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(71) Applicant: **UNIVERSITEIT ANTWERPEN** [BE/BE]; Prinsstraat 13, 2000 Antwerpen (BE).

(72) Inventors: **BAELUS, Christiaan**; Frans Van Hombeeck-plein 23, 2600 Antwerpen (BE). **VERWULGEN, Stijn Peter**; Kempensedreef 12, 2900 Schoten (BE). **TRUIJEN, Steven Jan J.**; Meerheideweg 23, 2980 Zoersel (BE). **DE MUNCK, Timon Willem E.**; Monterreystraat 61, 9000 Gent (BE).

(74) Agents: **WAUTERS, Davy** et al.; DenK iP bvba, Leuvensesteenweg 203, 3190 Boortmeerbeek (BE).

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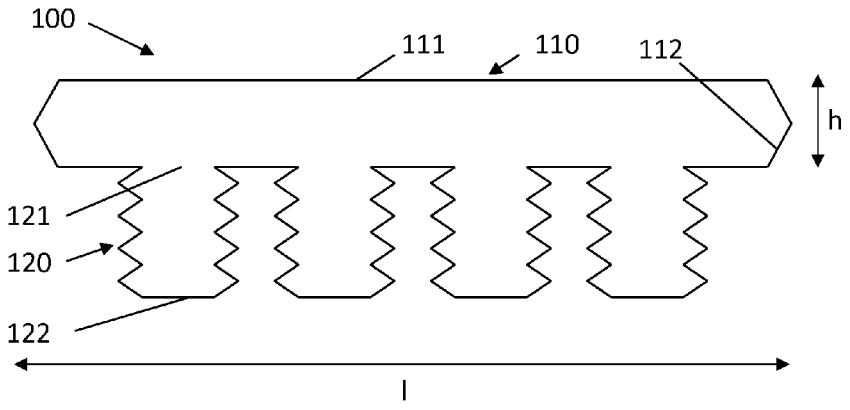



FIG. 1

(57) Abstract: The present invention describes a system (100) for positioning a plurality of elements on a surface, the surface possibly being not flat. The system comprises at least a first element and a second element (401) for being positioned on a surface to study, and a fluid filled, deformable, sealed housing (110) comprising a plurality of bellows (120), the bellows being in fluid interconnection with each other via an open side of the bellows, the bellows having furthermore a closed side to which the at least a first element and a second element (401) are connected. The elements thus are flexibly connected to each other such that a pressure applied to the housing is spread as a pressure on the elements, advantageously an equal pressure on the elements.

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# Sensor positioning system

## Field of the invention

The invention relates to the field of sensing. More specifically the present invention relates to a sensor positioning system for accurately positioning a sensing device comprising at least two sensor elements e.g. on an irregularly shaped surface, as well as to a method for positioning such a system.

## Background of the invention

In a plurality of applications, sensors need to be positioned on an irregularly shaped surface such as for example bodily parts. An accurate positioning and/or good contact thereby often is required in order to obtain good and reproducible measurement results.

A first example of an application where sensors need to be positioned on an irregular shaped surface are for muscle tone measurements. Such muscle tone measurements give an indication to which extent a muscle is strained. The muscle tone or the residual muscle tension is the continuous and passive contraction of a muscle or muscle group when it is in a resting state. An increased muscle tone indicates that the muscle or muscle group has an increased tension when it is in its resting state. An increased muscle tone indicates an unconscious increased tension of a muscle or muscle group when it is in a resting state.

Electrical impedance myography (EIM) is a non-invasive technique which is used for diagnosing a muscle state. In EIM an alternating current with high frequency and low intensity is transmitted through the muscle tissue. The current through the muscle tissue causes a voltage drop over the tissue. This voltage drop can be measured. Besides a voltage drop also a phase shift between the applied current and the measured voltage will be present. Based on such measurements the impedance of a certain muscle can be deduced.

The reproducibility of EIM measurements is important in order to make a good diagnosis. Olumuyiwa T. Ogunnika proposes “A handheld electrical impedance myography probe for the assessment of neuromuscular disease” (30th Annual International IEEE EMBS Conference Vancouver, British Columbia, Canada, August 2024, 2008).

The reproducibility improvement proposed by Ogunnika is based on the muscle anisotropy. However there is still room for other solutions in improving the reproducibility of EIM measurements.

A second example of an application where sensors need to be positioned on an irregular shaped surface is for electroencephalogram (EEG) measurements. For recording EEG, a plurality of sensors need to be positioned on the scalpel. Again accurate positioning and a good contact between the sensor and the surface may be required for obtaining sufficiently accurate measurements.

The above two examples illustrate that there is a need for an accurate and trustworthy sensor positioning system.

**Summary of the invention**

It is an object of embodiments of the present invention to provide an objective measurement tool and method for contacting sensor elements with a surface. It is an advantage of embodiments of the present invention that accurate positioning of sensor elements can be obtained. It is an advantage of embodiments of the present invention that a good contact between the different sensor elements and a surface, even if the surface is irregular, is possible. It is an advantage of embodiments of the present invention that accurate measurements can be performed using the sensor positioning system. Such measurements may for example include muscle tone measurements, embodiments of the present invention not being limited thereto. It renders diagnose and even objectively quantification of an enlarged muscle tone possible. It is an advantage of embodiments of the present invention that a series of objectively quantified muscle tones can be compared.

It is an advantage of embodiments of the present invention that the pressure of each element, e.g. electrode, against the surface of the object under study is equal for each element, e.g. electrode.

The above objective is accomplished by a method and device according to the present invention.

The present invention relates to a system for positioning a plurality of elements on a surface, the system comprising at least a first element and a second element for being positioned on a surface to study, and a fluid filled, deformable, sealed housing comprising a plurality of bellows, the bellows being in fluid interconnection with each other via an open side of the bellows, the bellows having furthermore a closed side to which the at least a first element and a second element are connected, the elements thus being flexibly connected to each other such that a pressure applied to the housing is spread as a pressure on the elements. In embodiments of the present invention the deformable fluid filled housing results in the pressure of each element, e.g. electrode, against the surface of the object under study being the same. This holds even if the surface is not a flat surface as long as the surface falls within the movement range of a bellow. It is an advantage of embodiments of the present invention that, even if the force exercised by the physiotherapist on the system is not exactly in the middle of the system, the applied force is distributed in an equal pressure of the element on the surface of the object under study. A fluid may be a liquid or a gas. The elements may for example be sensing elements, actuators or elements to provide therapy (application of drugs).

It is an advantage of some embodiments of the present invention that the sealed housing may be filled with a predetermined amount of fluid, the sealing housing thus not being an inflatable body.

It is an advantage of at least some embodiments of the present invention that the first element and the second element, or more generally the elements, may be rigid elements.

It is an advantage of at least some embodiments of the present invention that the bellows and optionally the sealing house including the bellows, are flexible but not stretchable.

Elements, e.g. each element, may be mounted to an end of a bellow (120), positioned at an extremity of a longitudinal direction wherein the bellow can extend.

It is an advantage of some embodiments of the present invention that the force applied is substantially perpendicular to the object to be measured/sensed/treated.

It is an advantage of embodiments of the present invention that bellows allow a good distribution of the pressure in the fluidly filled, sealed housing. The housing may have a common cavity forming one sealed cavity with the cavities defined by the different bellows. It is an advantage of embodiments of the present invention that a common cavity of the housing can be used to distribute the pressure between the cavities of the specific bellows. It allows a simple construction guaranteeing that the pressure in each of the bellows is the same.

The elements may be flexibly mounted to the housing, the system thus allowing a changing orientation of the element with respect to the housing. It is an advantage of embodiments of the present invention that the connection between the element and the housing is flexible, e.g. pivotable, such that a good contact with the surface is possible when the surface is curved. It is an advantage of embodiments of the present invention that the orientation of the elements can change such that a complete contact between each of the elements and the surface to be measured, e.g. the skin, is possible even if the surface under study is not completely flat.

The elements may be reversibly mounted to the housing, allowing mounting the elements on the housing and removing the elements from the housing repeatedly. It is an advantage of embodiments of the present invention that the electrodes are easily cleanable, as they can be removed from the system repeatedly. It is an advantage of embodiments of the present invention that the electrodes can be easily replaced. They may be mounted in a clickable way, a clippable way, through a snap connection, etc.

Each bellow may be a protrusion of a common cavity of the housing. It is an advantage of embodiments of the present invention that the bellow is integrated in the material of the housing.

The cavities of the bellows may be interconnected through tubes connected to the open sides of the bellows. It is an advantage of embodiments of the present invention that the housing can be made more compact than in the case a cavity was required in the housing.

The bellows may be cylindrical or conical. It is an advantage of embodiments of the present invention that the bellows allow a larger movement range along the cylindrical axis, resulting in improved positioning of the elements. It is an advantage of embodiments of the present invention that the air movement within the bellow can be more fluent for a conically shaped bellow.

The system may comprise a pressure control system for controlling the pressure in the housing. It is an advantage of embodiments of the present invention that the pressure in the housing can be controlled such that each measurement can be done at the same pressure. Doing measurements at the same pressure makes the measurement results comparative.

The pressure control system may comprise an additional bellow in the housing having the same pressure in its cavity wherein the pressure control system furthermore is adapted for triggering the start of a measurement based on contact between the additional bellow and a contact sensor or switch.

It is an advantage of embodiments of the present invention that the pressure control system does not require any additional complex components. It is an advantage of embodiments of the present invention that the pressure control system can be based on a similar bellow as the bellows outside the cavity. It is an advantage of embodiments of the present invention that the deformation of the additional bellow is directly related with the pressure inside the bellow. Therefore it is possible to define a trigger point in the space surrounding the additional bellow which, when touched, triggers the start of a measurement. It is an advantage of embodiments of the present invention that this start will always be at the same pressure level.

The elements may be electrodes.

The system furthermore may comprise any of a battery for powering the active components of the system, a display for indicating the measurement state and/or measurement result, a current generator for generating a current through some of the elements, an RC filter for limiting a current generated by a current generator, a microprocessor for monitoring and controlling a display and/or the pressure control system and/or a current generator, and/or for monitoring the voltage on some of the electrodes, a Bluetooth module for communication between a microprocessor and a laptop, at least one push button allowing the user to give commands to the processor and/or a docking station for charging the battery. It is an advantage of embodiments of the present invention that a measurement system, e.g. a muscle tone measurement system, is provided that is easy to handle. The system may be suitable for performing measurements using only one hand. It is an advantage of embodiments of the present invention that the pressure of the different electrodes on the surface is guaranteed to be equal.

