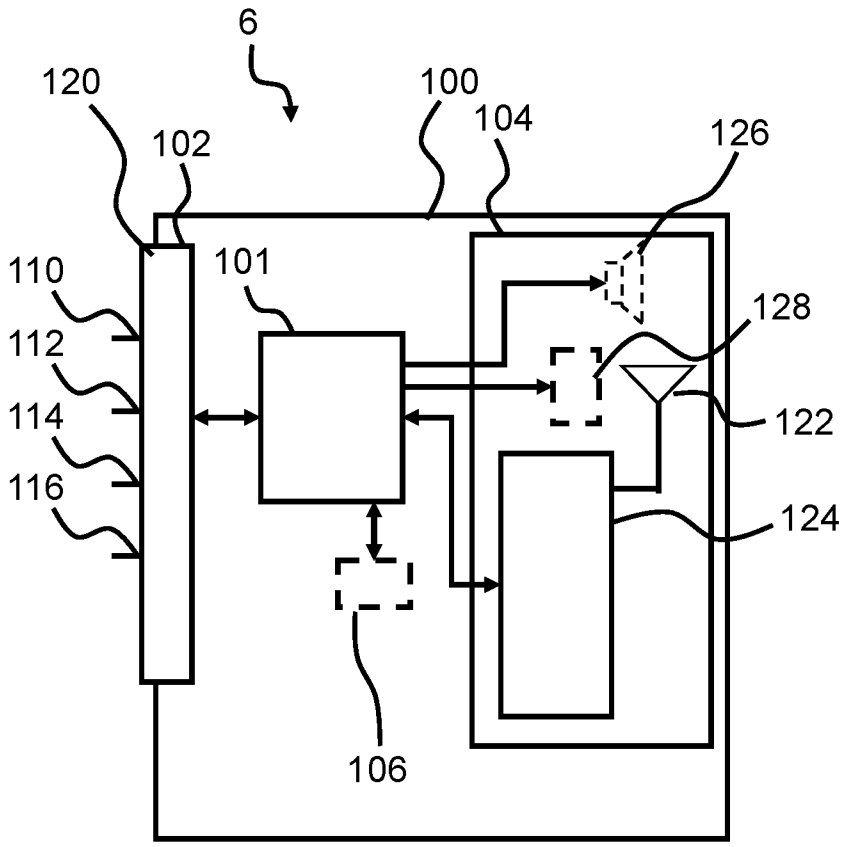

Fig. 2

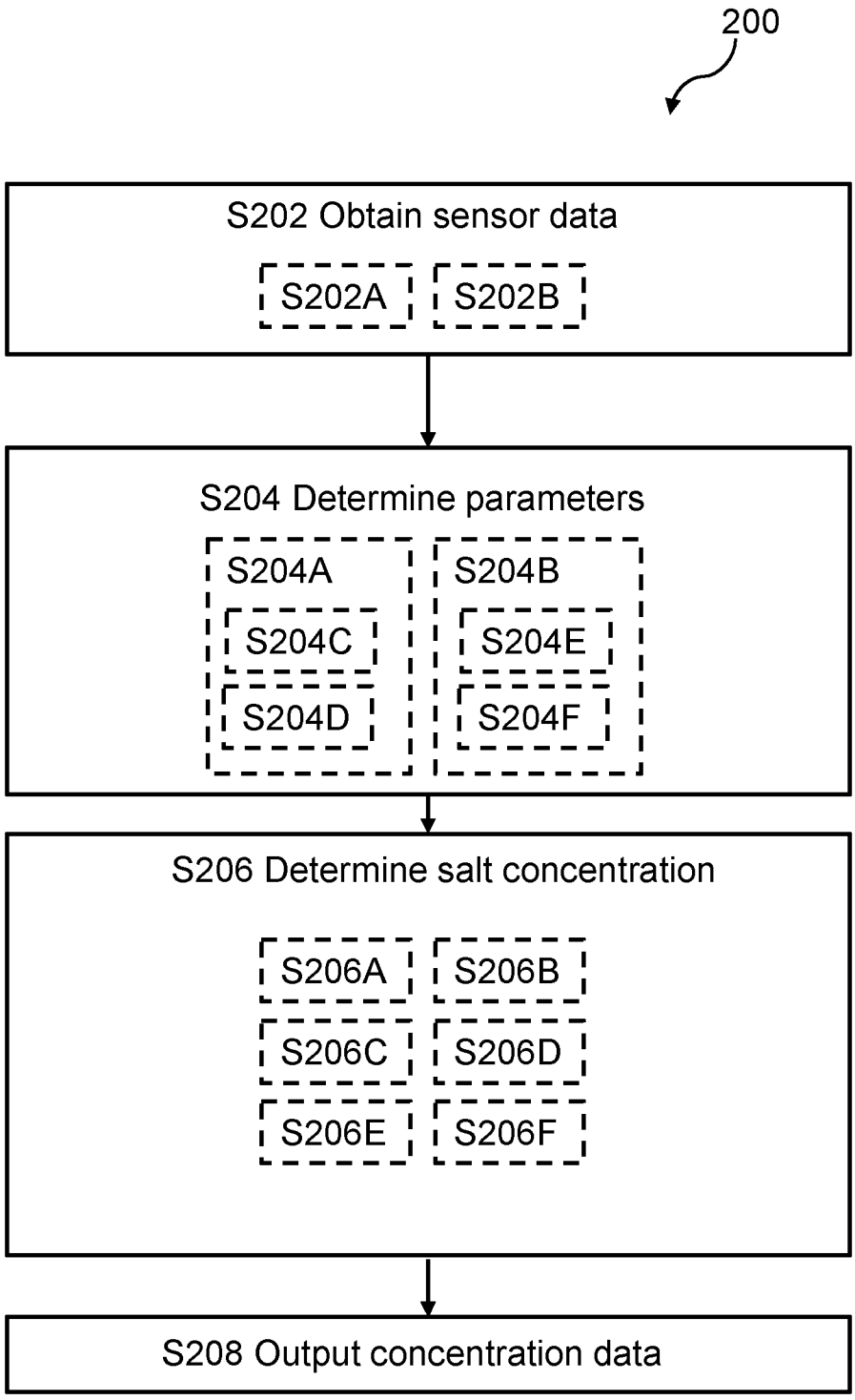
200
S202 Obtain sensor data
S202A
S202B
S204 Determine parameters
S204A
S204C
S204D
S204B
S204E
S204F
S206 Determine salt concentration
S206A
S206B
S206C
S206D
S206E
S206F
S208 Output concentration data