The present invention also relates to the use of a system for performing sensing measurements for sensing signals at different positions on a surface.

The present invention also relates to the use of a system for performing sensing measurements on a non-flat surface.

The present invention also relates to the use of a system for performing any of an electro impedance myography measurement, an electroencephalogram or an electro cardiogram. It is an advantage of embodiments of the present invention that the pressure of each electrode against the surface is the same. The pressure has an important effect on the reproducibility of the measurement. Varying pressure differences between the different electrodes will result in a different measurement result. Equal pressure levels over the different electrodes will result in a reproducible measurement result.

Particular and preferred aspects of the invention are set out in the accompanying independent and dependent claims. Features from the dependent claims may be combined with features of the independent claims and with features of other dependent claims as appropriate and not merely as explicitly set out in the claims.

These and other aspects of the invention will be apparent from and elucidated with reference to the embodiment(s) described hereinafter.

**Brief description of the drawings**

FIG. 1 provides a schematic side view of a system in accordance with embodiments of the present invention.

FIG 2. provides a schematic bottom view of a system in accordance with embodiments of the present invention.

FIG 3. provides a schematic side view of a system when pushed against a curved surface in accordance with embodiments of the present invention.

FIG 4. provides an exploded 3D-view of a system in accordance with embodiments of the present invention.

FIG 5. provides a 3D view of a system in accordance with embodiments of the present invention.

FIG 6. provides a 3D view of a system in accordance with embodiments of the present invention.

FIG 7. provides a 3D view of a system in accordance with embodiments of the present invention.

FIG 8. provides a 3D view of conical bellows which may be applied in embodiments in accordance with the present invention.

FIG 9. provides a 3D view of cylindrical bellows which may be applied in embodiments in accordance with the present invention.

FIG 10. provides a 3D view of a system in accordance with embodiments of the present invention.

FIG 11. provides a 3D view of a system in accordance with embodiments of the present invention.

FIG 12. provides a 3D view of a system in accordance with embodiments of the present invention.

FIG 13. provides a 3D view of a system in accordance with embodiments of the present invention.

FIG 14. provides a 3D view of a system in accordance with embodiments of the present invention.

FIG 15. provides a 3D view of a system in accordance with embodiments of the present invention.

FIG 16. provides a 3D view of a system in accordance with embodiments of the present invention.

FIG 17. provides a 3D view of a system in accordance with embodiments of the present invention.

FIG 18.provides a schematic overview of different components which might be present in a system in accordance with embodiments of the present invention.

FIG 19.provides a schematic drawing of a typical electrical impedance myography measurement.

FIG 20.provides a graph illustrating the influence of the electrode pressure on the measured voltage.

FIG 21.provides a side view of a system with pressure control in accordance with embodiments of the present invention.

FIG 22. provides a side view of a system with pressure control in accordance with embodiments of the present invention.

The drawings are only schematic and are non-limiting. In the drawings, the size of some of the elements may be exaggerated and not drawn on scale for illustrative purposes.

Any reference signs in the claims shall not be construed as limiting the scope.

In the different drawings, the same reference signs refer to the same or analogous elements.

**Detailed description of illustrative embodiments**

The present invention will be described with respect to particular embodiments and with reference to certain drawings but the invention is not limited thereto but only by the claims. The drawings described are only schematic and are non-limiting. In the drawings, the size of some of the elements may be exaggerated and not drawn on scale for illustrative purposes. The dimensions and the relative dimensions do not correspond to actual reductions to practice of the invention.

Furthermore, the terms first, second and the like in the description and in the claims, are used for distinguishing between similar elements and not necessarily for describing a sequence, either temporally, spatially, in ranking or in any other manner. It is to be understood that the terms so used are interchangeable under appropriate circumstances and that the embodiments of the invention described herein are capable of operation in other sequences than described or illustrated herein.

Moreover, the terms top, under and the like in the description and the claims are used for descriptive purposes and not necessarily for describing relative positions. It is to be understood that the terms so used are interchangeable under appropriate circumstances and that the embodiments of the invention described herein are capable of operation in other orientations than described or illustrated herein.

It is to be noticed that the term "comprising", used in the claims, should not be interpreted as being restricted to the means listed thereafter; it does not exclude other elements or steps. It is thus to be interpreted as specifying the presence of the stated features, integers, steps or components as referred to, but does not preclude the presence or addition of one or more other features, integers, steps or components, or groups thereof. Thus, the scope of the expression "a device comprising means A and B" should not be limited to devices consisting only of components A and B. It means that with respect to the present invention, the only relevant components of the device are A and B.

Reference throughout this specification to "one embodiment" or "an embodiment" means that a particular feature, structure or characteristic described in connection with the embodiment is included in at least one embodiment of the present invention. Thus, appearances of the phrases "in one embodiment" or "in an embodiment" in various places throughout this specification are not necessarily all referring to the same embodiment, but may. Furthermore, the particular features, structures or characteristics may be combined in any suitable manner, as would be apparent to one of ordinary skill in the art from this disclosure, in one or more embodiments.

Similarly it should be appreciated that in the description of exemplary embodiments of the invention, various features of the invention are sometimes grouped together in a single embodiment, figure, or description thereof for the purpose of streamlining the disclosure and aiding in the understanding of one or more of the various inventive aspects. This method of disclosure, however, is not to be interpreted as reflecting an intention that the claimed invention requires more features than are expressly recited in each claim. Rather, as the following claims reflect, inventive aspects lie in less than all features of a single foregoing disclosed embodiment. Thus, the claims following the

detailed description are hereby expressly incorporated into this detailed description, with each claim standing on its own as a separate embodiment of this invention.

Furthermore, while some embodiments described herein include some but not other features included in other embodiments, combinations of features of different embodiments are meant to be within the scope of the invention, and form different embodiments, as would be understood by those in the art. For example, in the following claims, any of the claimed embodiments can be used in any combination.

In the description provided herein, numerous specific details are set forth. However, it is understood that embodiments of the invention may be practiced without these specific details. In other instances, well-known methods, structures and techniques have not been shown in detail in order not to obscure an understanding of this description.

Where in some exemplary embodiments of the present invention reference is made to "the movement range of a bellow", reference is made to the distance range within which the second closed side 122 of the bellow 120 can freely move when the first open side 121 is on a fixed position. Herein the first open side 121 and the second closed side 122 are opposing sides of the bellow 120. With regard to the movement of the second closed side 122, "freely" means that the bellow itself is not limiting the movement because it is stretched or compressed too much. The bellow is limiting the movement of the second closed side if the pressure on the surface of the object under study changes more than 10% compared to the inside pressure of the bellow. Preferably the pressure change caused by the bellow itself is even smaller than 5% of the pressure inside the bellow.

In a first aspect, the present invention relates to a system for positioning a plurality of elements on a surface. The elements may for example be sensing elements, electrodes, actuators, elements for applying therapy (e.g. for applying drugs). The system advantageously may be used for positioning elements on a non-flat surface, such as a bodily part, but the invention is not limited thereto. The sensing may correspond with recording an electrical signal through electrodes, such as measuring a current, a voltage, a resistance, a capacity, an inductance, etc. . Nevertheless, embodiments of the present invention are not limited thereto and different types of measurements such as for example displacement measurements or others are also envisaged, such as EEG of EMG measurements. Also, applications of compression therapy: (bandages in case of skin burns or the prevention of oedema after breast cancer, stroke, varicose veins), might benefit a substantially constant pressure and are also envisaged by the present invention. For the sake of illustration, embodiments of the present invention will be described with reference to muscle tone measurements, but it will be clear that other type of measurements can be performed equally well, whereby the elements are selected as being elements for capturing the specific property to be measured or providing therapy. According to embodiments of the present invention, the system comprises at least a first element and a second element for being positioned on a surface to study, and a fluid filled, deformable, sealed housing to which the at least a first element and a second element are connected.

The elements thus may be flexibly connected to each other such that a pressure applied to the housing is spread as a pressure on the elements. It is an advantage of embodiments of the present invention that a substantially equal pressure will be applied to the different elements, resulting in more accurate measurements.

As indicated above, embodiments discussed below will be related to measuring muscle tone, but the present invention is not limited thereto. Embodiments illustrated below can be used for measuring different types of muscles, such as for example but not limited thereto: biceps, quadriceps, or tibialis anterior.

Although the elements may be directly connected to a deformable, fluid filled, sealed housing, according to some embodiments of the present invention the system comprises a plurality of bellows 120 wherein each of the bellows has a first open side 121, and a second closed side 122. The system 100 according to some embodiments furthermore comprises a common part within the housing 110. The first open side 121 of each bellow 120 is connected to the housing 110 such that the cavities formed by the bellows 120 form one sealed volume through the first open sides 121 of the bellows 120. In other words, the bellows 120 are fluidly interconnected with each other. In some examples this may be via a common cavity, in other examples this is via connection tubes between the different bellows. In embodiments of the present invention elements, for example electrodes 401, are mountable on the second closed sides 122 of the bellows 120. It thus becomes possible to push the elements 401 against the surface of an object under study. The object under study might for example be a muscle.

By way of illustration, FIG. 1 shows a cross-section of an exemplary embodiment of the present invention. The specific embodiment comprises four bellows 120 of which the open sides 121 are connected to a housing 120. Electrodes 401 are mountable on the second closed sides 122. The bottom view of the same embodiment is illustrated in FIG. 2. FIG. 3 illustrates how the embodiment guarantees that each of the electrodes pushes with the same pressure against a curved surface of an object under study and that each of the electrodes is in full contact with the surface of the object under study.

In some embodiments of the present invention, electrical impedance myography is applied. In electrical impedance myography the electrical impedance of a muscle is measured for diagnostic purposes. Therefore an active current is applied through two outer active electrodes 401 and at the same time a voltage is measured over two inner passive electrodes 401. This is also schematically illustrated in FIG. 18. The active electrodes 401 transmit the current through the muscle. The resistance of the muscle depends on the physical state of the muscle and therefore the resistance can be used as a diagnostic parameter. The resistance can be measured by measuring the voltage over two inner electrodes 401. These are the passive electrodes. In embodiments of the present invention their signal is converted into a voltage by an AD convertor on the PCB. By comparing the injected current signal with the measured voltage signal the physiotherapist has a means for diagnosing the

state of the muscle. The phase of the voltage and the phase of the current may be compared but also the amplitude of the voltage and the amplitude of the current may be compared. An increase in muscle tone can be detected by evaluating the difference between subsequent measurement results. The measurement result thereby may be: the measured voltage, the measured phase of the voltage compared to the measured phase of the current, the measured voltage divided by the amplitude of the injected current.

From validation of the electrical impedance myography method it became clear that an equal pressure distribution between the different electrodes 401 is crucial for obtaining a reproducible measurement result. Such a validation experiment is graphically illustrated in FIG. 19. The horizontal axis represents different types of applied pressures while the vertical axis show the measured voltage over the inner electrodes. The first point 1901 is the measured voltage when an additional pressure is applied on the active electrodes 401. In that case less resistance is registered than when applying no additional pressure. The second point 1902 is the measured voltage when no additional pressure is applied on any of the electrodes 401. The third point 1903 is the measured voltage when an additional pressure is applied on the passive electrodes 401. In that case more resistance is registered than when applying no additional pressure. The fourth point 1904 is the measured voltage when an additional pressure is applied on all of the electrodes 401. It can be seen from FIG. 19 that the measured voltage is almost the same when the pressure between all the electrodes is equally distributed (i.e. for the second point 1902 and the fourth point 1904). The measure voltage may vary in case of an equal pressure distribution by about 10 % of the measured voltage. Therefore it is an advantage of embodiments of the present invention that the pressure of the electrodes on the body is the same for each electrode. An equal pressure distribution between the electrodes is important for the reproducibility of an EIM muscle tone measurement.

Moreover it also became clear from validation experiments of the EIM method that a full contact of each of the electrodes 401 with the skin is crucial for obtaining a reproducible measurement result.

The EIM measurement technique has been evaluated on a group of man and woman of varying ages. It is an advantage of embodiments of the present invention that the EIM measurement technique is reproducible over different the different man and woman meaning that the voltage difference between a stretched and relaxed muscle is reproducible over the different test persons.

In the exemplary embodiments of the present invention an alternating current between 0 and 300 MHz, for example between 0,1kHz and 300MHz, for example between 10kHz and 400 kHz, or for example 50 kHz is transmitted between the outer electrodes. The electrodes 401 through which the current is transmitted are also called the active electrodes. The alternating current amplitude is between 0 and 1000 mA, for example between 0,001 mA and 1000 mA, for example between 0,1 and 20 mA, or for example about 1 mA. While transmitting the current through the outer electrodes,

the voltage may be measured on the inner electrodes 401. The electrodes for measuring the voltage are also called the passive electrodes. In the exemplary embodiment of FIG. 1 all electrodes are on one line and the inner electrodes are for measuring the voltage whereas the outer electrodes are for injecting the alternating current. Any other configuration of electrodes, suitable for injecting a current through a muscle and measuring an induced voltage over the muscle, is possible.

The distance between the center of the bellows 120 can be designed for each specific application. The distance between the center of the bellows 120 determines the distance between the electrodes. In embodiments of the present invention the distance is between 0 and 200 cm preferably between 1 and 80cm more preferably 15cm but note however that the bellows do not need to be positioned substantial equidistantially.

In embodiments of the present invention the outer electrodes 401 are used for transmitting an alternating current through the muscle. In these embodiments the inner electrodes 401 are used to measure a voltage over the muscle. In embodiments of the present invention the phase difference between the transmitted voltage/current and the measured voltage/current is an indicative parameter for muscle tone. Another indicative parameter might be the phase shift of the incoming versus measured sinusoidal current. In embodiments of the present invention the maximum distance between the current injection electrode and the closest voltage measuring electrode for obtaining a valid phase difference signal is between 15 cm and 20 cm. The voltage difference of an EIM measurement on a stretched muscle and an EIM measurement on a relaxed muscle is higher when the distance between the (inner) electrodes 401 is smaller. For diagnostic purposes it is advantageous if this difference is as high as possible.

In embodiments of the present invention the distance between the electrodes 401 is fixed. The distance is such that it is possible to measure around a palpation trigger point. The dependence of the measurement result on the position of the system 100 is evaluated for the biceps, for the trapezius and the epicondylus by positioning the system 100 on several places of the muscle. It is an advantage of embodiments of the present invention that a variation on the position of the system 100 has a minimal influence on the measured voltage difference between a stretched and a relaxed muscle (for example less than 6 % variation on the voltage when moving along the epicondylus).

In embodiments of the present invention the (plate) electrodes 401, e.g. pre-gelled disposable electrodes have a circular contact from biopac, or home made electrodes made from copper plates, or electrodes used for EEG registration, can be coupled and/or decoupled through a snap connection 403 which is hermetically clamped to the second closed side 122 of the bellows 120. These snap connections may be made of copper allowing a current towards the electrodes and may consists of e.g. a ball and socket joint which mounts the electrodes rotatable on the bellow 120.

In the exemplary embodiment of the present invention a cable in the bellow 120 connects the plate electrode 104 with one side of a connecting piece in the bellow 120. On the other side of

the connecting piece a cable is connected with for example a printed circuit board. As such an interconnection between the plate electrode 401 and a printed circuit board is realised. The connecting piece in the bellow guarantees a hermetically sealed bellow 120 and serves as a through connection for the electrical signal.

In embodiments of the present invention several types of electrodes can be used. For example electrodes used in electrocardiogram applications are applicable. In embodiments of the present invention the electrodes may comprise a metal connection point. The electrodes may comprise a low impedance Ag/AgCl sensor, a pre-gelled solid gel. In embodiments of the present invention Transcutaneous electrical nerve stimulation (TENS) sensors might be used. These electrodes comprise stainless fibers which are very flexible and guarantee an excellent conductivity. In an embodiment of the present invention, electrodes consist of copper plates of about 0.01-0.5 mm in thickness in combination with a conductive gel.

In the exemplary embodiment of the present invention the voltage difference between a stretched muscle and a relaxed muscle is dependent on the used electrode (amongst other parameters). In embodiments of the present invention the electrodes resulting in the highest voltage difference between a stretched and a relaxed muscle are preferable. By way of illustration, using TENS electrodes 4.56 V was measured for a relaxed muscle and 5.36 V for a stretched muscle. Using ECG electrodes 5.2 V was measured for a relaxed muscle and 5.36 V for a stretched muscle. The difference between both was 0.8 V when using TENS electrodes and 0.16 V when using ECG electrodes. Measurements were done when applying a 50 kHz / 20 mA signal through the outer electrodes.

In some embodiments of the present invention the size of the electrodes may vary, e.g. radius between 0.5 mm and 20 mm in case of disc shape electrodes, or between 30 x 50 mm and 15 x 30 mm or is more preferably equal to 30 x 30 mm. For these ranges, the difference between the voltage measured on a stretched muscle and the voltage measured on a relaxed muscle is the biggest when measuring with a 30 x 30 mm electrode.

It is an advantage of embodiments of the present invention that the electrodes can make a full equal pressure contact with the skin and this both for flat surfaces as well as for curved surfaces. It is an advantage of embodiments of the present invention that it is the system 100 itself which guarantees an equal pressure distribution between the electrodes 401. In embodiments of the present invention the force applied by the physiotherapist on the system 100 will be distributed over the different bellows 120 resulting in an equal pressure of the electrodes 401 on the skin of the patient.

It is an advantage of embodiments of the present invention that the technical complexity is limited. In embodiments of the present invention no active pressure regulating system, that controls the pressure of each electrode separately, is required.

It is an advantage of embodiments of the present invention that a compact handheld system can be made. It allows the physiotherapist to hold and operate the system 100 with one hand. The

physiotherapist moreover does not need to perform a special action in order to guarantee a good contact between the electrodes and the skin. It are the bellows themselves that change orientation in order to make a full contact between the electrodes and the skin under influence of the force exercised by the physiotherapist on the system 100. Similarly the force of the physiotherapist is equally distributed by the system 100 over the different bellows 120.

In some exemplary embodiments of the present invention the housing 110 comprises a first part 111 and opposite to the first part, a second part 112. In some exemplary embodiments of the present invention the first part can be made, at least partly, of solid material thereby forming a solid structure. In embodiments of the present invention at least two sidewalls have a concave area ergonomically formed such that they provide a handle 402 having a good grip for a hand. The same sidewalls might also be made of compressible material. In that case a convex compressible area is possible as long as it provides a good grip for a hand. When used, the system 100 is held in one hand at the first part 111 of the housing 110. In embodiments of the present invention the first part has a convex form such that it fits in the palm of a hand. In embodiments of the present invention the main area of the first part of the housing therefore is not exceeding 60 mm x 200 mm or more preferably 60 mm x 150 mm. Herein 60 mm is the width and 200 mm is the length. These dimensions are also indicated on the exemplary embodiment of FIG. 1 and FIG. 2 as l and w. In embodiments of the present invention the first part 111 of the housing is formed symmetrically such that it can be operated using the left as well as the right hand. In embodiments of the present invention the dimensions of the system 100 are compact such that it can be easily operated with one hand (for example 200 mm x 60 mm x 20 mm = l x w x h as indicated in FIG. 1 and FIG. 2).

The housing 110, or at least part of the housing 110, may be made of Acrylonitrile Butadiene Styrene (ABS). The first part 111 and the second part 112 of the housing 110 may be produced by injection moulding with a separate mould for each part. The sidewalls providing a good grip for the hand may be made of polyurethane. This makes a concave area of the surface possible hereby providing a good grip for the hand. This enables the physiotherapist to adequately apply a force on the electrodes 401.

In the exemplary embodiment of the present invention the bellows 120 are made of ethylene-vinyl acetate and may be produced using a mould.

In embodiments of the present invention the bellows are cylindrical. An example of such a cylindrical bellow is illustrated in FIG. 9.