Fig. 3

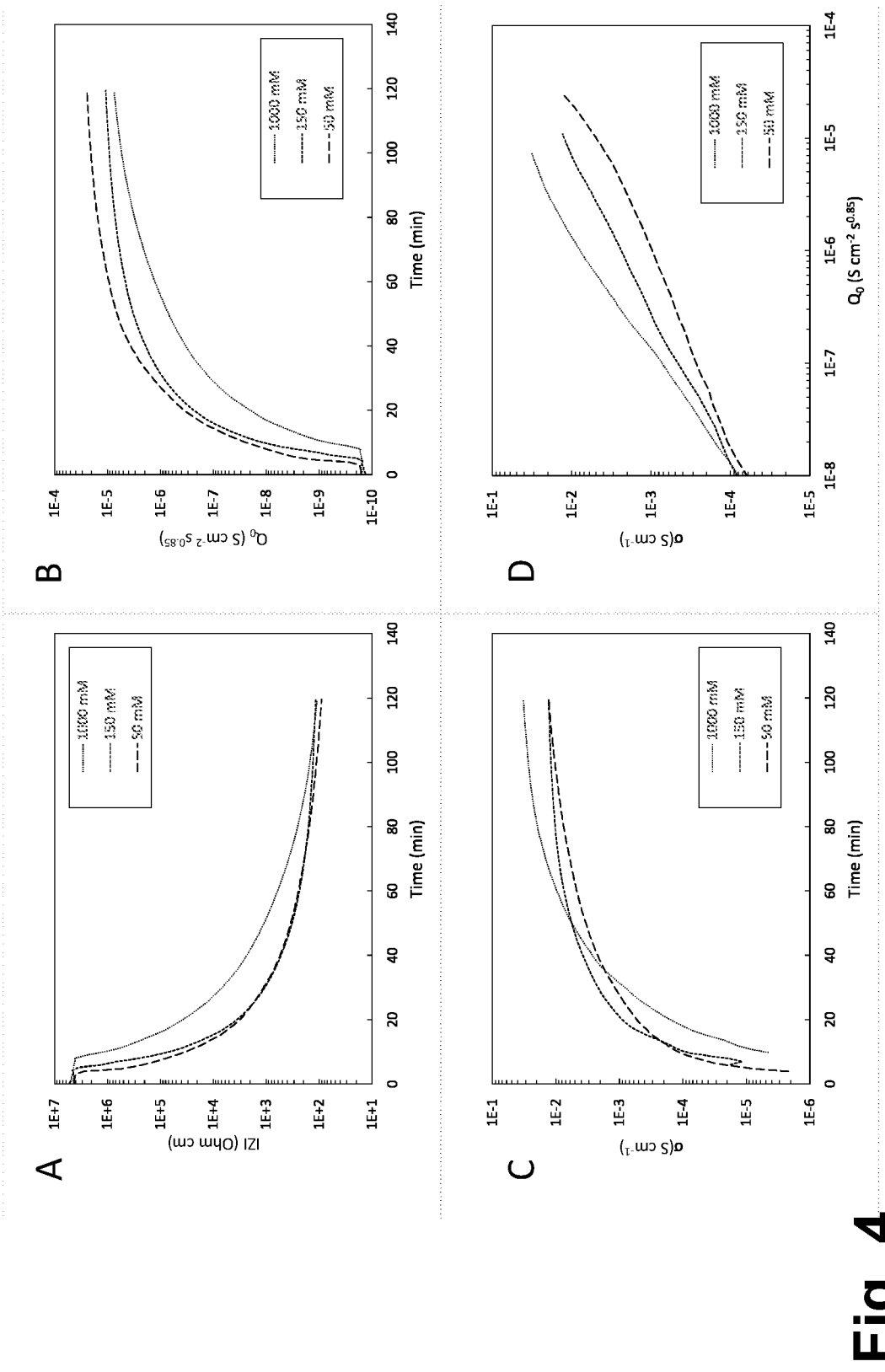
A
|Z| (Ohm cm)
Time (min)
1000 mM
150 mM
50 mM
B
Q_0 (S cm^{-2} s$^{0.85}$)
Time (min)
1000 mM
150 mM
50 mM
C
σ(S cm^{-1})
Time (min)
1000 mM
150 mM
50 mM
D
σ(S cm^{-1})
Q_0 (S cm^{-2} s$^{0.85}$)
1000 mM
150 mM
50 mM

Fig. 4

INTERNATIONAL SEARCH REPORT

International application No
PCT/DK2023/050328

A. CLASSIFICATION OF SUBJECT MATTER
INV. A61B5/145 A61B5/1468 A61B5/1477 G01N33/487 G01N27/02
G01N27/06 G01N33/49 G01N33/493 A61B5/00
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)
A61B G01N

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

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 2021/039806 A1 (PUBLIC UNIV CORPORATION SUWA UNIV OF SCIENCE FOUNDATION [JP] ET AL.) 4 March 2021 (2021-03-04)	12-15
Y	paragraphs [0020] - [0077]; figures 1-8	1-11
A	WO 2018/098417 A1 (ELWHA LLC [US]) 31 May 2018 (2018-05-31) page 40, line 23 - page 46, line 7; figure 9 page 67, line 5 - page 90, line 26	1-11
A	US 2019/231236 A1 (HEIKENFELD JASON CHARLES [US] ET AL) 1 August 2019 (2019-08-01) the whole document	1-15

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[x] Further documents are listed in the continuation of Box C.
[x] See patent family annex.

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

Date of the actual completion of the international search	Date of mailing of the international search report
18 March 2024	25/03/2024

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	Lazar, Zala

3

Form PCT/ISA/210 (second sheet) (April 2005)

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

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Y	US 2022/265173 A1 (ZHONG CHUAN-JIAN [US] ET AL) 25 August 2022 (2022-08-25) paragraphs [0034], [0046]	4
Y	US 2019/192334 A1 (HANSEN JAIS ASK [DK] ET AL) 27 June 2019 (2019-06-27) paragraphs [0022] - [0025]; figure 3	1-11

3

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/DK2023/050328

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