In an exemplary embodiment of the present invention the bellows are conical. An example of such a conical bellow 120 is illustrated in FIG. 8. These conical bellows have the ability to change the orientation of a mounted electrode 104 as well as the distance between the first side 121 and the second side 122 of the bellow. For a change of orientation of the electrode, the air movement within the conical bellows is more fluent than in case of a cylindrical bellow since their volume to surface ratio is smaller, for a conical shaped bellow, (causing less internal friction). This effect is however

only applicable for small conical/cilindrical shaped bellows. Another advantage of conical bellow is that the rigid part of the bellow 120 is more stable (FIG. 1). Therefore it will be easier (requiring less force) to position all electrodes 401 in direct contact with the skin, and this over the complete electrode area, when using conical bellows compared to cylindrical bellows. This is especially the case for a curved area of the object under study (a muscle).

In embodiments of the present invention the cavity of the housing 110 and the cavities of the bellows 120 form one sealed cavity. An exemplary embodiment thereof is illustrated in FIG. 10. It shows four bellows 120 of which the first open sides are all connected to the second part of the housing 112. The cavities of the bellows are all interconnected through the cavity of the housing 110. Therefore the pressure in all cavities is the same. As the cavity of the housing is a means for interconnecting the cavities of the bellows no extra tubes are required to make this interconnection.

In some embodiments of the present invention the cavities of the bellows 120 are interconnected through tubes 1101 connected to the first open sides 121 of the bellows 120. An illustrative embodiment thereof is shown in FIG. 11. The bellows 120 in FIG. 11 are interconnected with small tubes (interconnecting channels) 1101 guaranteeing an equal pressure in each of the bellows. The interconnecting tubes 1101 between the bellows 120 may be made of the same material as the bellows 120 themselves. In this embodiment it are the interconnecting tubes which guarantee an equal pressure distribution between the bellows 120. This as opposed to a previously mentioned embodiment where the cavity of the housing 120 mediated the pressure distribution between the bellows 120. Therefore the housing can be made more compact than in the case a cavity was required in the housing.

In embodiments of the present invention an interior board inside the housing 110 is mountable against the open sides of the bellows 120 thereby sealing the cavities of the bellows 120 from the outside of the bellows.

In this embodiment the plate electrode 401 is connected with the bellow 120 by means of a socket, e.g. a ball and socket joint. The socket allows to easily connect or remove the electrode 401. At the inside of the bellow 120 a cable is connected to the socket which interconnects the socket with the PCB 410. In the embodiment of FIG. 11 the second part of the housing 112 is a plate. The plate has an opening for a rubber sealing 1102 through which the electrical cables 1103 from the electrode 104 can leave the bellow 120. The rubber sealing hermetically closes each bellow 120. In embodiments of the present invention the bellows 120 and the interconnecting channels 1101 are made of ethylene-vinyl acetate and may be produced using a mould. This allows to create an air-tight model with flexible bellows 120 which are able to follow the curved area of a muscle.

In some exemplary embodiments of the present invention, each bellow 120 may be a resilient protrusion of the second part 112 of the housing 110. An exemplary embodiment thereof is shown in FIG. 12. In the embodiment of FIG. 12 the second part of the housing 112 and the bellows 120 are

made of ethylene-vinyl acetate in a mould. The bellows 120, being resilient protrusions of the second part 112 can be positioned in good contact with the area of a curved muscle. The second part 112 of the housing and the first part 111 of the housing can be sealed together hermetically such that an equal pressure is present in each of the cavities of the bellows 120. When the physiotherapist pushes the system 100 against a curved muscle such as illustrated on a model of a muscle in FIG. 13 the two inner bellows 120 are pushed inwards and the two outer bellows will come outwards caused by the increased pressure inside the cavities. By increasing the pressure, the outer bellows 120 go outwards until they touch the skin. The pressure required to increase the volume of the bellows is negligible compared to the pressure of the electrode against the skin. This statement holds as long as the bellow 120 is within movement range. When pushing the system 100 against a flat surface the air inside the system 100 is equally distributed between the bellows 120.

In some exemplary embodiments of the present invention the movement range of the bellows 120 determines the maximum curvature of the muscle which can be followed by the system 100. Meaning that for this maximum curvature an equal pressure of each of the electrodes against the muscle can be established.

In the exemplary embodiment of FIG. 14 the bellows 120 can extend more than in the exemplary embodiment of FIG. 12. The bellow 120 is made of ethylene-vinyl acetate and is obtained through thermoforming. In the embodiment of FIG. 14 only two bellows are present. The bellows can move to the inside of the system 100 as well as to the outside of the system 100. The two plates 1401 in FIG. 14 are mounted on the position where normally the electrodes 401 would be mounted.

FIG. 15 illustrates how one electrode 401 is moved upwards when pushing the other electrode downwards because the air moves from one bellow 120 to the other bellow such that the pressure is the same in each bellow, according to an embodiment of the present invention.

FIG. 16 illustrates the position of two electrodes when positioned against a flat surface. If a pressure is applied on the system 100, this pressure will be equally distributed between the two bellows 120, hence the pressure of the electrodes 401 against the surface will be the same. The pressure inside the system 100 is high enough such that the electrodes in the position of FIG. 16 extend beyond the surface of the second part of the housing 112. The bellows 120 in the exemplary embodiment of FIG. 16 are flexible and have, in this state, a curved surface towards the inside of the housing 110. If the system 100 is positioned on a curved surface, like for example a muscle, one bellow 120 will be pushed more inwards the housing 110 while the other bellow 120 will move in a direction outwards of the housing 110. The curved surface towards the inside of the housing 110 thereby leaves the housing allowing the bellow to extend away from the housing 110 (such as for

example in FIG. 15). Thereby a curved surface of a muscle can be touched by both electrodes as illustrated in FIG. 17 whereby a full contact between the electrodes and the skin is realised.

The embodiment of the present invention illustrated in FIGS. 14-17 has two electrodes. In other embodiments of the present invention more electrodes, for example 4, are possible. In embodiments of the present invention the length over which the bellow can extend may vary between 0 and 200 cm, preferably between 5 and 25 cm. In embodiments of the present invention the angle between the central axis of the bellow and a line orthogonal to the surface of the electrode may vary between 0 and 90°, depending on the curvature of the bodily surface, e.g. max 18°.

In some exemplary embodiments of the present invention the pressure in the bellows is measured using a pressure sensor. It is an advantage of embodiments of the present invention that the pressure inside the bellows and therefore also the pressure of the electrodes against the skin is known for each measurement. It allows the physiotherapist to repeat a measurement each time at the same pressure. When a certain pressure threshold is reached the measurement can start. The pressure threshold guarantees that a good contact between the electrodes and the skin is established. A pressure control system can be made in a plurality of ways, an example thereof being described in more detail below.

In embodiments of the present invention an additional bellow 412 is mountable in the housing opposing the other bellows 120 which are outside the housing. This might be a fifth bellow in case four bellows 120 are present on which electrodes are mountable.

In some exemplar embodiments of the present invention the additional bellow 412 is part of the same piece as the other bellows 120. The additional bellow 412 is folded over the neighbouring bellow such that the first open side of the neighbouring bellow is in direct contact with the first open side of the additional bellow. In embodiments of the present invention the bellows are mountable on the second part of the housing 112. In embodiments of the present invention the folding of the bellows is done over a plate 2101 in which a hole is present between the first open side of the neighbouring bellow and the first open side of the additional bellow. In embodiments of the present invention a rubber membrane is present in the hole in the plate 2101 between the first open side of the neighbouring bellow and the first open side of the additional bellow.

This membrane slows done the pass through of air between the additional bellow 412 and its neighbouring bellow 120 such that only after deformation of the bellows 120 outside the housing the bellow 412 inside the housing is deformed.

In an exemplary embodiment of the present invention the additional bellow 412 is smaller than the other bellows. The length of the additional bellow increases with an increasing pressure. The length of the additional bellow decreases with a decreasing pressure. A spring 2102 between the second closed side of the bellow and a fixed point in the housing therefore pushes against the second closed side of the additional bellow. When a certain pressure is reached a contact plate 2103 at the

second closed side of the additional bellow 412 closes a contact and thereby a signal is generated indicating that the pressure for a measurement has been reached.

In embodiments of the present invention a measurement is started by a processor as soon as the signal, indicating that the optimal measurement pressure is reached, is generated.

After a measurement has been done and the physiotherapist releases the pressure from the system 100 the additional bellow returns to its normal position under influence of the pressure from the spring 2102.

In exemplary embodiments of the present invention the system 100 comprises a battery 407 for powering the active components of the system 100.

In exemplary embodiments of the present invention the system 100 comprises a display 408 for indicating the measurement state and/or measurement result.

In exemplary embodiments of the present invention the system 100 comprises a current generator 1803 for generating a current through some of the electrodes 401. In embodiments of the present invention this current generator generates a block wave which is converted to a sine wave by an RC filter 1802, or any other suitable filter. The RC filter also limits the amplitude of the current to for example 1 mA.

In exemplary embodiments of the present invention the system 100 comprises an opamp for amplifying the sine wave to a constant alternating current of for example 1 mA.

In exemplary embodiments of the present invention the system 100 moreover may comprise a microprocessor 1801 for monitoring and controlling the display 408, and/or the pressure control system 412 and/or the current generator 1803, and for monitoring the voltage on some of the electrodes 401.

In exemplary embodiments of the present invention the total time it takes to perform a muscle tone measurement is below 10 seconds.

In exemplary embodiments of the present invention the system 100 moreover may comprise a Bluetooth module 1804 for communication between the microprocessor 1801 and a laptop 1805. Other communication modules can also be used. The information of the injected current and/or the information of the measured voltage and/or any other measurement results may be transmitted over the Bluetooth connection. This information may comprise amplitude information and/or phase information and/or the complete sampled signal. In embodiments of the present invention the Bluetooth connection is also used to transfer a list of muscles, to be measured, from the PC towards the processor 1801. This list of muscles can then be shown on the display 408 of the system 100. These can then be systematically selected and measured.

In exemplary embodiments of the present invention the system 100 moreover may comprise at least one push button 409 allowing the user to give commands to the processor 1801. It is an advantage of embodiments of the present invention that the at least one push button is within hand range and can be operated with the same hand the is pushing the system 100 against the muscle. In

embodiments of the present invention 3 push buttons 409 are present. One button for scrolling upwards on the display, one button for scrolling downwards on the display, one button which serves as enter button. In embodiments of the present invention the buttons may be positioned below the display 408. In embodiments of the present invention a button 409 may be positioned at the sidewalls of the first part 111 of the housing 110. In embodiments of the present invention the position of the buttons on the top of the housing may be preferable because this enables the physiotherapist to maintain a stable pressure on the system 100 while pushing the buttons.

In exemplary embodiments of the present invention a PCB 410 comprising all the electronics and battery should fit into the housing 110. Therefore in embodiments of the present invention the size of the PCB comprising all electronics is less than 40mm x 100 mm x 20mm (w x l x h in FIG. 1).

In exemplary embodiments of the present invention the system 100 moreover may comprise a docking station 1806 for charging the battery 407. Therefore charge contacts 404 are present in the system 100 according to embodiments of the present invention. These charge contacts 404 may be wired to the battery contacts 405. The battery 407 may be mounted on a battery plate 406.

In exemplary embodiments of the present invention a display 408 is mountable on top of the system 100. This is at the opposite side of the bellows 120. The display 408 may be integrated in the first part of the housing 111. The display may be positioned and oriented so that it is clearly visible for the physiotherapist when operating the system 100.

In exemplary embodiments of the present invention the applied pressure is shown in a display 408. This helps the physiotherapist to apply the same pressure for subsequent measurements. It is an advantage of embodiments of the present invention that it is possible to do measurements at a known and the same pressure level. This improves the reproducibility of the measurements and allows to compare a series of measurements. The distribution of the applied pressure over the different electrodes is guaranteed by the system 100 itself. In embodiments of the present invention the injected current information and/or the measured voltage signal information may be shown on the display.

In the exemplary embodiment of FIG. 5 the first part of the housing 111 comprises a handgrip 501. The handgrip 501 allows to have a good grip on the system 100. This allows a good positioning of the system and it allows the physiotherapist to effectively apply a force on the system 100.

In the exemplary embodiment of FIG. 6 the housing 110 is more compact than the housing in the exemplary embodiment of FIG. 5. The efficiency for applying a force might be smaller than in the embodiment of FIG. 5 especially when combining the application of a force and pushing a button 409 simultaneously.

FIG.7 shows a drawing of an exemplary embodiment according to the present invention. Similarly as in FIG. 5, the exemplary embodiment of FIG. 7 comprises a handgrip 501. In the exemplary embodiment of FIG. 7, the first part of the housing 111 is made of one U shaped piece whereas the second part 112 of the housing 110 is split in two parts each part for holding two bellows 120. Each of the parts of the second part 112 of the housing 110 are connectable to the outer ends of the U-shaped piece. If the material of the first part 111 of the housing 110 is flexible this has as advantage that the ends of the U-shaped piece can move with regard to each other. Therefore it is an advantage of this embodiment of the present invention that the outer ends of the U-shaped piece can adapt towards a curved muscle.

In embodiments of the present invention, the present invention also relates to the usage of a system as described above for performing sensing measurements on a surface, e.g. a non-flat surface. Such sensing measurements may include for example any of an electro impedance myography measurement, an electroencephalogram or an electro cardiogram. By way of illustration, embodiments of the present invention not being limited thereto a number of standard and optional steps are illustrated for an exemplary muscle tone measurement below. Other types of measurements can make use of some or all of the steps described, whereby the type of sensing performed is mutates mutandis matched with the type of measurement data to be captured. The usage thus may imply executing some or all or some of the following steps:

- Sending a list of the muscles to be measured towards a processor 1801 of the system 100.
- Taking the system 100 from the docking station and switching on the system 100.
- Selecting a muscle from the list on the display 408 using a push button 409.
- Placing the electrodes 401 of the system 100 against a selected muscle.
- Applying a pressure until the measurement starts. In embodiments of the present invention a measurement is started as soon as a certain pressure threshold level is reached.
- Retaining the pressure level during the duration of the measurement. In embodiments of the present invention this may take 5 seconds.
- Reading the obtained measurement result.
- Transmitting the result to a PC.
- Repeating the measurement until the muscles to be measured are all measured.
- Switching of the system 100.

The system may be adapted for performing one or more of these steps.

List of reference numbers

100 System
110 housing
111 first part housing (at least partly solid structure)
112 second part housing
120 Bellow
121 a first open side
122 a second closed side
401 electrode (plate electrode)
402 handle
403 snap connection
404 Charge contacts
405 Battery contacts
406 Battery plate
407 Battery
408 Display
409 Push button
410 Printed Circuit Board
411 Interior board
412 Pressure control system
501 Handgrip
1101 Tubes
1102 Rubber sealing
1103 Electrical cables
1401 Plate
1801 Processor
1802 RC Filter
1803 Generator (50 kHz)
1804 Bluetooth
1805 Laptop
1806 Docking station
2101 Plate
2102 Spring
2103 Contact plate

**Claims**

1.- A system (100) for positioning a plurality of elements on a surface, the system comprising
- at least a first element and a second element (401) for being positioned on a surface to study, and
- a fluid filled, deformable, sealed housing (110) comprising a plurality of bellows (120), the bellows being in fluid interconnection with each other via an open side of the bellows, the bellows having furthermore a closed side to which the at least a first element and a second element (401) are connected,
the elements thus being flexibly connected to each other such that a pressure applied to the housing is spread as a pressure on the elements.

2. A system according to claim 1, wherein each element is mounted to an end of a bellow (120), positioned at an extremity of a longitudinal direction wherein the bellow can extend.

3. A system according to the previous claim, wherein the elements (401) are flexibly mounted to the housing (110), the system thus allowing a changing orientation of the element (401) with respect to the housing (110).

4. A system according to any of the previous claims, wherein the elements (401) are reversibly mounted to the housing, allowing mounting the elements on the housing and removing the elements (401 from the housing repeatedly.

5.- A system (100) according to any of the previous claims, wherein each bellow (120) is a protrusion of a common cavity (112) of the housing (110).

6. A system (100) according to any of the previous claims, wherein the cavities of the bellows are interconnected through tubes (1101) connected to the open sides (121) of the bellows (120).

7.- A system (100) according to any of the previous claims, wherein the bellows (120) are cylindrical or conical.

8. A system (100) according to any of the previous claims, the system comprising a pressure control system (412) for controlling the pressure in the housing.

9.- A system (100) according to claim 8 wherein, the pressure control system (412) comprises an additional bellow (412) in the housing (110) having the same pressure in its cavity wherein the pressure control system furthermore is adapted for triggering the start of a measurement based on contact between the additional bellow and a contact sensor or switch.

10.- A system (100) according to any of the previous claims, wherein the elements are electrodes.

11.- A system (100) according to any of the previous claims, the system furthermore comprising any of a battery (407) for powering the active components of the system (100), a display (408) for indicating the measurement state and/or measurement result, a current generator (1803) for generating a current through some of the elements (401), an RC filter (1802) for limiting a current generated by a current generator (1803), a microprocessor (1801) for monitoring and controlling a display (408) and/or the pressure control system (412) and/or a current generator

(1803), and/or for monitoring the voltage on some of the electrodes (401), a Bluetooth module (1804) for communication between a microprocessor (1801) and a laptop (1805), at least one push button (409) allowing the user to give commands to the processor (1801) and/or a docking station (1806) for charging the battery (407).

12.- A system (100) according to any of the previous claims, wherein the elements are rigid elements and/or wherein the bellows are flexible but not stretchable.

13.- Use of a system (100) according to any of the previous claims, for performing sensing measurements for sensing signals at different positions on a surface.

14.- Use of a system (100) according to any of claims 1 to 12, for performing sensing measurements on a non-flat surface.

15.- Use of a system (100) according to any of claims 1 to 12, for performing any of an electro impedance myography measurement, an electroencephalogram or an electro cardiogram.

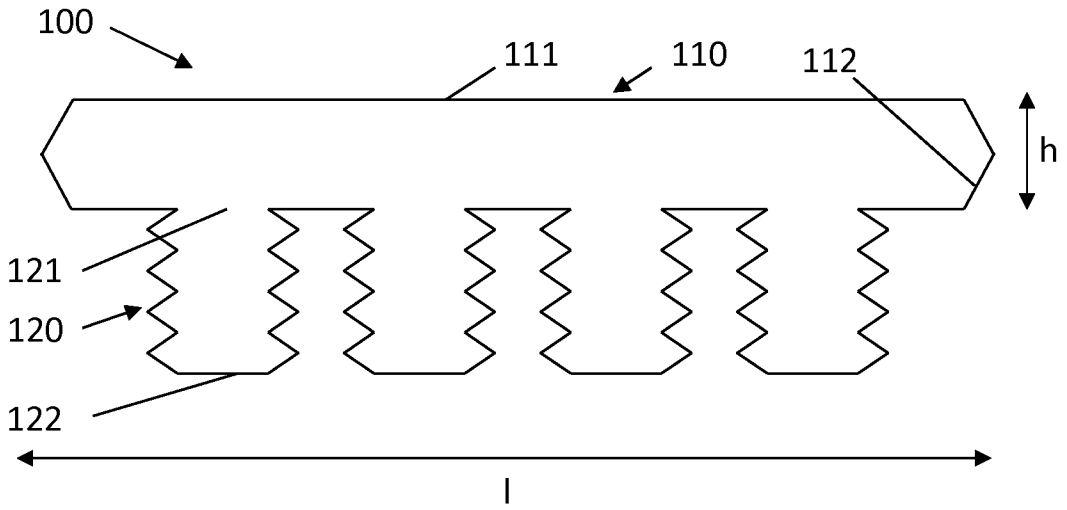



FIG. 1

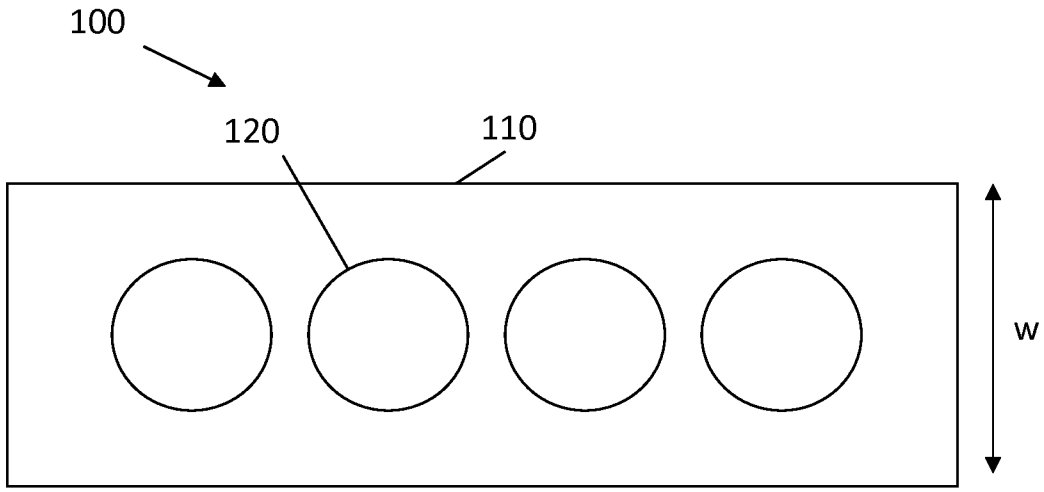



FIG. 2

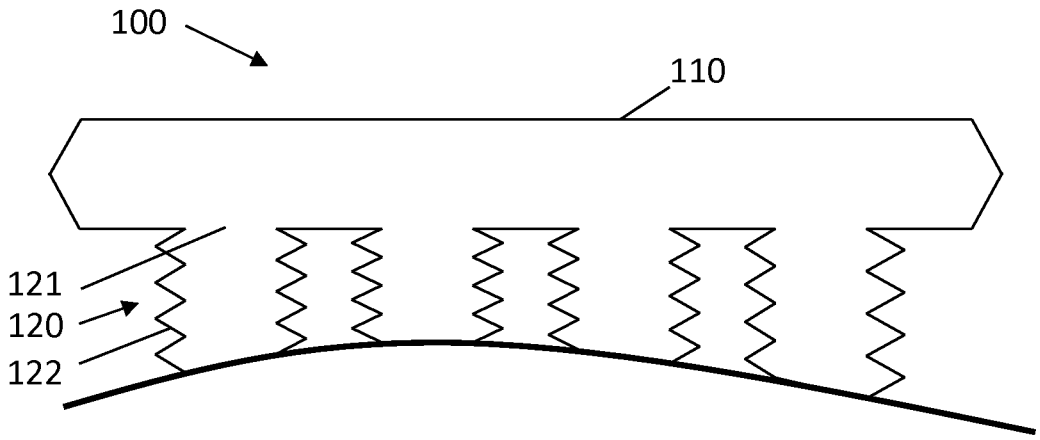



FIG. 3

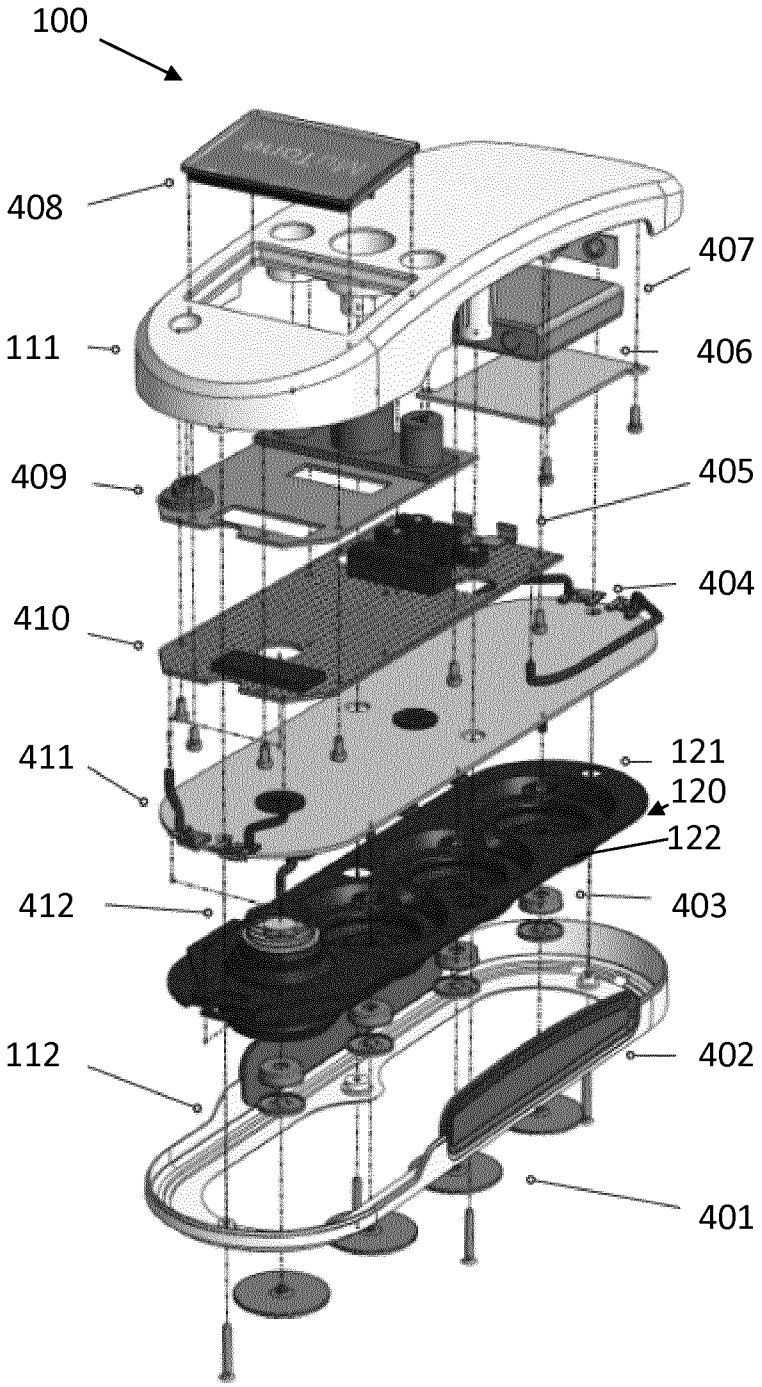

100
408
407
111
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404
410
411
121
120
122
412
403
112
402
401

FIG. 4

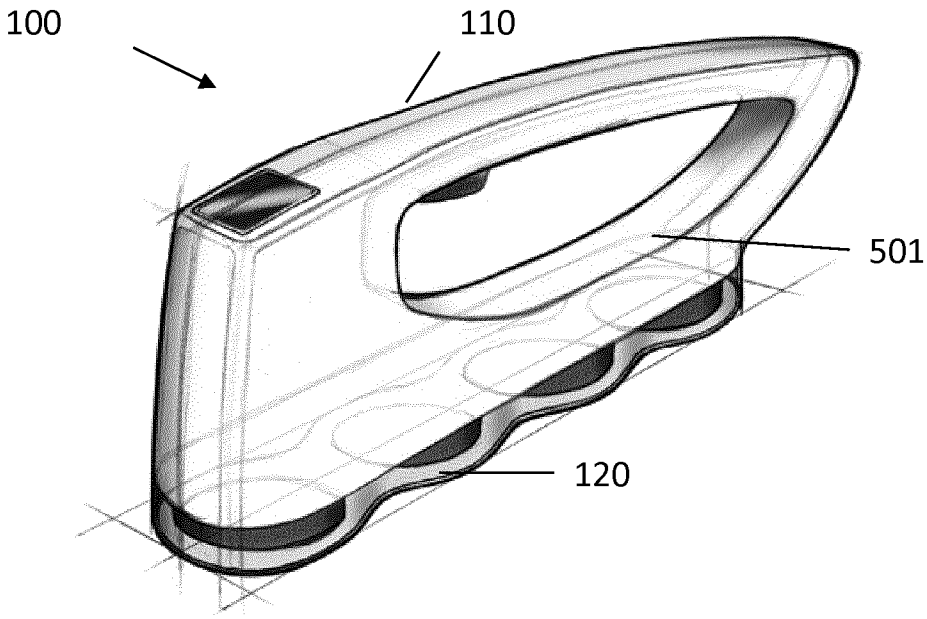



FIG. 5

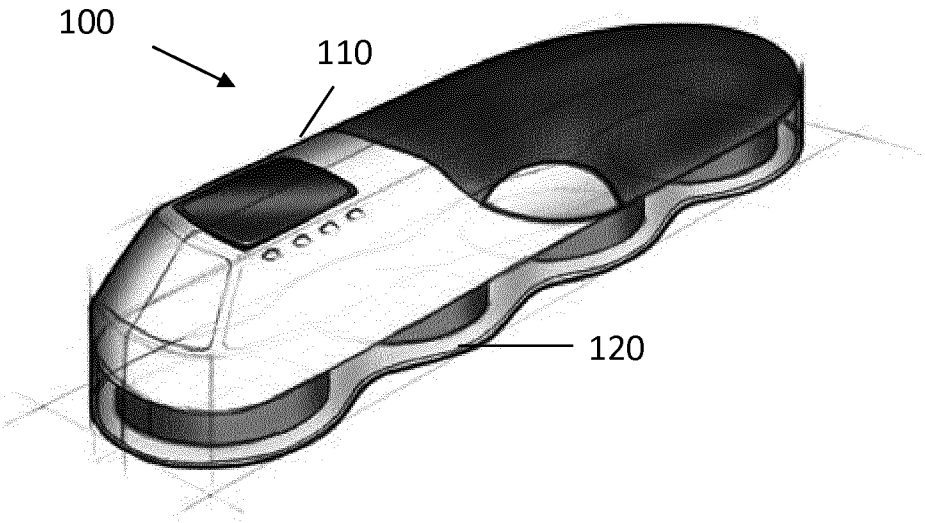



FIG. 6

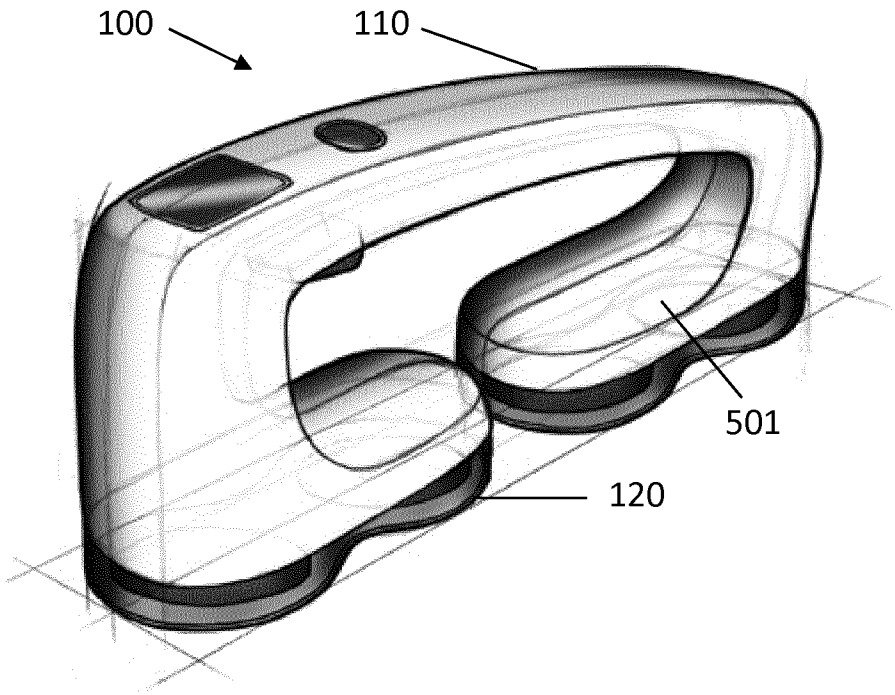



FIG. 7

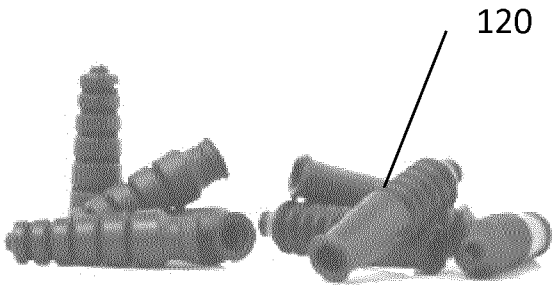



FIG. 8

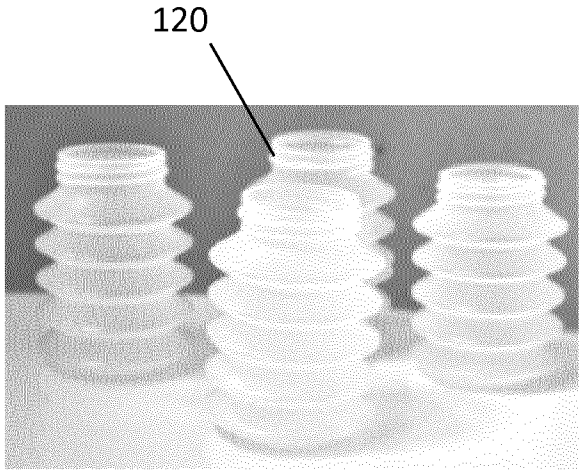



FIG. 9

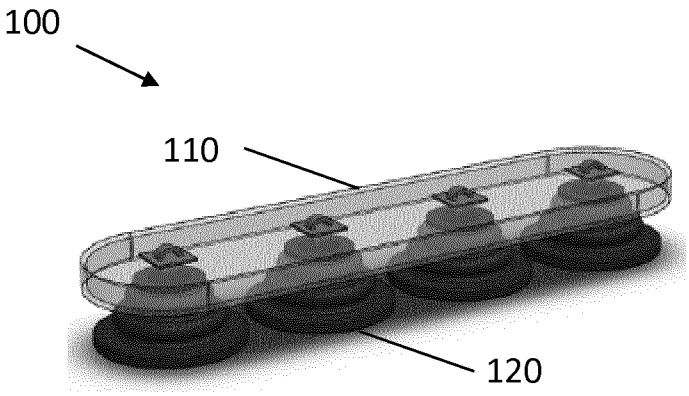



FIG. 10

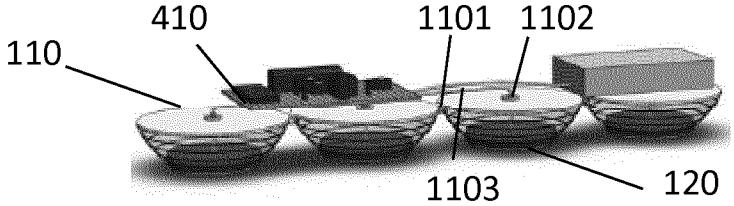



FIG. 11

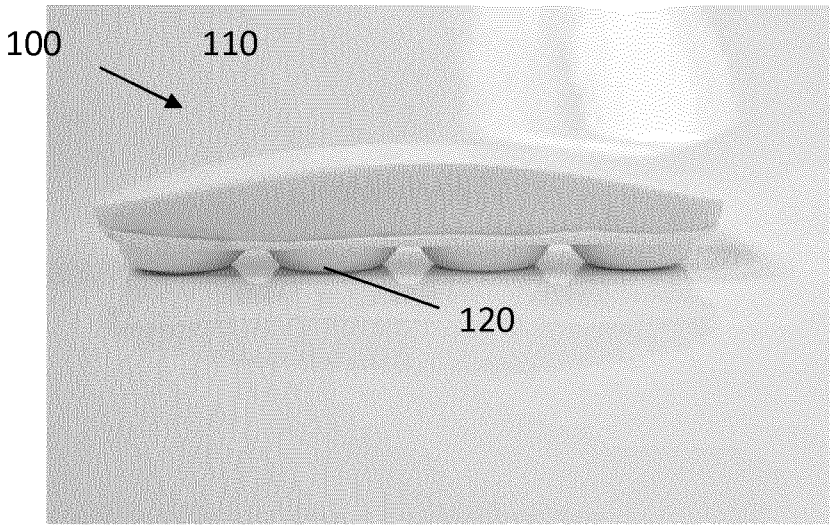



FIG. 12

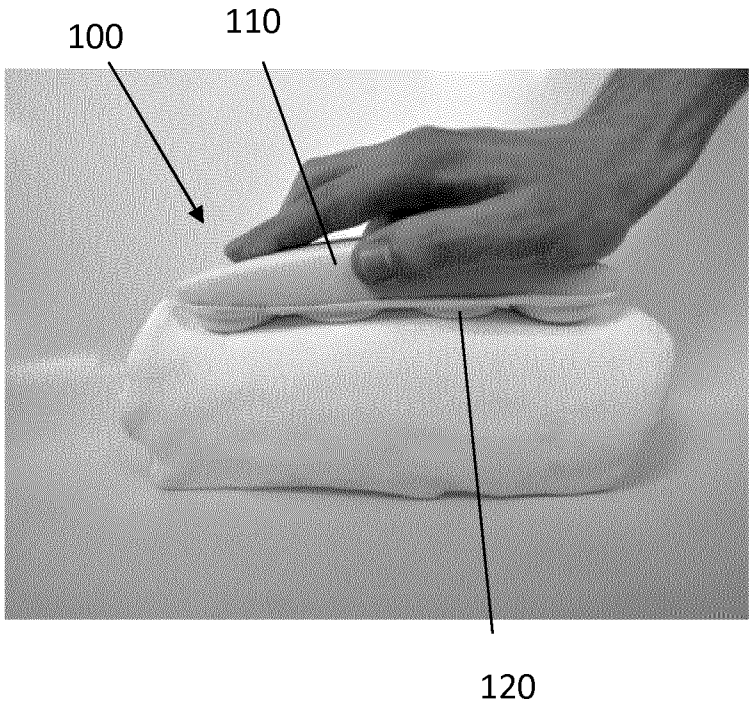



FIG. 13

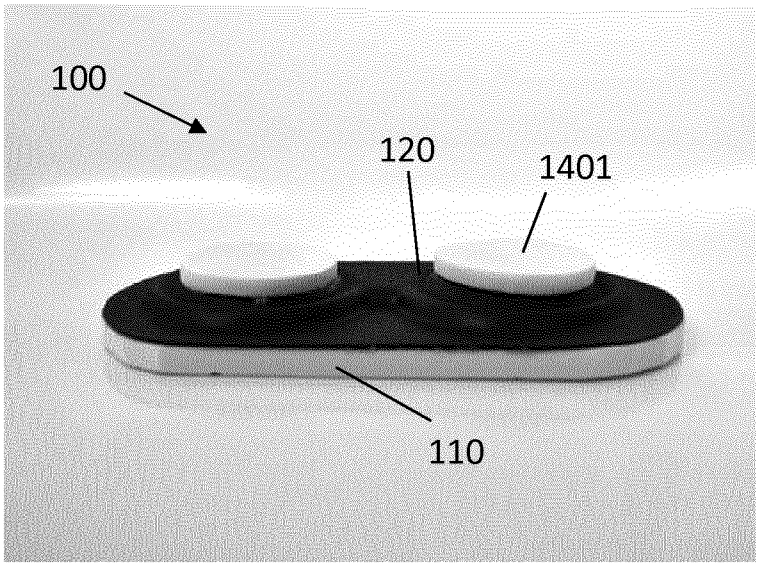



FIG. 14

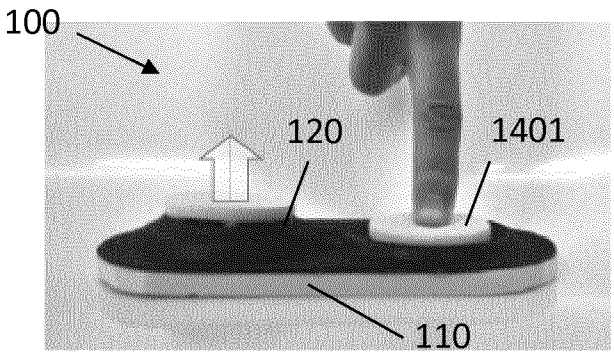



FIG. 15

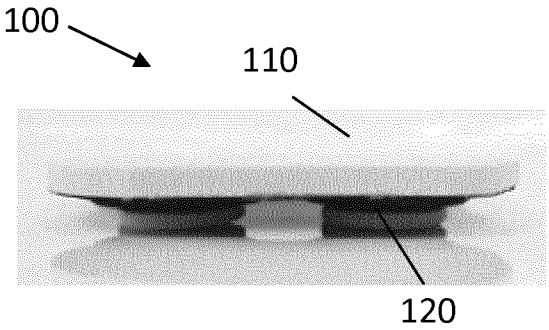



FIG. 16

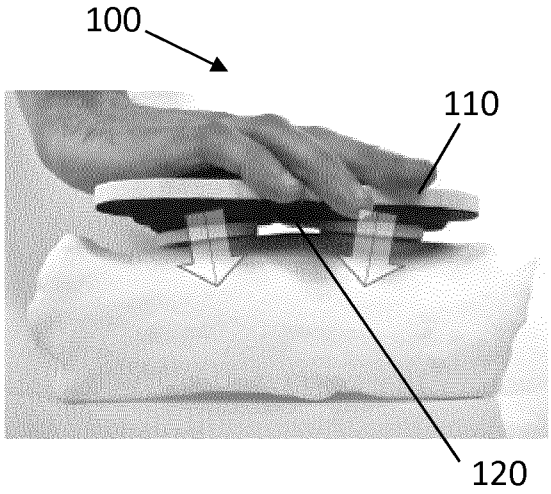

100
110
120

FIG. 17

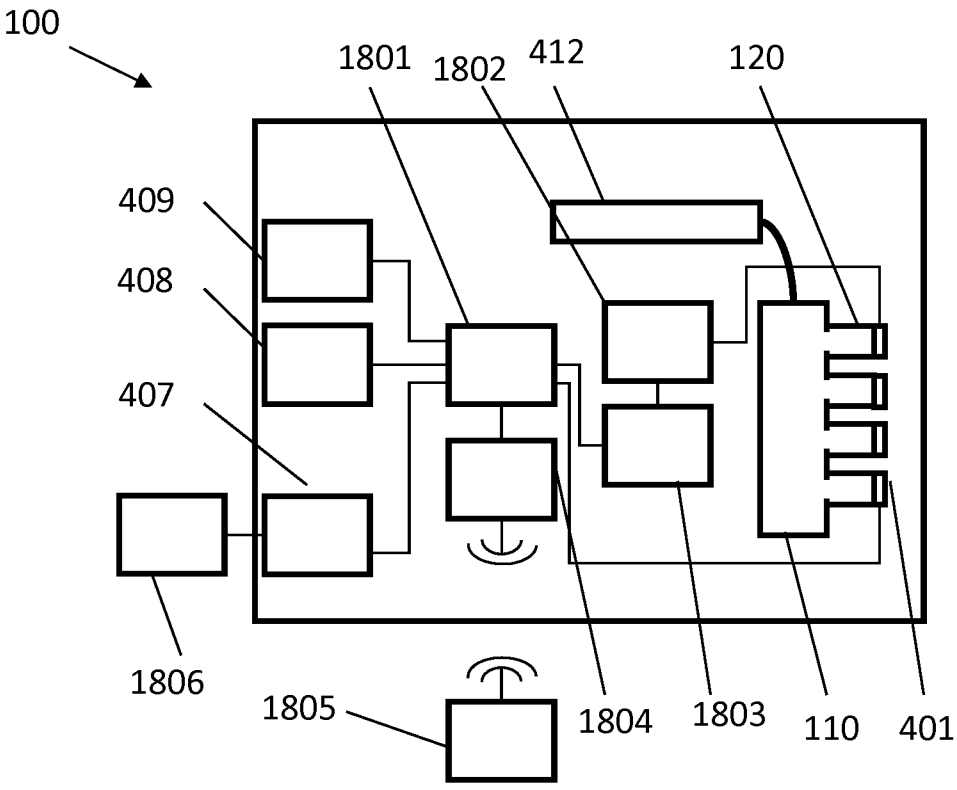

100
1801
1802
412
120
409
408
407
1806
1805
1804
1803
110
401

FIG. 18

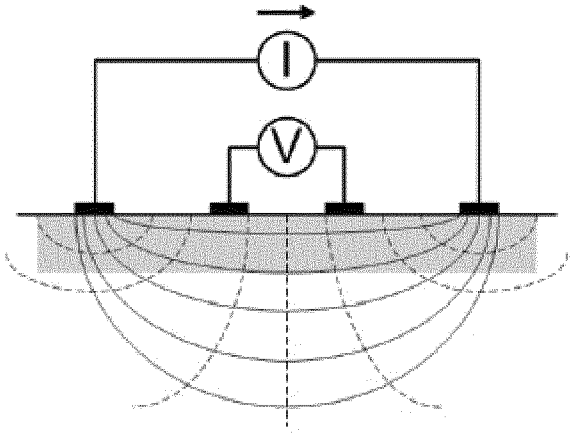

I
V

FIG. 19

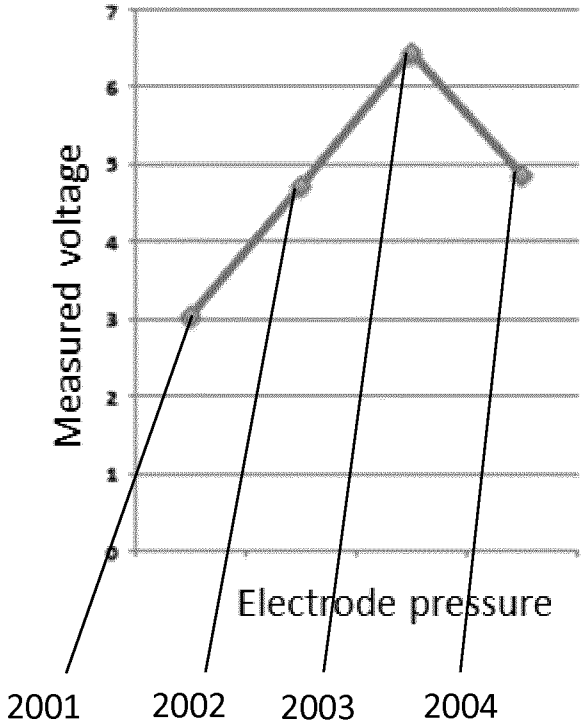

Measured voltage
Electrode pressure
2001
2002
2003
2004

FIG. 20

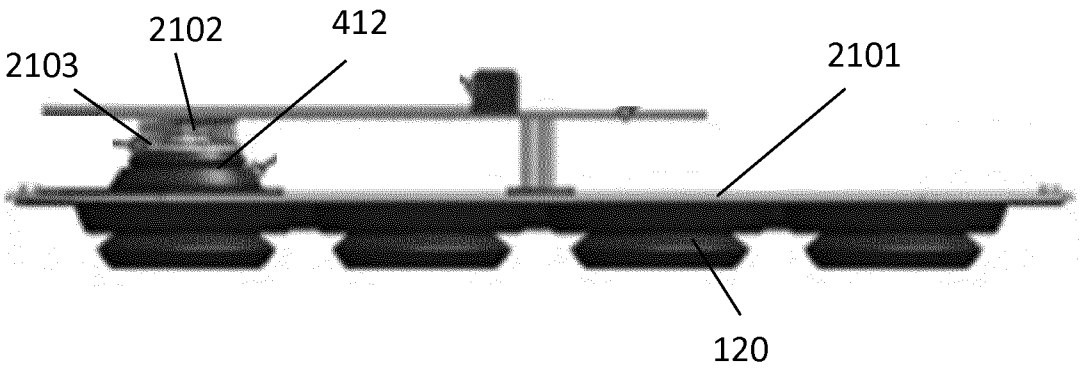



FIG. 21

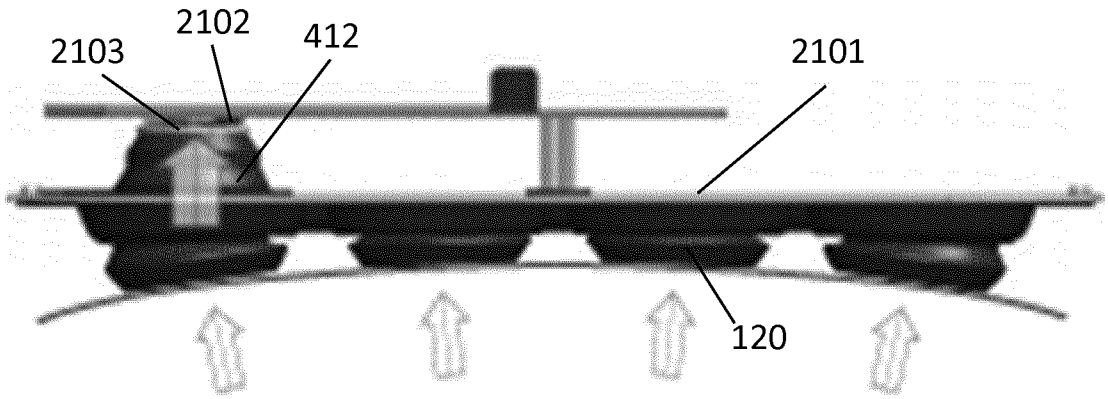



FIG. 22

# INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2016/051139

A. CLASSIFICATION OF SUBJECT MATTER
INV. A61B5/0408 A61B5/00 A61B5/0488 A61B5/0476 A61B5/0402
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

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 | EP 0 575 737 A1 (NELLCOR INC [US]) 29 December 1993 (1993-12-29) figures 1, 4, 5, 12, 13, 15-19 column 1, lines 4-16 column 6, lines 15-25 column 9, lines 21-51 column 10, lines 20-30 ----- | 1-15 |
| X | US 2011/224530 A1 (DAVID DANIEL [IL] ET AL) 15 September 2011 (2011-09-15) figures 16, 18-21 paragraphs [0132], [0133], [0136], [0137] ----- | 1-15 |
| X | US 2005/177929 A1 (GREENWALD RICHARD M [US] ET AL) 18 August 2005 (2005-08-18) figures 5, 7 paragraphs [0054], [0056], [0057], [0108] ----- | 1-15 |

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

☒ 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 |
|---|---|
| 12 April 2016 | 19/04/2016 |

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

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International application No
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